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MODELLING CONTAINER LOGISTICS PROCESSES IN CONTAINER TERMINALS: A CASE STUDY IN ALEXANDRIA

by

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A thesis submitted to Plymouth University
in partial fulfilment for the degree of

DOCTOR OF PHILOSOPHY

International Shipping and Logistics Group
Plymouth Graduate School of Management
Faculty of Business

September 2015

Acknowledgements

First and above all, I praise Allah, the Almighty for providing me the strength and courage and granting me the capability to proceed successfully.

Foremost, I would like to express my extreme gratitude to my supervisors, Professor John Dinwoodie, Professor Dongping Song, and Dr. Irina Neaga, for their constant support, guidance, and encouragement throughout the course of this study. Professor Dongping Song, you were a true example of a dedicated supervisor. I am truly thankful to you, without you this work could not have been done. My sincere gratefulness to Professor John Dinwoodie, who offered me invaluable advice, comments, and helped me improve my writing skills to a great extent. Although Dr. Irina only lately joined my supervisory team, her friendly support was very helpful to me. I was very pleased to work under all your supervision.

I would like to deeply thank my home university, the Arab Academy for Science, Technology, and Maritime Transport – College of International Transport and Logistics – Alexandria, for providing me an unconditional educational funding abroad. Many thanks are due to Dr. Gehan Saleh and Dr. Sara ElZarka for all kinds of aids they provided me.

Exceptional thanks and appreciation are dedicated to the company, which was the case study of this thesis. I would like to thank all the employees whom I contacted for their help while I was collecting data. In names, I would like to thank Admiral Ahmed Mansour, Admiral Alaa ElDin Nada, Mrs. Marcelle Milad, and Mr. Amr Abdalla. Special thanks to Mrs. Hanan ElSherif for her outstanding assistance during the course of my research.

My most heartfelt thanks to my family; my beloved husband, Ahmed; my children, Youssef, Habiba, and Haneen who welcomed our family in the last year of this research journey. You are part of this success, which would have been impossible without your emotional support, understanding, and motivation. I am greatly indebted to your unlimited sacrifices.

Last but not least, my warm thanks to my parents and my brothers for their love and encouragement, especially my mother who was mostly the first mom for my children. I dedicate this achievement to the soul of my grandmother who always prayed for me and wished to celebrate it with me. You are desperately missed.

Author's Declaration

At no time during the registration for the degree of Doctor of Philosophy has the author been registered for any other University award without prior agreement of the Graduate Sub-Committee.

Work submitted for this research degree at the Plymouth University has not formed part of any other degree either at Plymouth University or at another establishment.

This study was financed with the aid of a studentship form the Arab Academy for Science, Technology and Maritime Transport.

Relevant scientific seminars and conferences were regularly attended at which work was often presented; external institutions were visited for consultation purposes and few papers prepared for publication.

Publications:

- "Modelling Container Logistics Processes in Egyptian Container Terminals: A Case Study in Alexandria". Paper presented at LRN conference, Birmingham, UK, 5 September 2013.
- "Pipe flow Modelling of Container Terminal Logistics Processes: A Case Study in Alexandria". International Journal of Logistics Research and Applications. 2014.

Presentation and Conferences Attended:

- LRN conference, Birmingham, UK, 4-7 September 2013.
- The Postgraduate Society short conference series, the second short conference, Plymouth University, 14 March 2012.

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Word count of main body of thesis: 59856

Signed Hebatallah ElMesmary

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Date 30/03/2015

Abstract

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MODELLING CONTAINER LOGISTICS PROCESSES IN CONTAINER TERMINALS: A CASE STUDY IN ALEXANDRIA

This study aims to optimize the logistics processes of container terminals. Potentially powerful pipe-flow models of container terminal logistics processes have been neglected to date and modelling of terminals is rare. Because research which adopts a pipe flow and dynamic operational perspective is rare, a case application in Alexandria, Egypt collated empirical container and information flows using interviews and company records to describe its logistics processes and model container and information flows. The methodology used includes qualitative and quantitative methods and a descriptive methodology proceeds sequentially. Primary and secondary data were presented as a pipe flow model to show interrelations between the company's resources and to identify bottlenecks. Simulation modelling used Simul8 software.

Operational level modelling of both import and export flows simulated the actual inbound and outbound flows of containers from entry to exit. The import logistics process includes activities such as unloading vessels by quay cranes, moving containers by tractors to yard cranes to go for storage where customs procedures take place before exiting the terminal by customer's truck. The export logistics process includes the activities associated with customers' trucks, lifters, storage yards, tractors and quay cranes. The model takes into account the uncertainties in each activity.

This study focuses on operational aspects rather than cost issues, and considers container flows rather than vessel flows. Although the simulated model was not generalized, implementation elsewhere is possible.

Following successful validation of a base simulation model which reproduces the case company's historical scenario, scenario testing empowered the case company to pro-actively design and test the impact of operational changes on the entire logistics process. The study evaluates a typical container terminal logistics system including both import and export containers in the presence of multiple uncertainties in terminal operations (e.g. quay crane operations, tractor operations, yard crane operations). Sensitivity testing and scenario analysis can empower terminal managers to make decisions to improve performance, and to guide terminal planners, managers, and operators in testing future investment scenarios before implementation.

Keywords: container terminals, logistics processes, modelling, simulation, scenario analysis, sensitivity testing.

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List of Abbreviations

ACCHC	Alexandria Container and Cargo Handling Company
AGV	Automated Guided Vehicles
ALV	Automated Lifting Vehicles
ANN	Artificial Neural Network
CSOP	Constraint Satisfaction and Optimization Problems
CTLS	Container Terminal Logistics System
DCHC	Damietta Container Handling Company
DSS	Decision Support System
EDI	Electronic Data Interchange
FGA	Formal Graphical Approach
HGV	Heavy Goods Vehicles
HPC	High Performance Computations
ISL	Institute of Shipping Economics and Logistics
IT	Information Technology
LCL	Less than Container Load
LGV	Large Goods Vehicles
LNG	Liquefied Natural Gas
MIP	Mixed Integer Programming
MIS	Management information system
MRCC	Maritime Research and Consulting Center
PGA	Parallel Genetic Algorithm
PSCCHC	Port Said Container and Cargo Handling Company
QC	Quay Crane
RCP	Results Collection Period
RDT	Radio Data Terminal

RMG	Rail Mounted Gantry cranes
SA	Simulated Annealing
SCCT	Suez Canal Container Terminal
TEU	Twenty feet Equivalent Unit
TPB	Terminal Planning Board
TTS	Transtainer Scheduling
ULCS	Ultra Large Container Ships
UNCTAD	United Nation Conference on Trade and Development
VLCC	Very Large Container Carriers
YC RTG	Yard Crane – Rubber Tired Gantry crane

Chapter 1

Introduction

This study is concerned with modelling the logistics processes in an Egyptian container terminal through a case study. The first chapter is an introductory one that gives an overview of the research in terms of a brief background of the subject in section one, the main research aims and objectives in the second section, the methodology applied in the study in section three, and finally the structure of the research is outlined in the last section of the chapter.

1.1 Background

The increasing development of containerized transportation and the global competition among different ports are the main causes for the wide attention given by researchers to seaport container terminals. Because of this increased volume of container traffic, the container terminal has become an important interface between land and sea transportation (Lu et al, 2013). As a result of increasing competition between container ports, improving efficiency in container terminals has become a significant and instant challenge for all managers in order to gain higher competitiveness. The optimization of maritime container terminals is a research issue that has received, in recent years, increasing attention by the international research community. This is because the logistics of especially large container terminals has reached a degree of complexity where the planning of further improvements requires the application of scientific methods (Said and Elhorbaty, 2014). A container terminal is a transit point for containerized goods between sea vessels and land transportation modes, such as trucks (Skinner et al, 2012 and Sacone and Siri, 2009). With the rapid globalization of trade, marine transportation is getting more common. Large numbers of cargos are moved in containers through ports. Therefore, effective and efficient management of port container terminals is very important in marine transportation development in an increasingly competitive and global industry (Peng et al, 2013 and Lu et al, 2013).

This study tries to fill in the main gaps observed which are mainly a lack of research to address the terminal logistics processes from both pipe flow and dynamic operation perspectives; a lack of research which reports comprehensive scenario analysis of the impacts of various uncertainties in the logistics processes, on terminal performance; and a lack of research that has been undertaken into Egyptian container terminals.

1.2 Research Aim and Objectives

This research aims to model the logistics processes that take place in container terminals, especially Egyptian terminals, for both the import flow and the export flow of containers with a view to improving and optimizing the overall performance of the entire process. A case study for an Egyptian container terminal has been conducted and a simulation model for the terminal's entire logistics processes was developed. In this context, the main research objectives are to:

1. Analyse the characteristics of container terminal layout and operations and related logistics control issues.
2. Identify the various logistics processes performed within container terminals.
3. Synthesise the key issues that affect logistics processes in a case study of one Egyptian container terminal.

4. Develop a pipe flow model of the physical and information flows through a container terminal to identify the key bottlenecks in the case company.
5. Propose and evaluate appropriate techniques or tools to model dynamic flows in container terminals.
6. Build, evaluate and validate the simulation model, undertake sensitivity testing and scenario analysis and feedback the findings and results to the case company.

1.3 Research Methodology

The research follows a deductive and inductive approach. It incorporates both qualitative and quantitative data collection techniques, mainly interviewing. This represents a research choice of multiple methods. It also implements the case study strategy. The research follows a descriptive methodology by which data is dealt with according to sequential processes. Data was collected in terms of primary as well as secondary data (archival data from the case company). To facilitate problem framing, an appropriate initial data collection method to articulate salient viewpoints involved interviewing, whereby various interviews were conducted with different personnel from the case company. These commenced with the chairman of the company and progressed systematically to include different employees from various departments within the company.

The data, which had been collected, was then organized and presented in sets. Once organized, data was then used to propose a pipe flow model for the import logistics process and the export logistics process with a view to identifying the main bottlenecks facing the company. This pipe flow model was further enhanced with the collected detailed operational data to build and develop an integrated operational level simulation model of the entire logistics processes of import and export container flows, using Simul8 software. The model shows, to a great extent, the actual inbound and outbound flows of containers from the entry point to the exit point. The model has been verified and validated. It can reproduce the historical data for the case company. This initial simulation model, considered as a base model, enabled different scenarios to be designed to test and evaluate the impact of various uncertainties in the logistics processes and different combinations of resources on the overall performance of the entire process whereby the results of each scenario were displayed and interpreted.

1.4 Research Framework and Thesis Structure

This chapter introduced the overall framework of the research. The next chapter reviews the literature, which addressed the importance and layout of container terminals and logistics control issues relevant to container terminal operations as well as the research done in Egyptian container terminals. The chapter ends with specifying the research gaps and identifying the main research questions.

Chapter 3 gives an overview of Egyptian container terminals and the main logistics processes performed.

Chapter 4 presents the methodology used in the research in terms of the research framework, the case study approach, and data collection as well as methods of data analysis. The chapter also shows the logistics processes performed in the case company either for import or export processes that take place in the case company.

Chapter 5 details the modelling and simulation tools used throughout the research, along with the description of the proposed models. Verification and validation of the simulation model are presented in chapter 6.

Chapter 7 addresses the base simulation model and displays its results. This is followed by the first suggested scenario and a detailed analysis of its results.

In chapter 8, other scenarios are suggested for improvement, each scenario is explained, and its results are displayed and interpreted.

Chapter 9 is the discussion chapter where the research contributions to theory, industrial practice, and policy are discussed, and limitations of the existing work are identified.

The research ends by outlining the main general conclusions of the research in chapter 10. It also includes the recommendations of the research either for academic work or for the industry. The following figure shows the layout of the research.

1.5 Summary

This chapter has introduced the research context and overall framework in terms of the research aim and objectives, as well as the methodology adopted throughout the research. Chapter two will review relevant literature as regards the logistics processes within container terminals and then identify the research gaps and the basic research questions.

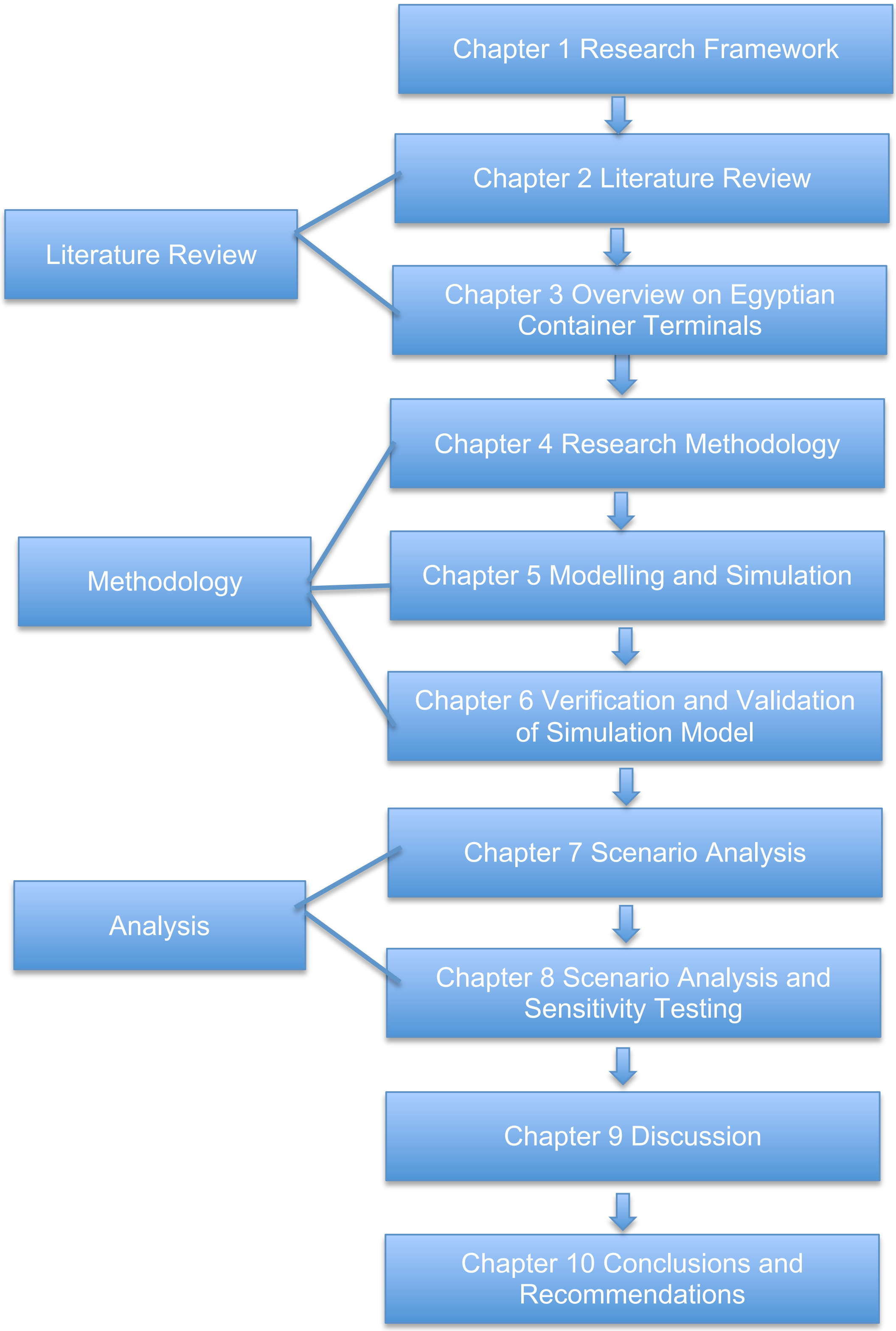


Figure 1.1: Research layout

Chapter 2

Literature Review

This chapter describes the logistics processes within container terminals. It reviews the literature on logistics control issues relevant to container terminal operations. The literature review is organized as follows: firstly, an overview of container terminal planning is provided, which includes strategic and tactical terminal planning, and operational planning. Secondly, the literature related to modelling logistics process at container terminals is reviewed. This section is divided into three sub-sections: terminal internal operations planning, landside operations planning, and integrated operations planning. Thirdly, the research undertaken on Egyptian container terminals is discussed. The chapter ends by identifying the research gaps and the basic research questions, followed by a brief summary.

2.1 Introduction

Container terminal logistics systems play an increasingly important role in modern international logistics (Li and Li, 2010) as global container traffic has grown from 28.7M to 152.0M movements between 1990 and 2008. This corresponds to an average annual compound growth of 9.5% and is projected at 10% until 2020. In the same period, container throughput went from 88M to 530M an increase of 500% (Salido et al, 2012). To cope with this rapid increase in number of containers is a key challenge that faces container terminals. They have to innovate ways to optimize their logistics processes (Rashidi and Tsang, 2005, 2013). Other issues facing container terminals today include capacity constraints, lack of adequate decision making tools, congestion, and environmental concerns (Sharif and Huynh, 2013).

It is increasingly important for terminals to be able to provide high-quality services for their users, particularly shipping lines as they focus on the provision of door-to-door logistics services (Panayides and Song, 2009). In order for a container terminal to be able to compete effectively, it has to provide a first class container logistics system through optimizing task assignment, resources allocation and scheduling management (Li and Li, 2010). However, managing the entire system is a very complex process that requires numerous decisions and stimulates the need to develop simulation tool systems for decision support. This is a crucial contribution whereby the simulation process encompasses parameters for measuring terminal productivity and identifies the required working processes. Efficient simulation tools assist managers to make appropriate operational decisions (Beškovnik and Twrdy, 2010).

In the light of that, this study aims to model the logistics processes that take place in container terminals, especially Egyptian terminals. In this context, the research problem is to evaluate a typical container terminal logistics system including both import and export containers at the presence of multiple uncertain operations. This model would give terminal planners and operators managerial insights and help them make relevant decisions for better performance and optimization.

2.2 Overview of Container Terminals

As a result of the increased growth rates on main container routes, competition between container terminals has also increased. Terminals are challenged to handle more containers in the minimum possible time at the lowest cost. This calls not only for enhancing handling capacities but also achieving higher productivity rates. Such requirements can be met through introducing new terminals layouts, new infrastructure requirements, the use of automation in container handling especially for high labour cost countries, the replacement of old manual equipment with new automated ones, and also more efficient IT support and improved logistics control software systems (Gunther and Kim, 2006 and Stahlbock and Vob, 2008).

A container terminal is a complex system characterized by a variety of handling equipment, transportation systems, and storage units that are highly interactive with each other. Uncertainty about the future is a significant feature for container terminals. Logistics planning and control issues of container terminals can be classified into levels. As shown in figure 2.1, these levels include: terminal design; operative planning and real-time control (Gunther and Kim, 2006).

Depending on the planning horizon of container terminals, planning levels can be categorized into strategic, tactical, and operational planning problems. At the strategic level, the location and layout design of new terminals, and the kind and number of equipment to be used as well as the degree of automation are the main decisions. These decisions last for years. Tactical decisions involve the space utilization within the terminal, i.e. assigning specific stacks to different types of containers such as reefer, empty, and special containers. The layout of traffic courses for the horizontal transport system is also a tactical decision. Tactical decisions usually last for months or weeks. At the operational level, plans for container terminal resources are generated to organize the service of vessels, trucks and trains. These decisions last for days or probably just seconds (Meisel, 2009). Strategic and tactical planning levels of a container terminal are referred to as terminal design, while operational problems are referred to as terminal logistics (Lehmann et al, 2006).

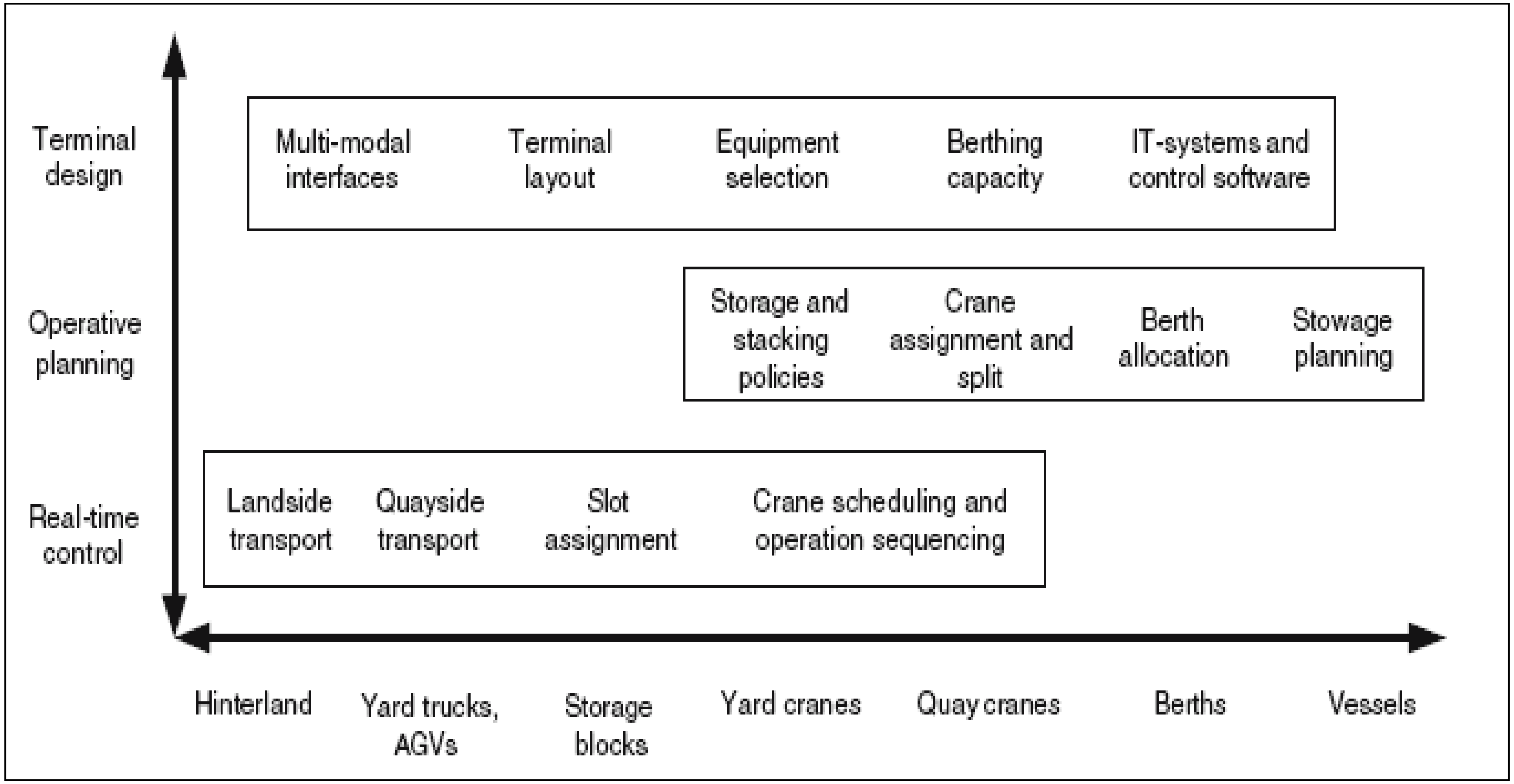


Figure 2.1: Logistics Planning and control issues in seaport container terminals (Source: Gunther and Kim, 2006)

2.2.1 Terminal Strategic and Tactical Planning

During the first stage of the planning process for a container terminal, planners have to tackle terminal design problems, they should analyse these problems in terms of economic as well as technical feasibility and performance. The various design problems include (Gunther and Kim, 2006):

2.2.1.1 Multimodal Interfaces

Many container terminals are directly connected to railway, truck and inland navigation system. The design of the terminal is greatly affected by the integration of such different modes of transport. The following figure 2.2 describes the transportation and handling chain of a container within a container terminal. As for an exported container, after its arrival at the terminal by truck or train, it is identified by registering its data such as content, destination, out bound vessel, and shipping line. Then it is picked up by internal transportation equipment to be moved to its allocated yard. Specific cranes or vehicles are used to store the container at the yard until its designated vessel arrives. Upon the vessel's arrival, the container is transported from the yard stack to the berth where it is loaded onto the vessel by quay cranes. Import container operations are performed in the reverse order (Gunther and Kim, 2006).

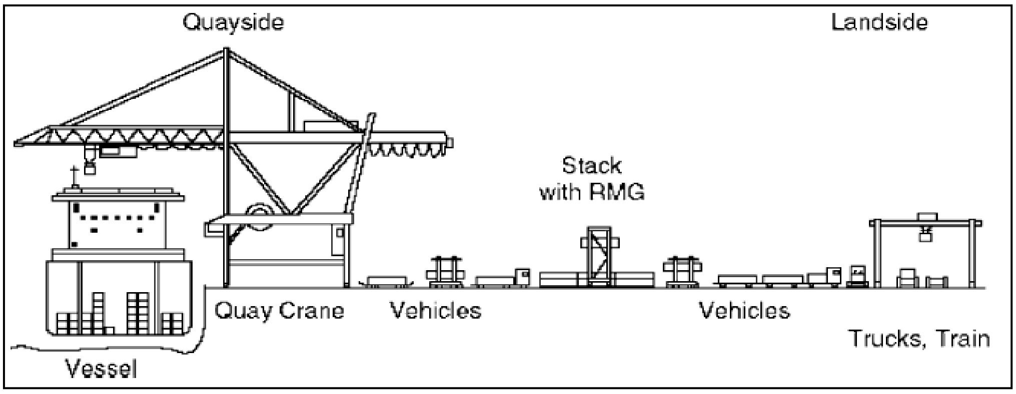


Figure 2.2: Transportation and a handling chain of a container (Source: Steenken et al, 2004 and Gunther and Kim, 2006)

Alessandri et al. (2007) controlled container transfer operations inside intermodal terminals by modelling and optimizing operations in a Mediterranean port in the Northern part of Italy. In (2009) they proposed a discrete-time dynamic model of the various flows of containers that are inter-modally routed from arriving carriers to carriers ready for departure. Le-Griffin et al. (2010) evaluated the impact that intra-terminal truck and equipment movements have on the terminal's overall performance through simulating Southern California ports. Chen et al. (2013) formulated the interaction between crane handling and truck transportation in a maritime container terminal as a constrained programming model and developed a three-stage algorithm.

2.2.1.2 Terminal Layout

A container terminal mainly consists of a storage area or yard, transportation routes, and quays. Their capacity and spatial arrangements determine the performance of terminal configuration. Terminal layout involves allocating specific areas for reefer, dangerous goods, empty, and special containers. Container terminals mainly consist of the same subsystem, although they may differ in size, function and geometric layout. Generally, container terminals can be described as an open system of material flow with two external interfaces; the quayside where ships are loaded and discharged; and the landside where containers are loaded and unloaded on/off trucks and trains. Containers are then stored in stacks to facilitate the operation of quayside and landside. Specifically, container terminals are described with regards to their equipment and stacking facilities. From a logistics point of view, terminals consist of only two components: stocks and transportation vehicles (Steenken et al, 2004 and Gunther and Kim, 2006).

Figure 2.3 shows the operation areas of a seaport container terminal and flow of transport. The ship operation or berthing area is equipped with quay cranes for loading and unloading vessels. Containers are stocked in a yard divided into a number of blocks (stacks). Special areas are allocated for reefer containers (as they need electrical power), special containers and empty containers. Some terminals employ sheds where containers are stuffed and stripped and goods are stored. This performs additional moves to link yard stacks to sheds. The same situation occurs if empty depots exist within the terminal. These moves encompass the transports between empty stocks, packing centre, and import and export container stocks. The truck and train operation area connects the terminal to the outside transportation system (Steenken et al, 2004 and Gunther and Kim, 2006).

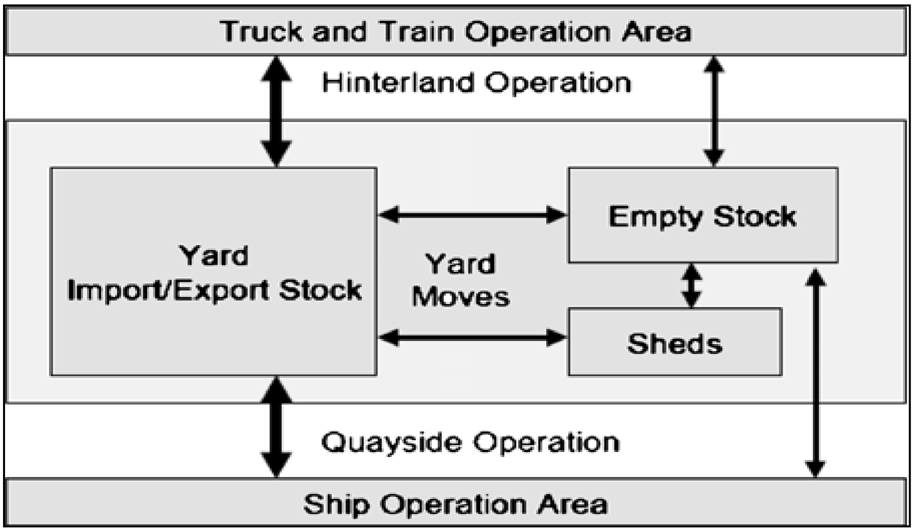


Figure 2.3: Operation areas of a seaport container terminal and flows of transport (Source: Steenken et al, 2004 and Gunther and Kim, 2006)

Cartenì et al. (2005) proposed a discrete event simulation model, which can be rather easily calibrated against real data, and applied to analyse the current configuration in Salerno Container Terminal and to simulate and evaluate alternative design configurations. Schmidt et al. (2005) presented an electronic terminal planning board (TPB) with generic applicability. This TPB was successfully applied to visualise initially the status quo and subsequently to explore possible extensions of the Tivoli Container Terminal in the Port of Cork, Ireland.

2.2.1.3 Equipment Selection

There is a great variety of handling equipment and transportation equipment that can be used within terminals. Terminals are currently gearing up to make use of automated equipment as well as automated vehicles instead of manually driven ones. Container terminals greatly differ with regards to the type of transportation and handling equipment used. Generally, terminals use gantry cranes either single or dual trolley, manual or semi-automatic. Among the most common types of yard cranes are rail mounted gantry cranes (RMGs), rubber tired gantry cranes (RTGs), straddle carriers, reach stackers, and chassis-based transports. Only RMG cranes are suited for fully automated containers handling. Different types of handling equipment and their comparative performance figures with respect to the number of TEUs that can be stored per hectare are shown in figure 2.4 (Steenken et al, 2004 and Gunther and Kim, 2006).

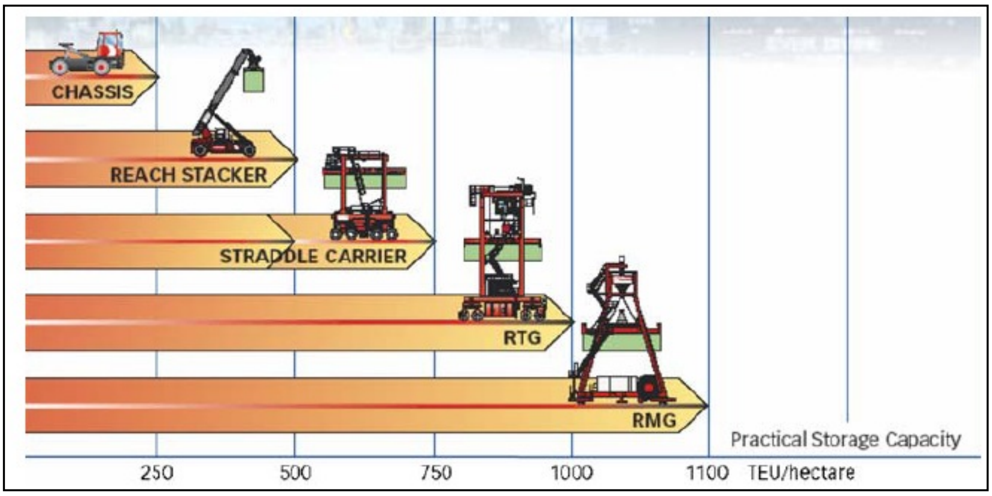


Figure 2.4: Different types of handling equipment (Source: Gunther and Kim, 2006)

Although there are a variety of equipment combinations, container stacking can be performed by one of two main categories: pure straddle carriers or gantry cranes system. The transport between ship and yard can be performed by multi-trailer system with manned trucks, automated guided vehicles (AGVs) and automated lifting vehicles (ALVs). Landside operation can also be served by such vehicles as trucks with trailers, multi trailers and straddle carriers (Vis and Harika, 2004, Yang et al, 2004 and Steenken et al, 2004).

Several factors should be considered when deciding on the equipment to be used within container terminals. A primary factor is the dimension of the space available in the terminal; gantry cranes are best suited for stocking containers if the space is limited. When constructing a new terminal, in the case of high labour cost regions, AGVs can be used.

Meersmans (2002) developed an exact Branch and Bound algorithm for solving the integrated scheduling problem of handling equipment at automated container terminals. A model for more general layouts of container terminals is presented. For this model, a Mixed Integer Programming (MIP) formulation is developed. Kim et al. (2004) used mathematical models to illustrate the efficient scheduling of operators of handling equipment through formulating a constraint satisfaction problem. Hartmann (2004) also applied a general model for various scheduling problems that occur in container terminal logistics in the Port of Hamburg. Chu and Huang (2005) presented a comparison of different container handling systems with regard to a terminal's capacity. Vis (2006) presented a simulation study for the evaluation and comparison of different terminal systems with manned SCs and RMGs in terms of costs and performances. Ottjes et al. (2006) developed a generic simulation model to design and evaluate the multi-terminal system for container handling in a container terminal in Rotterdam. Le-

Griffin et al. (2010) evaluated the impact that intra-terminal truck and equipment movements have on the terminal's overall performance in southern California ports. The study profiled the current intra-terminal movement of vehicles and equipment necessary to process a container transaction of differing transaction types. Using a series of computer simulations developed for different operation scenarios, the study captures and documents the sequence movements and time it takes to conduct the container handling process within a terminal. Zeng et al. (2011) proposed a simulation model to construct the system environment while the Q-learning algorithm is applied to learn optimal dispatching rules for different equipment.

2.2.1.4 Berthing Capacity

The number and size of vessels to be served as well as the storage yard space requirements and the fleet size of vehicles are all determined by the berthing capacity. The general performance factor of a container terminal is measured by its seaside dispatching capacity. Nam et al. (2002) examined the optimal number of berths and quay cranes for a terminal in Busan (Korea) through a simulation model.

2.2.1.5 IT Systems and Control Software

As container terminals are highly dynamic and highly complicated logistics systems, real time control of logistics activities is of great importance. In large-sized container terminals, logistics control is considered as a complex task that requires real time decisions to assign equipment units to the queuing handling tasks and provide relevant data for each container. Certain events or situations require solving decision problems in a very short time, may be less than a second, which implies real-time control (planning) and requires different modes of software and IT support and also implementing optimization tools. Examples of real-time decisions include the assignment of transport orders to vehicles, routing and scheduling the vehicle trips for landside transportation as well as for transportation between the berth and the storage yard, the assignment of storage slots to individual containers, and the determination of detailed schedules and operation sequences for quays and stacking cranes (Gunther and Kim, 2006).

Through mathematical models and algorithms, Legato and Monaco (2004) developed a branch-and-bound algorithm in order to solve real-world instances of the Gioia Tauro terminal, Italy effectively. A heuristic approach to a set-covering type problem is derived. In addition, Lim et al. (2004) proposed an NP-hard manpower allocation model with time windows from a real-life problem at the port of Singapore.

Table 2.1 summarizes the literature reviewed on terminal strategic and tactical planning level.

To conclude this section, it is obvious that the undertaken research regarding terminal strategic and tactical planning mainly focused on either one of the various design problems at container terminals in general or with application on a specific case study. The use of modelling and simulation was the key method used in such research.

Author	**Category of Study**	**Idea of Content**	**Method Applied**	**Case Study (if any)**
Cartenì *et al*. 2005	Terminal layout	Applying models for supporting performance analysis of a container terminal through performance indicators.	Simulation, Optimization	Salerno Container Terminal
Schmidt *et al*. 2005	Terminal layout	Depicting the status quo of Tivoli container terminal through an electronic terminal planning board to develop alternate terminal layouts.	Modelling, Visualisation	Tivoli container terminal, Port of Cork, Ireland
Le-Griffin *et al*. 2010	Multimodal Transport, Equipment handling	Evaluates the impact that intra-terminal truck and equipment movements have on the terminal's overall performance.	Simulation	Southern California Ports
Meersmans 2002	Equipment handling	Providing models and algorithms for efficient scheduling of terminal handling equipment.	Mathematical models and algorithms	
Vis 2006	Equipment handling	A simulation study for the evaluation and comparison of different terminal systems with manned SCs and RMGs in terms of costs and performances.	Simulation	
Legato and Monaco 2004	IT	A branch-and-bound algorithm is developed in order to solve real-world instances effectively. A heuristic approach to a set-covering type problem is derived.	Mathematical programming models, algorithms, heuristic	The Gioia Tauro terminal, Italy
Zeng et al. 2011	Equipment handling	A simulation model to construct the system environment while the Q-learning algorithm reinforcement learning algorithm) is applied to learn optimal dispatching rules for different equipment.	Simulation & algorithms	

Author	Category of Study	Idea of Content	Method Applied	Case Study (if any)
Kim *et al*. 2004	Equipment handling	The efficient scheduling of operators of handling equipment through formulating a constraint satisfaction problem.	Mathematical models	
Chu and Huang 2005	Equipment handling	A comparison of different container handling systems with regard to a terminal's capacity.	Survey	
Alessandri *et al*. 2007	Multimodal Transport	Modelling, optimizing and controlling container transfer operations inside intermodal terminals.	Modelling, Optimization	A Mediterranean port in North Italy
Lim A *et al.* 2004	IT	An *NP*-hard manpower allocation model with time windows from a real-life problem at the port of Singapore.	Algorithms, Optimization	The port of Singapore
Ottjes *et al.* 2006	Equipment handling	A generic simulation model to design and evaluate the multi-terminal system for container handling.	Simulation	A container terminal in Rotterdam
Nam et al. 2002	Berth capacity	A simulation model to examine optimal number of berths and quay cranes for a terminal in Busan.	Simulation	A terminal in Busan (Korea)
Hartmann 2004	Equipment handling	A general model for various scheduling problems that occur in container terminal logistics.	Modelling & algorithms	Port of Hamburg (Germany)
Alessandri et al. 2009	Multimodal Transport	A discrete-time dynamic model of the various flows of containers that are inter-modally routed from arriving carriers to carriers ready for departure is proposed.	Mathematical models	
Chen et al. 2013	Multimodal Transport	The interaction between crane handling and truck transportation in a maritime container terminal is formulated as a constraint programming model and a three-stage algorithm is developed.	Mathematical models and algorithms	

Table 2.1: A summary of literature review on terminal strategic and tactical planning

2.2.2 Operational Planning Level

The level of operative planning consists of the main planning steps to perform the various logistics processes in a container terminal. When planning and scheduling the use of available resources for a short term planning horizon, usually several days or weeks, specific issues should be considered (Steenken et al, 2004 and Gunther and Kim, 2006).

Figure 2.5 gives an overview of the planning problems of a container terminal at the seaside operation, the yard operations, and the landside operations (Meisel, 2009).

2.3 Modelling Logistics Process at Container Terminals

2.3.1 Terminal Internal Operations Planning

This section reviews the planning problems at a container terminal from the modelling perspective. This literature is more relevant since the main purpose of this study is to model the logistics process through the different stages of operations planning. This section is classified into three sub-sections: terminal internal operations planning either at the seaside operations planning or the yard operations planning, landside operations planning, and integrated operations planning.

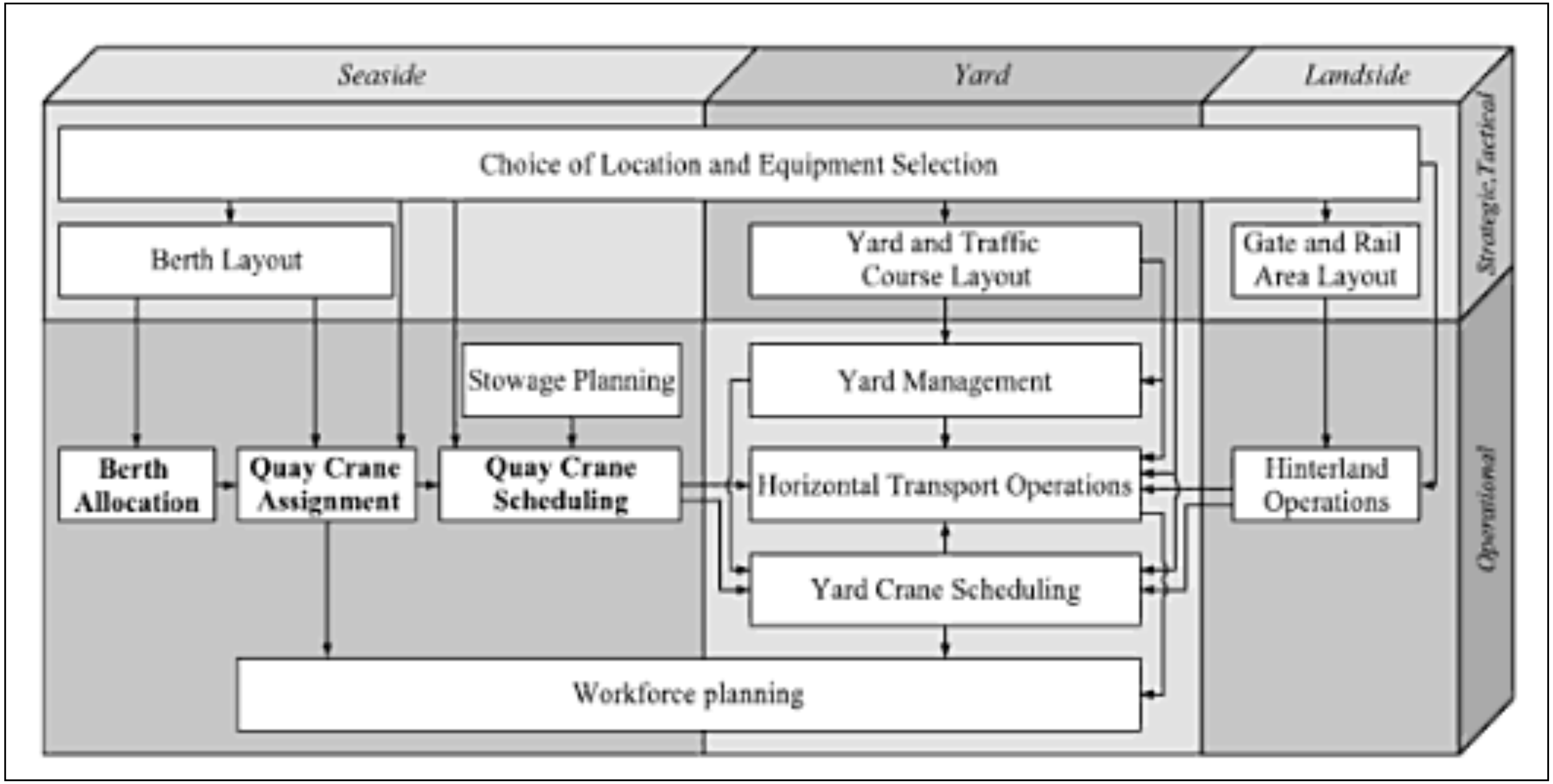


Figure 2.5: Planning problems of container terminals (Source: Meisel, 2009 and Bierwirth and Meisel, 2010)

2.3.1.1 Seaside Operations Planning

Berth Allocation

A berth has to be allocated to a ship before its arrival. Additional data such as vessel's length, draft, expected time of arrival and the prospective handling time should be considered. Vessels should be berthed at positions of sufficient water depth. Container vessels usually stay at the assigned berthing position during the entire service to avoid increasing the handling time. In case of ship delays, automatic and optimized berth allocation is of vital importance as in this case, a new berthing place should be assigned to the ship whereas containers are already stored in the yard. Generally, minimizing the vessels port stay time, the workload of terminal resources, and the number of rejected vessels to be served at the terminal, are all the objectives behind berth planning.

In this regards, Nishimura et al. (2001) developed a heuristic procedure, based on a genetic algorithm, to focus on the problem of dynamic berth assignment to ships in the public berth system. Henesey et al. (2004) presented a berth allocation management system for simulating and evaluating berth allocation policies at a container terminal. Cordeau et al. (2005) used a tabu search (TS) algorithm for solving the berth allocation problem in the Gioia Tauro terminal, Italy. Also Briano et al. (2005) presented a simulation model to be used as a tool for supporting realistic planning inside Italian maritime ports with container terminals. The paper outlined the integration between a flexible simulator which represents the marine-side operations of a container terminal with a Linear Programming model for improving berth assignment management policies and yard stacking management policies.

Moorthy and Teo (2006) proposed a framework to address the home berth design problem. They modelled this as a rectangle-packing problem on a cylinder and used a sequence pair based simulated annealing algorithm to solve the problem. Wang and Lim (2007) transformed the NP-hard berth allocation problem into a multiple stage decision-making procedure through a stochastic beam search algorithm. Vis and Anholt (2010) performed a simulation study to compare the performance of traditional one-sided marginal berths and indented berths. Arango et al. (2011) applied the berth allocation planning problems using simulation and optimisation with Arena software to the port of Seville. Zhen et al. (2011) developed a decision model for the berth allocation problem under uncertain arrival time or operation time of vessels.

Crane Assignment

To load and unload a large container vessel, three to five cranes may be used, while feeder ships can be operated with one or two cranes. The problem is to assign cranes to vessels in order to fulfil all the required transhipments of containers. Allocating or assigning cranes to vessels is referred to as “crane split”. Regarding this problem, two decisions should be made. Firstly, sufficient crane number and capacity should be assigned to serve each vessel, taking into account the accessibility of cranes at the berth and the impossibility to exchange cranes between different berths at the terminal. The berthing times given by the present berth plan have to be considered when assigning cranes to vessels. The second decision is to determine the specific cranes that make up the set of assigned cranes. Deciding on these specific cranes that are used to serve vessels and minimizing the number of crane setups or the crane travel times are the goals that should be achieved. Crane split allocates a number of cranes to a ship and its sections (bays) on hold and deck and determines the schedule, according to which, bays have to be operated. The objective behind this is to minimize the ship's delays, and maximize its performance as well as to maximize the economic utilization of cranes.

In 2007, Linn et al. proposed an approach for predicting the quay crane rate in a terminal in Hong Kong using the artificial neural network (ANN) paradigm of a multilayer perception with a back propagation-learning algorithm. Li and Vairaktarakis (2004) developed an optimal algorithm and some heuristic algorithms are developed for the case of a single quay crane to address the problem of minimizing the unloading time for a vessel at a container terminal with a fixed number of internal trucks.

As for the quay crane scheduling, Kim and Park (2004) proposed a branch-and-bound algorithm and a greedy randomized adaptive search procedure to solve the quay crane scheduling and load-sequencing problem. Lee et al. (2008) used mathematical models and algorithms to develop an NP-complete quay crane scheduling with consideration of non-interference constraints. Liang and Mi (2007) developed a multi-objective model for the quay crane scheduling in the berth allocation-planning problem. Tavakkoli-Moghaddam et al. (2009) formulated a novel, mixed-integer programming model for the quay crane scheduling and assignment problem, namely QCSAP, in a container terminal. In (2010), Legato et al. developed a simulation-based optimization model for QC modelling problem with the objective of finding the schedule that optimizes a classical objective function. The search process for the optimal schedule is accomplished by a simulated annealing algorithm. Also Bierwirth and Miesel (2010) developed new classification schemes for berth allocation problems and quay crane scheduling problems.

Further references concerning the quayside management include: Bish et al. (2005), who used algorithms that focus on the quayside process of discharging and uploading containers to and from a single vessel. Möhring et al. (2005) also developed a real-time algorithm for AGV routing. Whereas Zhang et al. (2005) proposed three mixed 0–1 integer programming models for dispatching vehicles such as AGVs or yard trucks at the quayside. Canonaco et al. (2008) used a queuing network model and a manager-friendly simulation tool for the management of container discharge and loading at any given berthing point. Zeng and Yang (2009) developed a simulation optimization method to schedule loading or unloading containers in container terminals. The optimization algorithm is used to search the solution space; and the simulation model is used to evaluate the solutions generated by the optimization module. Thus the intelligent decision mechanism of optimization algorithm and the evaluation function of simulation method are integrated. Recently, Ursavas (2014) proposed a decision support system for optimizing operations on the quayside of a container terminal. He conducted a real life case study at the Port of Izmir in Turkey to show the practical application of the DSS presented.

Stowage Planning

Stowage planning is undertaken in two steps. The first step is carried out by the vessel operators who have the information regarding the ports of call and the expected number of containers to be loaded and unloaded in each port. These shipping lines assign ship's slots to container categories. Containers are categorized according to their type, destination, length, and weight. For example, reefer containers can be assigned to slots providing electric supply. This results in achieving the objective of maximum utilization of the vessel's capacity. The second step starts when this assignment is transferred by means of EDI to the terminal operator who assigns individual containers to slots of their container categories.

Based on this stowage plan, terminal planners determine the sequence of unloading inbound containers and of loading outbound containers. For export containers, besides their loading sequence, they are also assigned to vessels slots according to their categories as set by the vessel operator. The overall objective is the minimization of reshuffles within the vessel as well as within the yard. A reshuffle occurs when a container has to be accessed while other containers on top of it should be firstly removed. As reshuffles are unproductive container moves, thus minimizing their number will result in a shorter vessel handling time.

Ambrosino et al. (2004) proposed a LP model that considers the stowage planning problem, denoted as master bay plan problem, at a terminal in Genoa (Italy) while taking a set of structural and operational restrictions into account. Imai et al. (2006) proposed a multi-objective integer-programming model to focus on container stowage and loading plans of a ship.

Table 2.2 summarizes the literature review that covers the seaside operation planning of container terminals.

In summary, this section gives an overview of the seaside operations in container terminals. This will draw the first lines when formulating the initial stages of the desired model, without going into the details of this stage that were already addressed through the previous work presented.

Author	Category of Study	Idea of Content	Method Applied	Case Study (if any)
Henesey *et al.* 2004	Berth Allocation	A berth allocation management system for simulating and evaluating berth allocation policies at a container terminal.	Simulation	
Cordeau *et al.*2005	Berth Allocation	A tabu search (TS) algorithm for solving the berth allocation problem.	Algorithms	The Gioia Tauro terminal, Italy
Wang and Lim 2007	Berth Allocation	Transforming the *NP*-hard berth allocation problem into a multiple stage decision-making procedure through a stochastic beam search algorithm.	Modelling, Algorithms	
Ambrosino *et al.* 2004	Stowage Planning	A LP model is proposed that considers the stowage planning problem, denoted as master bay plan problem, while taking a set of structural and operational restrictions into account.	Modelling, Optimization	A terminal in Genoa (Italy)
Imai *et al.* 2006	Stowage Planning	A multi-objective integer-programming model is proposed to focus on container stowage and loading plans of a ship.	Modelling	
Kim and Park 2004	Quay Crane Scheduling	A branch-and-bound algorithm and a greedy randomized adaptive search procedure to solve the quay crane scheduling and load-sequencing problem.	Algorithms	
Lee *et al.* 2008	Quay Crane Scheduling	An NP-complete quay crane scheduling with consideration of non-interference constraints.	Mathematical models, algorithms	
Canonaco *et al.* 2008	Quay Side Management	A queuing network model and a manager-friendly simulation tool for the management of container discharge and loading at any given berthing point.	Modelling, Simulation	Gioia Tauro terminal
Arango et al. 2011	Berth Allocation	The berth allocation planning problems using simulation and optimisation with Arena software.	Simulation	The port of Seville
Liang and Mi 2007	Quay Crane Scheduling	A multi-objective model for the quay crane scheduling in the berth allocation-planning problem.	Mathematical models, algorithms	

Author	Category of Study	Idea of Content	Method Applied	Case Study (if any)
Bish *et al.* 2005	Quay Side Management	Algorithms that focus on the quayside process of discharging and uploading containers to and from a single vessel.	Algorithms	
Möhring *et al*. 2005	Quay Side Management	A real-time algorithm for AGV routing.	Algorithm	
Zhang *et al*. 2005	Quay Side Management	Three mixed 0–1 integer programming models for dispatching vehicles such as AGVs or yard trucks at the quayside.	Mathematical Programming	
Nishimura *et al.* 2010	Berth Allocation	A heuristic procedure, based on a genetic algorithm, is developed to focus on the problem of dynamic berth assignment to ships in the public berth system.	Algorithms, Heuristic	
Li and Vairaktarakis 2004	Quay Crane Scheduling	An optimal algorithm and some heuristic algorithms are developed for the case of a single quay crane to address the problem of minimizing the (un)loading time for a vessel at a container terminal with a fixed number of internal trucks.	Algorithms, Heuristic	
Zeng and Yang 2009	Quay Side Management	A simulation optimization method for scheduling loading operations in container terminals.	Simulation, Optimization	
Briano et al. 2005	Berth Allocation	A simulation model to be used as a tool for supporting planning of a great reality inside Italian maritime ports with container terminals.	Modelling, Simulation	La Spezia Harbor, Italy
Moorthy & Teo 2006	Berth management	A framework to address the home berth design problem modelling this as a rectangle packing problem on a cylinder and use a sequence pair based simulated annealing algorithm to solve the problem	Algorithms	
Tavakkoli-Moghaddam et al. 2009	Quay Crane Scheduling	A novel, mixed-integer programming (MIP) model for the quay crane (QC) scheduling and assignment problem, namely QCSAP, in a container port (terminal).	Modelling	

Author	**Category of Study**	**Idea of Content**	**Method Applied**	**Case Study (if any)**
Legato et al. 2010	Quay Crane Scheduling	A simulation-based optimization model for QC S modelling problem with the objective of finding the schedule that optimizes a classical objective function. The search process for the optimal schedule is accomplished by a simulated annealing (SA) algorithm.	Simulation & algorithms	
Linn *et al.* 2007	Quay Crane Scheduling	An approach for predicting the quay crane rate using the artificial neural network paradigm of a multilayer perception with a back propagation-learning algorithm.	Mathematical models, algorithms	A terminal in Hong Kong
Bierwirth & Miesel 2010	Quay Crane Scheduling & Berth Allocation	A review to provide a support in modelling problem characteristics and in suggesting applicable algorithms. New classification schemes for berth allocation problems and quay crane scheduling problems are developed.	Survey	
Vis & Anholt 2010	Berth configurations	A simulation study to compare the performance of traditional one-sided marginal berths and indented berths.	Simulation	
Zhen et al. 2011	Berth Allocation	A decision model for the berth allocation problem (BAP) under uncertain arrival time or operation time of vessels.	Modelling	

Table 2.2: Summary of the literature review that covers the seaside operation planning of container terminals

2.3.1.2 Internal Operations Planning

The efficiency of storage and stacking containers is one of the most important factors for a container terminal. In container terminal operations, the storage yard plays an essential role for a terminal's overall performance because it links the seaside and landside and serves as the buffer area for storing containers. Therefore, storage and stacking logistics has become a field that increasingly attracts attentions in both academic and practical research during the recent years (Luo et al, 2011 and Said and Elhorbaty, 2014).

Yard Management

Yard management involves three tasks. The first task is the reservation of yard areas that fit the expected transhipment volume of a vessel. For exported containers, the reserved areas can be divided according to container categories to avoid reshuffles. Yard reservation realizes high space utilization overtime. Reserved areas should be available before containers arrive at the yard rather than at the time of reservation. The second task is the selection of storage location for individual containers. This implies selecting a yard block first. This minimizes reshuffles as well. The third task for yard management is remarshalling, i.e. repositioning of containers in the yard. The objective of remarshalling is to minimize the container moves necessary to resolve the inappropriate storage location and stacking orders of containers (Lee and Hsu, 2007).

Modelling and programming techniques for yard management were applied by Kim et al. (2000) who developed a dynamic programming model for determination of the storage location of export containers in order to minimize the number of reshuffles expected for loading movements. Zhang et al. (2003) used a rolling-horizon approach to solve the storage space allocation problem in the storage yards of terminals. Also, Kim and Lee (2006) applied the constraint satisfaction problem technique to the problem of allocating storage space to export containers at a terminal in Busan. Tranberg (2005) discussed the problem of positioning containers in a yard block of a port container terminal through modelling and optimization as well. Dekker et al. (2006) explored different stacking policies for containers in automated terminals by means of simulation in Europe Container Terminals (Rotterdam).

Vacca et al. (2007) applied an approach to yard management which takes into account the impact that gate operations and transshipment operations have on the yard at the container terminals of Antwerp (Belgium) and Gioia Tauro (Italy). In 2010, some studies were conducted regarding yard management. For example, Asperen and Dekker (2010) developed a discrete-event simulation model to evaluate online container stacking rules. Ku et al. (2010) formulated a generic problem specification with parameterised scenarios and yard planning strategies, and formulated a generic mathematical model that solves for the optimum weekly yard plan template for that given problem. Wiese et al. (2010) proposed an integer linear program for planning the layout of container yards. Dong and Song (2012) formulated the container-leasing problem as part of a dynamic system with multiple voyages and inland transportation times. They used a simulation-based optimisation approach to solve the problem under typical container operational rules. Sharif and Huynh (2013) presented a novel approach for allocating containers to storage blocks in a marine container terminal. The model utilizes an ant-based control method. In the same year, Dong et al. used a simulation tool to evaluate and compare the performances of empty containers repositioning policies that were classified into origin–destination based solutions and state–based dynamic rules. A recent study conducted by Carlo et al. (2014) presented an in-depth overview of storage yard operations, including the material handling equipment used, and highlighted current industry trends and developments. They also discussed the current operational paradigms on storage yard operations.

Yard Crane Scheduling

Yard cranes are those gantry cranes operated with a yard. Their scheduling includes the deployment of cranes to yard blocks and scheduling of stacking and retrieval operations for single containers.

Zhang et al. (2002) formulated the crane deployment problem as a mixed integer-programming (MIP) model and solved it by Lagrangean relaxation. Linn et al. (2003) presented an algorithm and a mathematical model for the optimal yard crane deployment. The potential of the model in optimizing yard crane deployment was tested with a set of real operation data extracted from a major container yard terminal.

Simulation in this issue was investigated by Kim et al. (2003) who used modelling and simulation approaches and decision rules for sequencing pickup and delivery operations for yard cranes and outside trucks. Also, Liu et al. (2004) evaluated, through simulation, the impact of deploying AGVS in two commonly used container terminal configurations. Ng (2005) modelled the NP-complete scheduling problem as an integer program to study the problem of scheduling multiple yard cranes in order to minimize the total loading time or the sum of truck waiting times in a yard zone. In the same year, he and Mak proposed a branch-and-bound algorithm for solving the NP-complete problem of scheduling a yard crane performing a given set of (un)loading jobs with different ready times. Lee et al. (2006) studied the scheduling of two transtainers operating in two different yard blocks at the same time through a Genetic

Algorithm. In (2007), they developed an SA approach to solve the problem of scheduling two yard cranes which serve the loading operations of one quay crane at two different container.

Nang Laik (2008) presented two practical applications of the proposed Integer Programming model for the problem of container assignment and YC deployment and the container terminal simulation model in the context of planning the container terminal operations at two ports, namely the Port of Felixstowe and Port of Piraeus. Petering et al. (2009) evaluated several real-time yard crane dispatching systems by a fully-integrated, discrete event simulation model of a pure transhipment terminal that is designed to reproduce the multi-objective, stochastic, real-time environment at an RTGC-based, multiple-berth facility. He et al. (2010) developed a dynamic scheduling model using objective programming for yard cranes based on a rolling-horizon approach. To resolve the NP-complete problem regarding the yard crane scheduling, a hybrid algorithm, which employs heuristic rules and parallel genetic algorithm (PGA), is then employed. Then a simulation model is developed for evaluating this approach.

Table 2.3 summarizes the literature reviewed about internal operations planning.

As indicated, an extensive research was undertaken regarding yard management operations as being the core stage of the container terminal logistics processes. This section helps in shaping the following stages of the model and highlights the main decisions that should be taken into consideration.

Author	Category of Study	Idea of Content	Method Applied	Case Study (if any)
Liu *et al.* 2004	YS Yard Crane	Evaluating, through simulation, the impact of deploying AGVS in two commonly used container terminal configurations.	Simulation	Port of Long Beach, USA Port of Kelung, Taiwan
Zhang *et al*. 2002	YS Yard Crane	The crane deployment problem is formulated as a mixed integer-programming (MIP) model and solved by Lagrangean relaxation.	Mathematical Programming	
Vacca *et al*. 2007	YS Yard Management	An approach to the yard management which takes into account the impact that gate operations and transhipment operations have on the yard.	Optimization	Antwerp (Belgium) and Gioia Tauro (Italy)
Tranberg 2005	YS Yard Management	The problem of positioning containers in a yard block of a port container terminal.	Modelling, Optimization, Programming	
Linn *et al.* 2003	YS Yard Crane	An algorithm and a mathematical model for the optimal yard crane deployment.	Mathematical models and algorithms	A major container yard in Hong Kong
Zhang *et al.* 2003	YS Yard Management	Using a rolling-horizon approach to solve the storage space allocation problem in the storage yards of terminals.	Mathematical programming models	
Kim & Lee 2006	YS Yard Management	Applying the constraint satisfaction problem technique to the problem of allocating storage space to export containers.	Mathematical models	A terminal at Busan
Lee & Hsu 2007	YS Yard Management	An integer-programming model for the container-remarshaling problem for a single ship and a yard served by a RMG.	Modelling	
Ng & Mak 2005	YS Yard Crane	A branch-and-bound algorithm is proposed for solving the *NP*-complete problem of scheduling a yard crane performing a given set of unloading jobs with different ready times.	Mathematical models and algorithms	
He et al. 2010	YS Yard Crane	A dynamic scheduling model using objective programming for yard cranes is developed based on rolling-horizon approach.	Modelling, Simulation	

Author	Category of Study	Idea of Content	Method Applied	Case Study (if any)
Lee *et al.* 2006	YS Yard Crane	The scheduling problem of two yard cranes operating in two different yard blocks at the same time through a revised Genetic Algorithm.	Algorithms	
Lee *et al.* 2007	YS Yard Crane	A mathematical formulation for the two-transtainer scheduling problem (TTS) is provided. Also, a simulated annealing (SA) algorithm for the TTS is proposed.	Algorithms	
Kim *et al.*2000	YS Yard Management	A dynamic programming model for determination of the storage location of export containers in order to minimize the number of reshuffles expected for loading movements.	Modelling, Programming	
Kim *et al.* 2003	YS Yard Crane	Approaches and decision rules for sequencing pickup and delivery operations for yard cranes and outside trucks.	Modelling, Simulation Programming,	
Petering et al. 2009	YS Yard Crane	Several real-time yard crane dispatching systems are evaluated by a fully-integrated, discrete event simulation model of a pure transhipment terminal that is designed to reproduce the multi-objective, stochastic, real-time environment at an RTGC-based, multiple-berth facility.	Simulation	
Ng 2005	YS Yard Crane	The *NP*-complete scheduling problem is modelled as an integer program to study the problem of scheduling multiple yard cranes in order to minimize the total loading time or the sum of truck waiting times in a yard zone.	Mathematical models and algorithms	
Ku et al. 2010	YS Yard Management	A generic problem specification with parameterised scenarios and yard planning strategies, and formulate a generic mathematical model that solves for the optimum weekly yard plan template for that given problem.	Mathematical models	

Author	Category of Study	Idea of Content	Method Applied	Case Study (if any)
Wiese et al. 2010	YS Yard Management	An integer linear program for planning the layout of container yards.	Mathematical models & optimization	
Dong & Song 2012	YS Yard Management	A simulation-based optimisation approach is used to solve the problem of container leasing under typical container operational rules.	Simulation	
Sharif & Huynh 2013	YS Yard Management	A novel approach for allocating containers to storage blocks in a marine container terminal. The model utilizes an ant-based control method.		
Asperen & Dekker 2010	YS Yard Management	A discrete-event simulation model to evaluate online container stacking rules.	Simulation	
Dong et al. 2013	YS Yard Management	A range of scenarios are designed based on realistic cases considering the stochastic and dynamic nature of liner services. A comprehensive set of simulation experiments are conducted and analysed.		

Table 2.3: A Summary of the literature reviewed about internal operations planning in container terminals

2.3.2 Landside Operations Planning

Landside operations are classified into rail operation, truck operation and internal transport.

Rail Operation

Trains are served either by using straddle carriers or gantry cranes spanning the rail tracks. Landside operations are similar to seaside operations. A loading plan deciding on which wagon a container has to be placed. The container's destination, type, weight and maximum load of wagon and the wagon's position in the train sequence are all factors determining the wagon position of a container. A loading plan can be produced by the railway company, and sent via EDI to the terminal operator, or by the terminal operator himself. The rail operator aims to minimize shunting activities of trains, while the terminal operator aims to minimize the reshuffles and minimize crane waiting times and empty travel of vehicles.

Arnold et al. (2004) dealt with the problem of optimally locating rail/road terminals for freight transport. A linear 0-1 program is formulated and solved by a heuristic approach. The model is applied to the rail/road transportation system in the Iberian Peninsula. Benna and Gronalt (2008) presented a simulation-based tool that can be used to plan and design a railroad container terminal, by simulating different terminal configuration in advance and accessing performance and utilization limits of the planned terminal.

Truck operation

These empty distances, previously mentioned, can be minimized if trucks transporting export containers and truck transporting import containers are operated simultaneously.

Nishimura et al. (2005) proposed a trailer assignment method called ‘‘dynamic routing’’ and developed a heuristic to increase the productivity of the terminal. Tan et al. (2006) applied a hybrid multi-objective evolutionary algorithm to find the Pareto-optimal routing to a transportation problem for moving empty or laden containers for a logistics company with a limited number of trucks and trailers. Ng et al. (2007) formulated an NP-hard MIP problem that is solved by use of a GA to address the problem of scheduling a fleet of trucks at a container terminal in order to minimize the makespan.

Internal Transport

Horizontal transport operations include three decisions. The overall objective of these operations is to minimize the empty travel of vehicles. The first decision is that vehicles are either assigned exclusively to quay cranes or they are pooled where each vessel serves different quay cranes. The second decision is the assignment of transport orders to vehicles and sequencing of assigned orders. The third decision is choosing the travel routes and controlling of traffic. In manually operated container terminals, this decision is left to drivers as they can find the shortest route to the desired destination. AGVs and ALVs are less flexible to route selection as they have to follow a set traffic course.

Within terminals, some internal movements and additional transports may occur if sheds for stuffing empty containers exist at the terminal. Also import containers are moved to sheds for stripping. Packed containers are transported to the export stock. Finally, unpacked containers should be stored in empty depots or in the yard. Soriguera et al. (2006) analysed the internal transport subsystem in a container terminal by means of queuing theory and simulation.

A summary of the literature reviewed on landside operation planning in container terminals is shown in table 2.4.

Author	Category of Study	Idea of Content	Method Applied	Case Study (if any)
Benna and Gronalt 2008	Rail operation	A generic simulation for railroad container terminals.	Simulation	
Arnold et al. 2004	Rail operation	Modelling a rail/road intermodal transportation system in the Iberian Peninsula.	Modelling	The Iberian Peninsula.
Nishimura *et al.* 2005	Truck operation	Proposing a trailer assignment method called ‘‘dynamic routing’’ and developing a heuristic aiming at increasing the productivity of the terminal.	Mathematical models, algorithms, heuristic	
Soriguera *et al.* 2006	Internal transport	Analysing the internal transport subsystem in a container terminal by means of queuing theory and simulation.	Simulation, Modelling	
Ng *et al.* 2007	Truck operation	A formulated NP-hard MIP problem is solved by use of a GA to address the problem of scheduling a fleet of trucks at a container terminal in order to minimize the makespan.	Simulation, Algorithms, Programming,	
Tan *et al*. 2006	Truck operation	A hybrid multi-objective evolutionary algorithm is applied to find the Pareto-optimal routing to a transportation problem for moving empty or laden containers for a logistics company with a limited number of trucks and trailers.	Algorithms	

Table 2.4: A summary of literature review covering landside operation planning

2.3.3 Integrated Operations Planning

Some of the reviewed contributions are mainly dedicated to sophisticated models for single decision problems at container terminals such as the quay crane scheduling problem, the berth allocation problem, yard operations …etc. Others studied a combination of problems and integration of solution methods into unique approaches such as the integration of berth allocation and quay crane scheduling, integration of yard block allocation and container transfers, and the integrated scheduling of handling equipment in a container terminal. Another trend in the literature considered the container terminal as a global system, instead of single optimization problems, the entire flow of containers is considered and optimized and all the container terminal operations are studied altogether.

As regards the literature that dealt with container terminal operations, Gambardella and Rizzoli (2000) reviewed how simulation and optimization techniques have been applied to help and improve the management of intermodal container terminals. Merkuryeva et al. (2000) used simulation metamodels such as traditional regression models and *If-then* type production rules are used to make *What-if* analysis for a simulation model define its sensitivity and the logic of terminal operations at the Baltic Container Terminal in Riga. In 2001, Legato and Mazza presented a queuing network model and a simulation experiment of the logistic processes at a container terminal.

Meersmans and Dekker (2001) also gave an overview of the use of operations research models and methods in the field of design and operation of container terminals in addition to its decision problems on strategic, tactical and operational level. In the same context, Kim (2005) introduced the various operations in container terminals and decision support problems that require support by scientific methods. Murty et al. (2000, 2003, and 2005) used mathematical models and algorithms to develop a decision support system that describes the various interrelated complex decision problems occurring daily during operations at container terminals with a view to enhancing the operational efficiency of these terminals. The ultimate goal of these decisions is to minimize the berthing time of vessels, the resources needed for handling the workload, the waiting time of customer trucks, and the congestion on the roads and at the storage blocks and docks inside the terminal; and to make the best use of the storage space. Given the scale and complexity of these decisions, it is essential to use decision support tools to keep the terminals in Hong Kong as the most efficient in the shipping industry.

Shabayek and Yeung (2002) developed and described an application of a simulation model (using Witness software) to simulate Kwai Chung container terminals. Also Liu et al. (2002) developed Microscopic simulation models for four different automated container terminal. Henesey et al. (2003) developed a market-based approach (multi-agent system approach) to container terminal management. Blok et al. (2003) used a visualization-simulation tool to explore the various technical, economic, political, spatial and logistical issues of container terminals in an early stage of complex inter-organizational decision-making on infrastructures in such a way that it enhances quality and progress of this decision-making. Further literature on container terminal logistics can be found in Steenken (2003) with his comprehensive description of logistics and optimization systems in container terminals especially in Burchardkai Hamburg.

Steenken et al. (2004) presented a wider description and classification of the main logistics processes and operations in container terminals and presenting a survey of methods for their optimization. An approach for generating scenarios of seaport container terminals that can be used as input data for simulation models was proposed by Hartmann (2004). The purpose is to outline the parameters that are important to produce realistic scenarios of high practical relevance and to propose an algorithm that computes scenarios on the basis of these parameters. The generator has been developed within the simulation project at the HHLA Container-Terminal Altenwerder in Hamburg, Germany. Alessandri et al. (2005) applied modelling and optimization methods to control container transfer operations inside intermodal terminals. A Mediterranean port in the Northern part of Italy was selected to be a case study. Maione and Ottomanelli (2005) simulated the operations at a container terminal through proposing a container terminal simulation model within the theoretical framework of Petri Nets that allow taking into account the different aspects of the considered system. Jing et al. (2005) evaluated container terminals and elaborated on the issues involved in container terminal simulation, the design and features of the adaptable simulator developed.

Günther and Kim (2006) reflected the recent developments and examined research issues concerned with quantitative analysis and decision support for container terminal logistics. Other references include: Kozan (2000); Rashidi and Tsang (2005) and Shu et al. (2007). Bielli et al. (2006) outlined a container terminal simulation model and gave components architecture that was implemented with Java. This paper provided a help tool in a port decision support system through simulator calibration and validation. The object oriented software design using UML diagrams is also deployed in this project. Gronalt et al. (2006) developed an approach for efficient resource-planning and effective capacity analysis of Hinterland container terminals. This paper presented the first results of an HCT overall solution tool which integrates configuration, simulation and reporting, and which is understood as a prototype of a special hinterland container terminal optimization-environment. By means of simulation different material handling technologies, shift patterns, resource scheduling and infrastructure capacity are analysed. Longo et al. (2006) used a simulation model to analyse and test several operative and security scenarios in a container terminal. The authors proposed an approach based on the complete parameterization of a container terminal simulator giving to the user (system's experts) an advanced interactive tool for scenarios testing, what if analysis and problems solving.

Legato and Trunfio (2007) proposed a holistic modelling paradigm for discrete-event simulation modelling based upon the process interaction worldview. The paper briefly describes the high-level architecture of a tool for the optimal management of large and complex systems via DES. It defines the main concepts of the simulation MP and illustrates its potentiality by modelling some logistics processes at the Gioia Tauro maritime terminal. Stahlbock and Voß (2008) provided an expository update of research on operations research methods applied on maritime container terminal operations. They provide a comprehensive survey of the state of the art of operations at a container terminal as well as of methods for their optimization. Huang et al. (2008) applied a simulation system to analyse three container terminals in Singapore. Froyland et al. (2008) developed algorithms to manage the container exchange facility, including the scheduling of cranes, the control of associated short-term container stacking, and the allocation of delivery locations for trucks and other container transporters.

Legato et al. (2009) developed a simulation model using queuing-networks and mathematical models or heuristics approaches to evaluate feasible solution for container terminal problems. The paper depicted the queuing network model used to represent the core logistic processes at the Gioia Tauro container terminal. Then it discusses why High Performance Computations (HPC) computational frameworks are a key added value into the study of real systems through discrete-event simulation. Li and Li (2010) fused Harvard architecture and agent-based computing paradigm to model the operational processing of CTLS. Longo (2010) proposed a modelling and simulation-based approach supported by advanced design of experiments for designing effective operational policies and practices to manage better the flow of containers toward the inspection area as well as understanding the impact on the container terminal efficiency of the integration of the inspection activities in the normal operations. Rashidi and Tsang (2013) presented a survey of literature over operations, simulations and performance, and problems in CT and each of the problems' scheduling decision and their formulation as Constraint Satisfaction and Optimization Problems (CSOPs).

Work Force Planning

When planning for a work force in a container terminal, two decisions should be made; the first one is deciding on the work force capacity required to handle the workload of a terminal within a certain period of time i.e. determining the number of workers needed to operate the equipment. The second decision regarding work force planning is the scheduling of labour tasks. Scheduling of individual workers is vital for handling special containers. Labour task scheduling aims at minimizing the delay of completing tasks and minimizing the required number of workers.

Kim et al. (2004) proposed the efficient scheduling of operators of handling equipment through formulating a constraint satisfaction problem.

Table 2.5 summarizes the literature review covering integrated operations planning.

This section represents the most relevant section to the aim of this research. As mentioned earlier, this research aims to model the logistics process in Egyptian container terminals. Accordingly, reviewing the literature that considers the integrated operations in container terminals is of a great importance as it fits the research aim and helps achieve a few of the research objectives. The major guidelines for the whole logistics process in container terminals were stimulated from this thorough review. Modelling and simulation are the dominant data analysis methods employed in most research as reflected by the literature. Mainly discrete-event simulation, queuing modelling, and algorithms are the mostly implemented modelling tools, but most of them did not consider the dynamic perspective of the logistics operations. Decision support systems also quite commonly used as they are challenging for decision making, especially at different levels of organization such as strategic, tactical, and operational (Liu et al, 2009) which represent the basic planning decisions when it comes to the operations of container terminals. It is also revealed that uncertainty, although it is an essential characteristic in the logistics processing activities of container terminals such as consolidation, movement, handling, discharge, maintenance and repair (Song et al, 2007), little research addressed this issue.

Author	**Idea of Content**	**Method Applied**	**Case Study (if any)**
Huang *et al* 2008	A simulation system that is applied to analyze three container terminals.	Modelling, Simulation	3 container terminals in Singapore
Merkuryeva *et al.* 2000	A simulation of containers processing at the Baltic Container Terminal in Riga.	Meta-modelling, Simulation	Baltic Container Terminal
Henesey *et al.* 2003	A market-based approach to container terminal management.	Multi-agent system approach	
Murty *et al.* 2005	Using decision support systems to make inter-related decisions during daily operations at a container terminal.	Mathematical models and algorithms	Hong- Kong terminals
Stahlbock and Voß 2008	Providing the current state of the art in container terminal operations and operations research.	Survey	
Jing *et al.* 2005	An evaluation of container terminals using an adaptable container terminal simulator.	Simulation	
Legato and Trunfio 2007	A simulation-modelling paradigm based on the process interaction world view for the optimal management of logistics activities in a modern container terminal.	Modelling, Simulation	The Gioia Tauro terminal
Rashidi and Tsang 2005	Classifying container terminals' problems into scheduling decisions where each is formulated as constraint satisfaction and optimisation problems.	Survey, Optimization	
Steenken *et al.* 2004	A description and classification of the main logistics processes and operations in container terminals and presenting a survey of methods for their optimization.	Survey	
Froyland *et al.* 2008	Algorithms to manage the container exchange facility, including the scheduling of cranes, the control of associated short-term container stacking, and the allocation of delivery locations for trucks and other container transporters.	Mathematical models and algorithms	Patrick Corporation's container terminal at Port Botany in Sydney, Australia
Bielli *et al*. 2006	Outlining a container terminal simulation model and giving components architecture that are implemented with Java.	Modelling, Simulation	

Author	Idea of Content	Method Applied	Case Study (if any)
Murty *et al.* 2000	Developing a decision support system to enhance the operational efficiency of container shipping terminals.	Mathematical models and algorithms	
Blok *et al.* 2003	A visualization-simulation tool is used to explore the various technical, economic, political, spatial and logistical issues of container terminals.	Simulation, Visualisation, Gaming	
Alessandri *et al*. 2005	Modelling, optimizing and controlling container transfer operations inside intermodal terminals.	Modelling, Optimization	A Mediterranean port in the Northern part of Italy
Günther and Kim 2006	Reflecting the recent developments and examining research issues concerned with quantitative analysis and decision support for container terminal logistics.	Survey	
Legato *et al.* 2009	A simulation model using queuing-networks and mathematical models or heuristics approaches to evaluate feasible solution for container terminal problems.	Simulation, Modelling	The Gioia Tauro container terminal
Meersmans and Dekker 2001	An overview of the use of operations research models and methods in the field of design and operation of container terminals with its decision problems on strategic, tactical and operational level.	Survey	
Murty *et al.* 2003	Describing various interrelated complex decision problems occurring daily during operations at a container terminal.	Mathematical models and algorithms	
Shabayek & Yeung 2002	An application of a simulation model (using Witness software) to simulate Kwai Chung container terminals is developed and described.	Simulation, Modelling	Kwai Chung container terminals
Hartmann 2004	An approach for generating scenarios of sea port container terminals that can be used as input data for simulation models.	Simulation, Optimization	HHLA container-terminal Altenwerder in Hamburg, Germany

Author	Idea of Content	Method Applied	Case Study (if any)
Shu *et al.* 2007	The Information Sharing Platform for Port Container Terminal Logistics using Virtual Reality.		Tianjing Container Port in China
Maione and Ottomanelli 2005	A model to simulate the operations at a container terminal.	Simulation, Modelling	
Kim 2005	Introducing various operations in container terminals & decision support problems that require support by scientific methods.	Survey	
Kozan 2000	A network model reflecting the logistics structure of a terminal and the progress of containers is shown.	Modelling	
Steenken 2003	A comprehensive description of logistics and optimization systems in container terminals.	Optimisation	Burchardkai Hamburg
Legato and Mazza 2001	A queuing network model and a simulation experiment of the logistic processes at a container terminal.	Simulation, Modelling	
Yun and Choi 2003	An object-oriented simulation model for analysis of container terminals.	Simulation, Modelling	
Liu et al. 2002	Microscopic simulation models are developed for four different automated container terminal.	Simulation	
Longo *et al.* 2006	A simulation model used to analyze and test several operative and security scenarios in a container terminal.	Modelling, Simulation	
Salido et al. 2012	A decision support system to guide the operators in the development of loading/unloading tasks of containers in a vessel.	Mathematical models and algorithms	
Rashidi and Tsang 2013	A survey of literature over operations, simulations and performance, and problems in CT and each of the problems' scheduling decision and their formulation as Constraint Satisfaction and Optimization Problems (CSOPs).	Survey, Optimization	
Li & Li 2010	Harvard architecture and agent-based computing paradigm are fused to model the operational processing of CTLS.	Simulation Modelling	

Author	Idea of Content	Method Applied	Case Study (if any)
Longo 2010	A modelling and simulation-based approach supported by advanced design of experiments for designing effective operational policies and practices to manage better the flow of containers toward the inspection area as well as understanding the impact on the container terminal efficiency of the integration of the inspection activities in the normal operations.	Simulation, Modelling	
Bell et al. 2011	A transfer of the classic frequency-based transit assignment method of Spiess and Florian to containers demonstrating its promise as the basis for a global maritime container assignment model.	Modelling	
Petering 2011	New numerical results on yard capacity, fleet composition, truck substitutability, and terminal scalability issues are obtained using fully-integrated, discrete event simulation model of a vessel-to-vessel transshipment terminal that is designed to reproduce the microscopic, stochastic, real-time environment at a multiple-berth facility.	Simulation, Modelling	
Gronalt *et al.* 2006	An approach for efficient resource-planning and effective capacity analysis of Hinterland Container Terminals.	Simulation	

Table 2.5: A summary of the literature review covering integrated operations planning

2.4 Container Terminal Performance Measures

Container terminals are facilities for transferring containers between different modes of transport and providing a package of activities/services to handle and control container flows from vessel to railroad, or road, and vice versa.

According to Thomas and Monie (2000), ports and terminals must measure their performance. The measurement of port or terminal efficiency is of particular importance because they are vital to the economy of the country and to the success and welfare of its industries and citizens. Thus, it is essential that port/terminal managers measure its performance, set performance targets, and then regularly assess its performance against those targets.

Fourgeaud (2000) implied that container terminals performance depends on:

• Ratio loaded vs. unloaded containers.

• Unproductive moves.

• The level of automation of the gantry-cranes.

• The average weight of containers and the proportion of containers requiring special attention.

• Commercial constraints; most of the lines calling at a port may have similar commercial constraints, leading to unevenly distributed calls.

There are many classifications of measuring performance of a container terminal. For instance, Thomas and Monie (2000) proposed that the performance measures can be classified into four categories. These are production, productivity, utilization, and service measures (Esmer, 2008). Bichou and Gray (2004) proposed a framework of port performance through conceptualizing ports from a logistics and supply chain management approach. Le Griffin and Murphy (2006) assessed the productivity of the Los Angeles and Long Beach ports, and, where possible, compared these measurements with those of other major container ports in the U.S. and overseas. Bae et al. (2007) proposed a framework for analysing container terminal performance and developed an approach to figure out best practices and provide benchmarks for decision making at Busan port container terminal. Kulak et al. (2008) presented an Arena-based simulation model to describe the terminal operations and allow evaluating some pre-defined performance criteria such as average productivity, average resource utilization and average waiting time of the resources to detect possible bottlenecks of the operational areas, namely the quay cranes, the storage yard and the transportation system.

Esmer (2008) analysed the existing literature about performance measures of container terminal operations. Azevedo et al. (2009) applied Data Envelopment Analysis as the methodology of the study to evaluate the performance measurement of the main Iberian container terminals. The main goal of this study is to establish performance key indicators of the operational management of these terminals and to value them during 2007 and at the same time to verify the availability of this information in the international network sites.

The Tioga Group, Inc. (2010) established an agreed set of productivity measures for marine terminals through analysing a survey. Beškovnik and Twrdy (2010) proposed a planning organization and productivity simulation tool, with a special emphasis on orientations to the optimization of operations in a maritime container terminal. Yi-zhong (2010) provided a practical approach to estimate the throughput capacity of a container terminal considering the types of the vessels, and it is also helpful for the decision makers to raise the throughputs of the container terminals by optimizing the combination patterns of the types of arriving vessels.

Table 2.6 summarizes the literature reviewed about container terminal performance measures.

The previous section is crucial for this particular research, because one of the previously mentioned research objectives is to identify the key issues that affect the performance of the whole process in the case company. In this regards, it is vital to review the main measures that assess container terminals performance and how they can be measured in order to be further, fully or partially, implemented throughout this study to help measure the performance of the logistics processes in the case company and thus enable various scenarios for improvement to be suggested. This also provides answers for the main research questions of the study.

Author	Idea of Content	Method Applied	Case Study (if any)
Le-Griffin & Murphy 2006	Providing the background for a discussion on container terminal productivity.	Survey, Analysis	Port of Los Angeles and Long Beach
Tioga Group, Inc. 2010	Establishing an agreed set of productivity measures for marine terminals.	Survey, Analysis	
Bichou & Gray 2004	A proposed framework of port performance through conceptualizing ports from a logistics and supply chain management approach.	Survey	
Esmer 2008	Analyzing the existing literature about performance measures of container terminal operations.	Survey	
Thomas & Monie 2000	Analyzing the existing literature about performance measures of container terminal operations.	Survey	
Azevedo et al. 2009	Assessing the ports performance of the containerised cargo terminals in the Iberian seaports hinterland using Data Envelopment Analysis.	A Bench-marking approach	Iberian seaports
Bae *et al.* 2007	A framework for analyzing container terminal performance. An approach to figure out best practices and provide benchmarks for decision-making.	Simulation, Modelling	Busan port container terminal
Kulak *et al*. 2008	A performance evaluation model for container terminal systems using Arena based simulation.	Simulation, Modelling	
Beškovnik & Twrdy 2010	A proposed planning organization and productivity simulation tool, with a special emphasis on orientations to the optimization of operations in a maritime container terminal.	Simulation	

Table 2.6: A summary of the literature review about container terminal performance measures

2.5 Research in Egyptian Container Terminals

Unfortunately, little research has been done covering the container terminal aspects particularly in Egypt. Some examples of the work done in this respect include Kheir-El-Din et al. (2005), who provided an overview of the maritime sector in Egypt, its regulatory framework from an economic perespective. Also Ghoniem and Helmy (2007) provided an overview of the status of maritime and related logistical services in Egypt aiming at identifying the points of strength and weakness. The study delved into the details behind the weak performance of some maritime and related logistics services, and finally provided some policy and regulatory suggestions to improve the status of such services. In addition, Abbas and Mokhtar (2003) proposed a number of potential measures, considerations, and policies aiming at improving the current logistics chain of the case company (which is a container handling company in Alexandria container terminal) in particular, as well as other container handling companies. The paper started by examining and comparing statistics of main ports in Egypt as well as comparing the performance indicators of the main container handling companies in Egypt. Then, the logistics chains of the case company were devloped. Based on the analysis of these logistics chains, a questionnaire was conducted to navigation lines and customers' brokers. This questionnaire aimed at eliciting the perception of the company's customers with regards to the services offered by the company.

El-Naggar (2010) described a methodology designed to support the decision-making process by developing seaport infrastructure to meet future demand. In order to determine an optimum number of berths at a seaport, queuing theory was applied in the light of port facilities and activities. The aim was to avoid inadvertent over and under-building. Within this methodology, the movements in port were firstly analysed. The waiting time of vessels outside the port and in queue was calculated in accordance with the considered queuing model. The theoretical functions representing the actual vessel arrival and service time distributions were determined. For the economic considerations, cost estimate studies including cost of port and waiting vessels were carried out. Finally, the optimum number of berths that minimizes the total port costs was decided. Both proposed mathematical and economical models were applied to Alexandria port in Egypt. Ragheb et al. (2010) in their paper, they firstly reviewed the key literature on seaport simulation and simulation model validation techniques. Then they studied the validation of a seaport simulation model, namely the port of Alexandria, Egypt. One of the most important techniques is to build a regression metamodel that represents the relationship between the model inputs and model outputs. They proved that the simulation model is valid. The output of this study was a decision-support model that will form the base of a decision-support system that can be used by management to improve the decision-making process.

Younis et al. (2010) discussed the problems of public sector container terminals in Egypt and pointing particularly to Port Said Container Terminal, focusing on existing problems and suggested solutions for solving and improving the performance and productivity to compete and face the challenges due to the continuous growth in container shipping market. The paper aims to introduce some practical solutions to increase the performance and competitive power of Port Said container terminal. Elazony et al. (2011) focused on design and implementation of reusable, interactive, simulation-based training activities at the port and logistics sector using Formal Graphical Approach (FGA) and e-learning system, to deliver the learning objects to learners in an interactive, adaptive and flexible manner. They applied the simulator at Damietta port in Egypt as a real-world case study and developing effective web-based and computer-based learning contents in order to reach an optimal use of simulators in operational port training actions. They analysed the performance of the system and benefits of applying formal graphical approach on the training simulator. Recently, Elkalla and Elshamy (2012) measured Alexandria container terminal production, productivity, utilization and service measures performance indicator, which is considered very important in determining the terminal

capabilities and its future trend. In 2014, Said et al. developed a discrete event simulation model that can be used to analyze the performance of container terminal operations. Finally, Said and ElHorbaty (2015) presented an approach using discrete-event simulation modeling to optimize solution for storage space allocation problem, taking into account all various interrelated container terminal handling activities. The proposed approach is applied on a real case study data of container terminal at Alexandria port.

Table 2.7 summarizes the literature reviewed on Egyptian container terminals.

As a conclusion, most of the research done on Egyptian container terminals followed the survey strategy. Only a few papers introduced simulation models, mainly discrete event simulation models. Uncertainty was not given a lot of attention in such research. Moreover simulation models that enable suggesting further scenarios have been also neglected.

Author	Idea of Content	Method Applied	Case Study (if any)
Abbas and Mokhtar 2003	Assessing the services offered by the case company in order to suggest a package of improvements.	Survey	A company in Alexandria container terminal
Said et al. 2014	Simulation and optimization of container terminal operations: A case study.	Simulation	El Dekhiela Container Terminal
Ghoniem and Helmy 2007	Over viewing the maritime transport and related logistics services in Egypt.	Survey	
Younis et al. 2010	A development strategy of the Port Said container terminal.	Survey	Port Said container terminal
Elkalla and Elshamy 2012	Assessment of Alexandria container terminal efficiency by applying performance indicators.		Alexandria Container Terminal
Elazony et al. 2011	Design and implementation of reusable, interactive, simulation-based training activities at the port and logistics sector using Formal Graphical Approac.h	Simulation	Damietta container terminal
El-Naggar 2010	A methodology designed to support the decision-making process by developing seaport infrastructure to meet future demand.	Queuing theory	Alexandria seaport
Ragheb et al. 2010	Validating a port simulation model with application to the port of Alexandria, Egypt.	Simulation	Alexandria port
Said et al. 2014	Solving container terminals problems using computer based modelling.	Modelling	Alexandria Container Terminal
Said and Elhorbaty 2015	A simulation modeling approach for optimization of storage space allocation in container terminal.		Alexandria port
Kheir-El-Din et al. 2005	An overview of the maritime sector in Egypt, its regulatory framework from an economic perspective.	Survey	

Table 2.7: A summary of literature review on Egyptian container terminals

2.6 Research Gaps and Research Questions

From the literature review, it is obvious that research on container terminal planning is abundant, with a specific group of literature focusing on using modelling and simulation techniques and tools to study container terminal operations and how they are interrelated. Within this group, some researchers focused on a particular planning level while others attempted to address a combination of two or several planning levels.

Three aspects of research gaps can be observed. Firstly, although integrated operations planning in container terminals has attracted a lot of attention in the last decade (Stahlbock and Voß, 2008, Günther and Kim, 2006 and Steenken et al, 2004), and provided that the process of decision-making in terminals is too complex to use mathematical programming and exact approaches, there is a lack of research to address the terminal logistics processes from both pipe flow and dynamic operation perspectives in terms of the desired findings not only the approach employed. The pipe flow model would add its contribution as an approach through analysing the aggregate capacities along the stages of the pipe and reveal its findings by identifying bottleneck resources/activities at a higher planning level, whereas the dynamic operation model would enable to evaluate the interacting effect between various activities at a lower planning level. Therefore, the findings of our model would help terminal planners and operators to make decisions related to the strategic/tactical and operational planning problems discussed in the literature review section (Meisel, 2009 and Lehmann et al, 2006). Secondly, uncertainty is an inherent characteristic in container terminal logistics processes. Many existing studies adopted a deterministic approach, or focused on a specific type of uncertainty in a specific activity (Arango et al, 2011, Legato et al, 2010 and He et al, 2010). However, there is a lack of research, which presents comprehensive scenario analysis of the impacts of various uncertainties in the logistics processes on the terminal performance. This study attempts to evaluate a typical container terminal logistics system including both import and export containers in the presence of multiple uncertainties in terminal operations (e.g. quay crane operations, tractor operations, yard crane operations). Specifically, the simulated model investigates uncertain variables such as the arrivals of vessels, the dwell time for imports, the dwell time for exports, the dwell time for empty containers, and the numbers of containers handled by storage yards. Scenario testing enables terminal managers to make managerial decisions for the improvement of performance in areas which concern them. It can also be used by terminal planners, managers, and operators as a guidance tool to yield managerial insights or as a forecast tool to test the future investment scenario before making the real implementation. Thirdly, although some studies included case studies for some container terminals worldwide, very little research was undertaken in Egyptian container terminals. However, there is a growing need for research in the areas of simulation and modelling of integrated container terminal operations with specific applications in Egyptian container terminals, not for being unique in their operations, but with a view to raising the performance level of such terminals to cope with the worldwide changes in global terminals. To address this gap, the study considers a case study application to an Egyptian container terminal. In addition, it provides essential data and information regarding major Egyptian container terminals, giving insights for future research and work.

The basic aim of this research is to model the logistics processes in container terminals. This case study research go deep into the details of the case company and highlight the main problems that face this company aiming to find solutions to improve the overall performance of the company through applying relevant techniques. The contribution of this research goes beyond enhancing knowledge, as it will also benefit the case company by providing potential solutions for its real problems that will result in improving the overall performance of the company. In the light of this framework, the main research questions can be summarized as:

1. How are the main logistics processes in the container terminal carried out and how do they interact with each other?
2. Where are the bottlenecks in the container terminal logistics processes?
3. How can the container terminal's managers overcome the main problems or bottlenecks?
4. How is the container terminal's performance measured for individual resources and as a whole system?
5. How can performance measures be improved?

2.7 Summary

This chapter has reviewed the literature available on the container terminals planning levels and logistics issues as well as the container terminal performance measures. It also reviewed the research undertaken on Egyptian container terminal. This extensive literature review led to identifying the research gaps and setting the research aim and questions in the last section of the chapter.

The next chapter will present an overview for the main Egyptian container terminals and their specifications as the surrounding environment for the case study. It will also refer to the executed and the future possible investments in each of the major Egyptian container terminals.

Chapter 3

Overview of Egyptian Container Terminals

This chapter is linked to the third research gap identified in chapter two. A lack of investigation in Egyptian container terminals necessitates studying their main specifications to show either their similarity or their uniqueness to other container terminals previously studied in other research. This would also create opportunities for further research to consider these terminals in other studies, given this collected data and information. Accordingly, this chapter presents an overview of the main Egyptian container terminals. This overview shows the environment of the case study that will be handled by this research. The chapter starts with an introduction in the first section, followed by a brief on the total container traffic handled in Egypt over the past years, the transhipped container traffic as well as the expected growth for Egyptian container ports in section two. In section three, the major container terminals in Egypt and their main specifications are presented. Section four highlights the executed, current, and future investments in Egyptian ports and terminals. The new Suez Canal project and its prospective benefits are outlined in section five. A SWOT analysis for maritime transport and logistics industry in Egypt is also given in the last section of the chapter.

3.1 Introduction

Strong competition between international ports and container terminals has been driven by worldwide trend towards globalization and free trade. Container terminals are enhancing their market competitiveness through improving efficiency, developing quality services along with their management styles.

Egypt is characterized by a unique location (a map showing the strategic location of Egypt is attached in Appendix V). It enjoys not only more than 4000 Km of sea shores as it faces two international seas, but also about 2000 Km of coastal frontiers as it is located at the crossroads of three continents. Its North border is located on the Mediterranean Sea, where Alexandria port which is one of the oldest ports in the world is in operation; such a location makes Egypt by nature a "hub" of the Mediterranean area (a map showing the location of Alexandria is attached in Appendix VI). Its East border is located on the Red Sea, where it is blessed with the Suez Canal which constitutes a major waterway for vessels either in their East-bound or West-bound journeys. The Suez Canal is considered as a fundamental source of income to the country. It is the policy of the Egyptian Government to enhance exports and increase the regional share of international markets for container handling, transient and transhipment. The success of this policy largely depends on the efficient and effective movement of cargo and containers through Egyptian ports (Abbas and Mokhtar, 2003).

3.2 Total Handled Container Traffic

As figure 3.1 shows below, in 2009, the Egyptian ports handled approximately 6.2 million TEU compared to 6.1 million TEU in 2008 and 5.1 million TEU in 2007 achieving a growth rate up to 1.5% in 2009 compared to 2008 and 19.8% in 2008 compared to 2007, thus the Egyptian ports maintained their positive growth rates from one year to the other from 2005 to 2009. This increase can be attributed to the increase of local and transit container handling (Ministry of Transport, 2010).

The number of local containers handled by the Egyptian ports reached approximately 2.3 million TEUs in 2009, 2.2 million TEUs in 2008 and 1.8

million TEUs in 2007, achieving a growth rate up to 3% in 2009 compared to 2008 and 22.8% in 2008 compared 2007. This increase can be due to the increase of the local export and import containers handling (Ministry of Transport, 2010).

In 2011, the January 25th revolution followed by the continued unrest in Egypt have adversely affected the performance of the transport and logistics industry. This led to an overall decline of 10% in year 2011 for containers handling, cargo handling, and vessels traffic, this decline versus a growth of 5% in the previous year. Due to the political and economic unrest in other Arab Spring countries it was estimated an average decline of 5.2% in year 2011/2012. Particularly, containers handled in Egyptian sea terminals reached 6.7 million TEUs in year 2010 versus 6.25 millions in year 2009, followed by a rise of 15% to reach 7.7 million TEUs in year 2011and then decline to 7.35 in 2012 by 5% (Review of Maritime Transport, 2012, 2013, and 2014). During year 2013, total containers handled in Egyptian ports were estimated to 6.073 million TEUs, carrying 58.946 million tons. The percentage of containerized cargo was 48% of the total volume of cargo handled during the year (Maritime Transport Sector, 2014).

Figure 3.1: Total container handled in Egyptian ports (Source: World Bank, 2012)

3.2.1 Transhipped Container Traffic

Most of the Mediterranean ports are competing to become hub points, through attracting container movements, especially transit containers, across the containers of Africa, Asia and Europe. Availability of sufficient capacities, quality and service levels, in addition to costs offered by these ports, are the main keys to such competition. Asia and Europe are considered the largest continents in handling transit containers with Egyptian ports. This shows the importance of Egyptian ports particularly those located on main navigational routes (Ministry of Transport, 2008).

For Egypt to become a regional hub for transhipments and containerized trade, the government has adopted a master plan (2001-2017) to modernize Egyptian ports by creating independent profit-oriented, cost-based corporations to management ports. It is revealed that this plan is not effectively implemented. In addition, policies should be adopted to enhance the operating efficiency of Egyptian maritime ports, introduce EDI systems, develop multi-modal transport, connect maritime ports with local transport networks and achieve higher safety and security levels in all modes of transport. Moreover, deepening of the Suez Canal to reach a depth of 72 feet will facilitate passage of large vessels (Ghoneim and Helmy, 2007).

In 2009, the number of transit containers handled by the Egyptian ports reached approximately 3.9 million TEUs compared to 3.87 million TEUs in 2008 and 3.3 million TEUs in 2007, achieving a growth rate up to 0.7% in 2009 compared to 2008 and 18.2% in 2008 compared 2007 (Ministry of Transport, 2010).

3.2.2 Growth Potential for Egyptian Container Ports

In a previous study conducted in 2007 by ISL (Institute of Shipping Economics and Logistics) and MRCC (Maritime Research and Consulting Center), it was expected that both direct and transhipment traffic via Egyptian container ports will rapidly grow to reach about 12.5 million TEUs by the end of year 2015 with 30% direct traffic and 70% transhipment traffic. It was assumed that the share of Egyptian ports of the total East Mediterranean ports will reach 19% within direct traffic and 65% within transhipment traffic with about 38% related to total direct and transhipment quantities (Ekalla and Elshamy, 2012). The following table 3.1 shows the expected container traffic via Egyptian container ports.

Ports	**Direct**		**Transhipment**		**Total**	
	2005	2015	2005	2015	2005	2015
Egyptian ports	1.1	3.7	2.5	8.8	3.6	12.5
Other Med East ports	8.4	15.8	1.5	4.7	9.9	20.5
Total	9.5	19.5	4.0	13.5	13.5	33.0

Table 3.1: Market potentials for Med East Egyptian ports within the region until year 2015 in 1000 TEUs (Source: ISL, 2007)

According to the transport and logistics sector review conducted by CI Capital Research (2012), despite the regional political instability in addition to the continued unrest in Egypt that took place in the past few years, it is believed that the industry will resume a growth pattern where a gradual increase is expected to reach 11.6% by year 2015/2016 for all the lines of business including containers handling, cargo handling, and vessels traffic. As regards container handling, it is expected to reach 9.8 million TEUs by 2016.

3.3 Egyptian Container Terminals

The following section gives an overview of the major Egyptian container terminals. A general description of each terminal’s specification, layout, operations and system are given. This reflects the main logistics processes that are performed by main Egyptian container terminals.

3.3.1 Alexandria Container Terminal

Alexandria Container and Cargo Handling Company (ACCHC)

Alexandria Container and Cargo Handling Company (ACCHC) is the first specialized container handling terminal in Egypt. It was established in 1984 to execute all activities related to container handling. It operates two major terminals; the first is Alexandria container terminal at the port of Alexandria, and the second is El Dekhiela terminal at El Dekhiela Port (ACCHC, 2015).

Alexandria container terminal has three berths for container vessels and one berth for RORO vessels. The terminal is located in the middle of Alexandria Port over an area of 163000 m^2. The terminal quay allows the anchorage of three ships at one time. It is designed to handle about 160000 TEUs per year. The storage capacity is 14000 TEUs as indicated by table 3.2. The terminal's layout is shown in figure 3.2 (ACCHC, 2015).

	Alexandria Container Terminal	**El Dekheilla Container Terminal**
Terminal area	163000 M2	380000 M2
Storage capacity	14000 TEU	15000TEU
Quay lengths	531 M	1040 M
Water depth	13.8 M	12-14.5 M
RO-RO quay length	164 M	Part of the main quay
RO-RO slide width	50 M	50M
Reefer connections	500 connection	400 connection

Table 3.2: Infrastructure characteristics in Alexandria and El Dekheila container terminals (Source: ACCHC, 2015)

In 1996, the company established a new container terminal in El Dekhiela Port. It started operation with one berth that accommodates three vessels at a time. The terminal area is about 380000 m^2 and its storage capacity is 15000

TEUs as indicated by table 3.2. El Dekhiela terminal layout is shown in figure 3.3 (ACCHC, 2015).

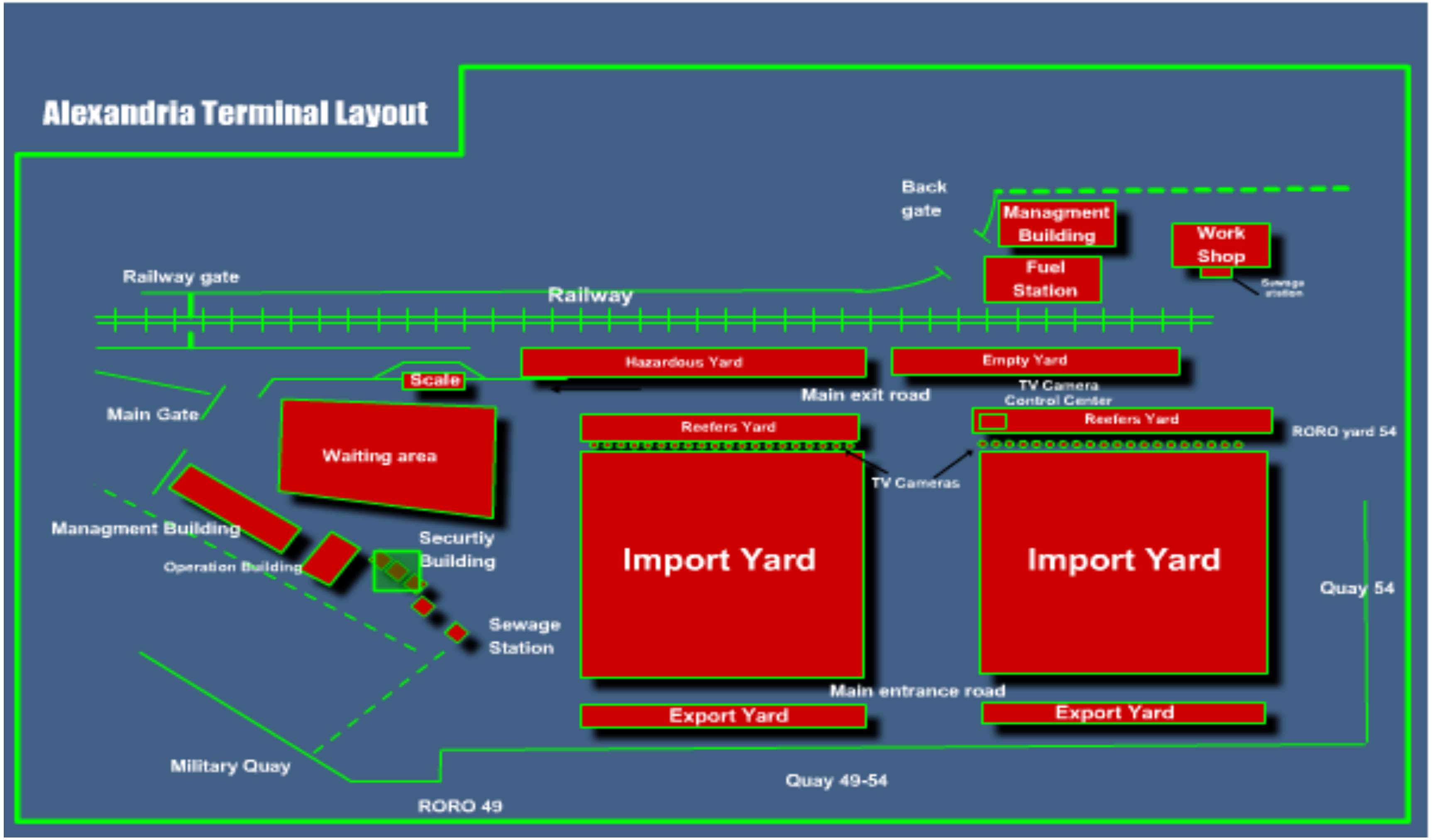


Figure 3.2: Alexandria terminal layout (Source: ACCHC, 2015)

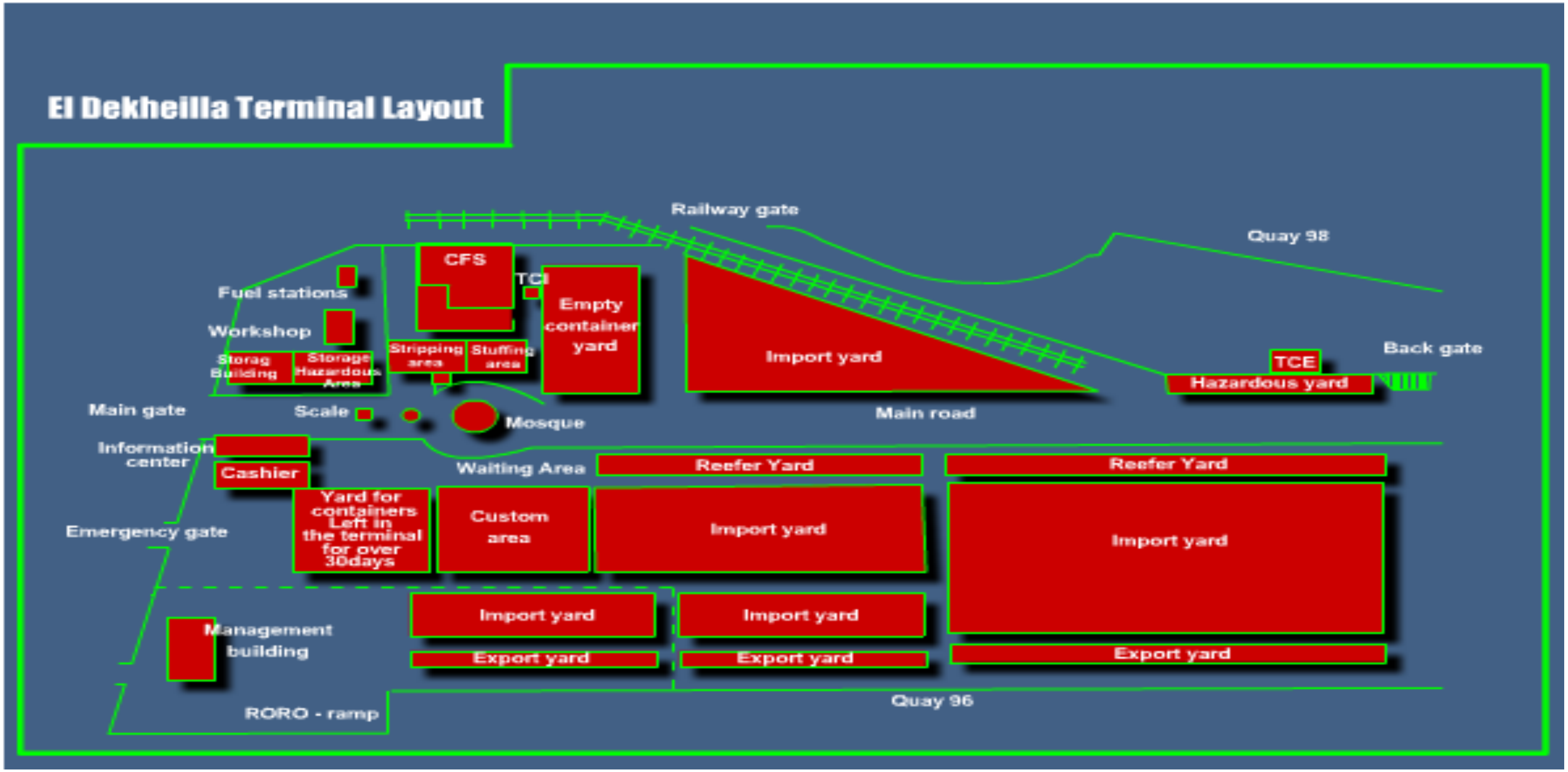


Figure 3.3: El Dekhiela terminal layout (Source: ACCHC, 2015)

3.3.2 Port Said Container Terminal

Port Said Container and Cargo Handling Company (PSCCHC)

Port Said port is located at the Northern entrance of the Suez Canal, on the international navigation route, in the middle of trade route between North and South, located at the crossroad of the most important world sea trade route between East and Europe via Suez Canal. Moreover, it's the most important hub port in the world (Port Said Port Authority, 2010).

PSCCHC is located at Port-Said port in the Mediterranean at the northern entrance of Suez Canal. This unique location, according to world studies, reduces handling cost by $2.5 per container and saves from 3 to 24 hour of vessel's waiting duration. Also this unique location facilitates handling container vessels calling at PSCT and joining the convoy without any delay. Port Said container quay and terminal are located at the extension of Abbas basin South Port-Said port and West canal navigation course (PSCCHC, 2015).

PSCCHC is an international port linked to more than 100 countries around the world. It has a container yard area of 467,130 square meters. It handles about 900,000 TEUs annually as shown in table 3.3. PSCCHC serves markets in North and South Europe, the Mediterranean and the Far East (PSCCHC, 2010).

PSCCHC was established to handle, store and transport containers to the designated yards or warehouses. Container handling activity started in 1988 with a handling volume 25479 TEUs. It began to grow year after year as a result of the continuous development incurred in the terminal including quays, yards, equipment, computer system…etc. until it reached 1,026,023 TEUs in 2006/2007 as indicated by figure 3.4. Container handling activity represents

90% of the company activities and accordingly it represents 90% of its income (PSCCHC, 2015).

Container yard	467130 m^2
Terminal annual capacity	800000 TEU
LCL store	13000 m^2 capable of storing contents of 250 TEU
Reefer receptacles	650 plug
Rail facility	1 terminal
Handling rate	27 box/hour/crane
Quay Productivity	1158 box/meter/year

Table 3.3: Port Said container terminal specifications (Source: PSCCHC, 2015)

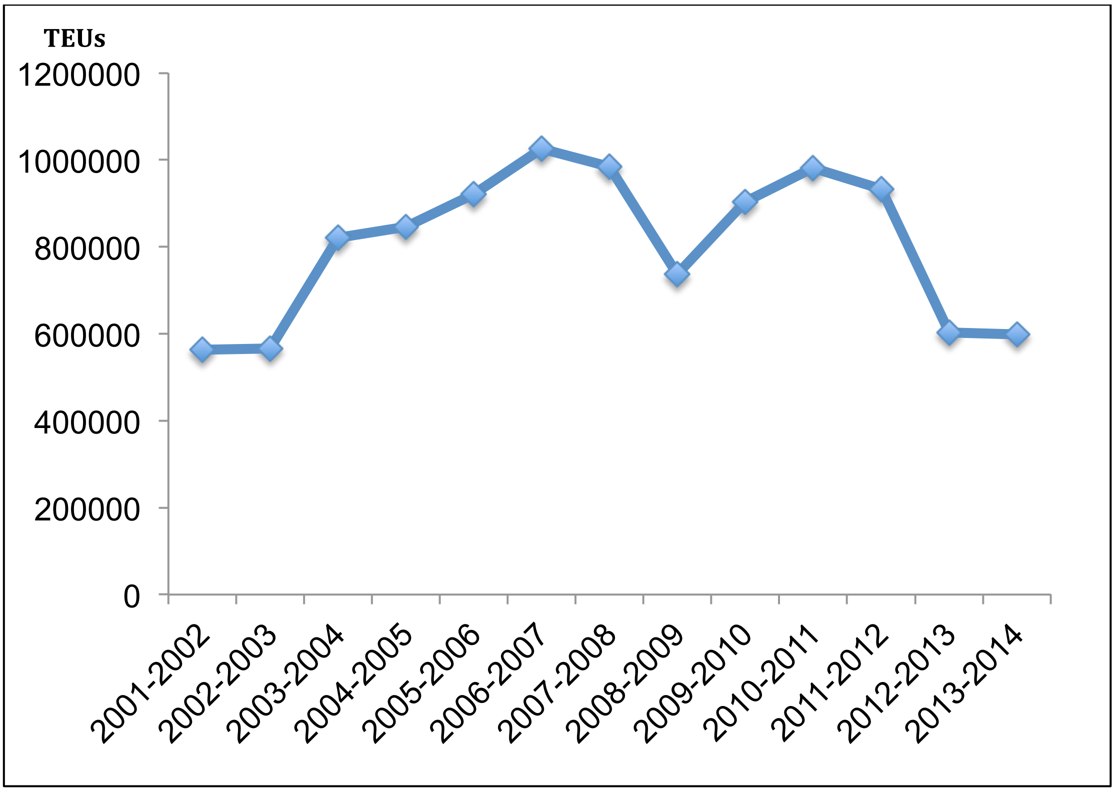


Figure 3.4: Container handling per year/TEU in Port Said container terminal (Source: PSCCHC, 2015)

Logistics of Imported Containers

Figure 3.5 shows the import yard in Port Said container terminal. The import yard area is 75,000m^2 carrying out unloading of L.C.L (Less than Container Load) in Container Freight Station warehouse whereby stripping and storing can be processed. The warehouse area is 6,000 m^2 capable of storing up to 250

TEUs. Safe cargo is secured by applying the most updated international storage systems. All equipment required for stripping, stacking and stowing goods is available. PSCCHC has allocated a special area for reefer containers (cooling and freezing) equipped with all facilities required to supply containers with electricity. The area can accommodate up to 650 reefer boxes and supply electric current in addition to relevant technical services required (PSCCHC, 2015).

Figure 3.5: Import yard at PSCCHC (Source: PSCCHC, 2015)

Logistics of Exported Containers

PSCCHC established a new external yard of 35000m^2 to handle Egyptian products and store them using electrical forklifts and stuff them in containers by applying most up to date storing methods. This export yard is characterized by rendering outstanding facilities and services with the view to promoting the export of Egyptian products. Also transporting empty containers (free of charge) to export yard to be stuffed and back alongside to be shipped on the allocated ships. PSCCHC provides some advantages for exported containers such as (PSCCHC, 2015):

- Providing the necessary handling equipment free of charge except handling dues of gantry cranes.
- Granting 50% discount on handling dues of export containers and cargoes.

- Providing electric power for reefer boxes, following up temperature and carrying out minor maintenance operations.
- Granting 50% discount on handling dues for exported reefer containers, after the free storage period.
- Providing clients (exporters) with the convenient containers to export their shipments.
- Providing proper stowage for shipments so as to be received by the consignees in good condition.
- Providing custom clearance service for exports.

PSCCHC Operation System

Figure 3.6 illustrates the terminal operation system in Port Said container terminal involving the whole logistics processes and operations performed by Port Said Container and Cargo Handling Company. The logistics processes, as shown in the figure, take place through three systems; planning system, operation system, and management system (PSCCHC, 2015).

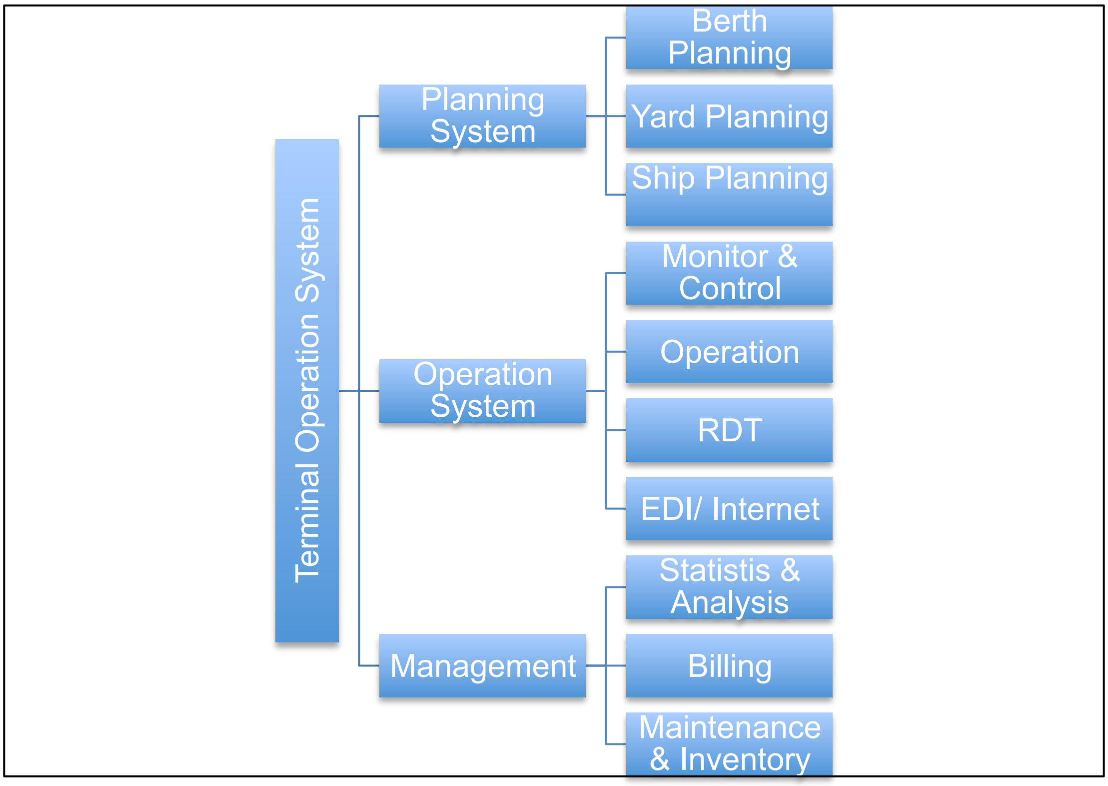


Figure 3.6: Terminal operation system at PSCCHC (Source: PSCCHC, 2015)

Vessel and yard planning and operation: This stage comprises three operations. Firstly, berth planning where a certain berth is allocated to the arriving ship to anchor and then the suitable gantry crane is allocated to discharge containers on board ships to the quayside. Upon completion of unloading containers, each container is stored at the allocated yard according to its cargo type through the yard planning operations. The final operation in this stage is the ship planning. This operation includes recording the vessel's master data including ship lines, agents, vessel type, vessel data, vessel profile, vessel unused cells…etc. After recording these data, gantry crane sequence as well as discharging and loading sequences should be identified. Finally shifting plans have to be established for yards and vessels. Planning system at PSCCHC is displayed in figure 3.7.

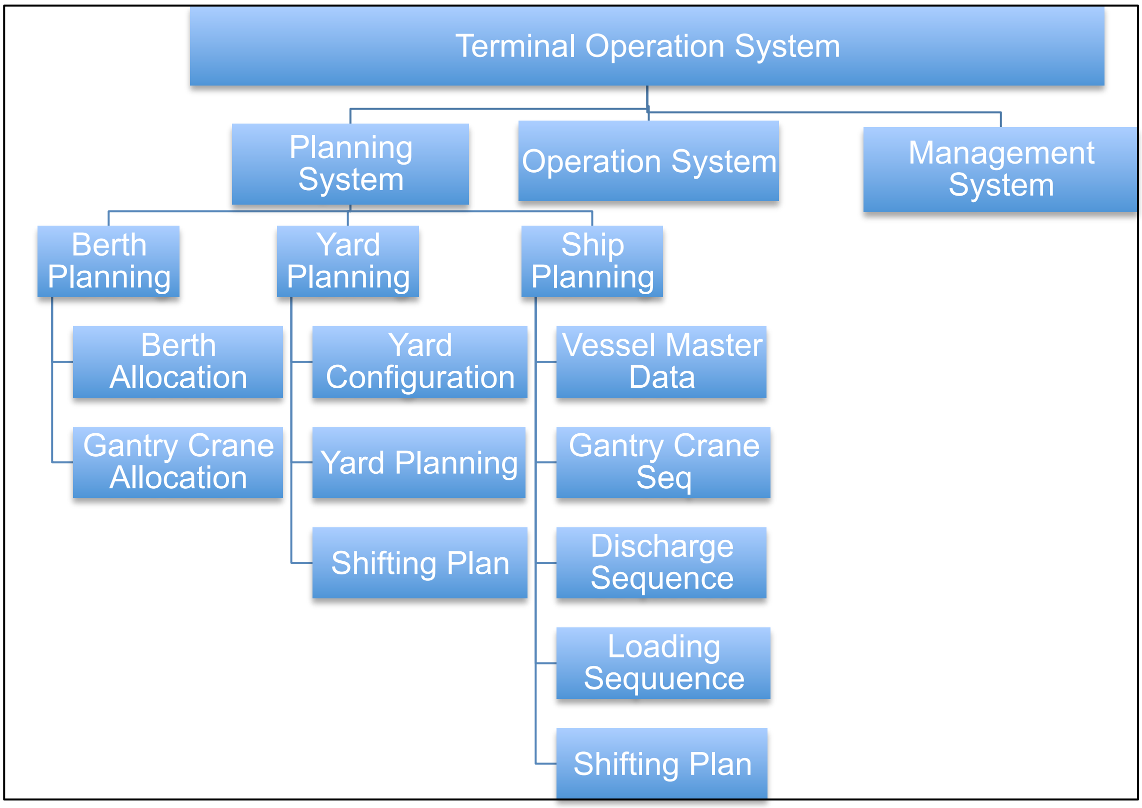


Figure 3.7: Planning system at PSCCHC (Source: PSCCHC, 2015)

Operation systems: The operation system of PSCCHC is classified into four main classifications as shown in figure 3.8. PSCCHC has a Radio Data Terminal (RDT) with two antennas to cover inside container terminal and external depot area. Using RDT increases terminal's productivity. The RDT modules cover; discharging and loading of vessels; shifting aboard vessels; receiving containers from vessels to yards; exiting containers from yards for loading vessel operations; shifting containers from yard to yard or within the same yard; and tracing containers.

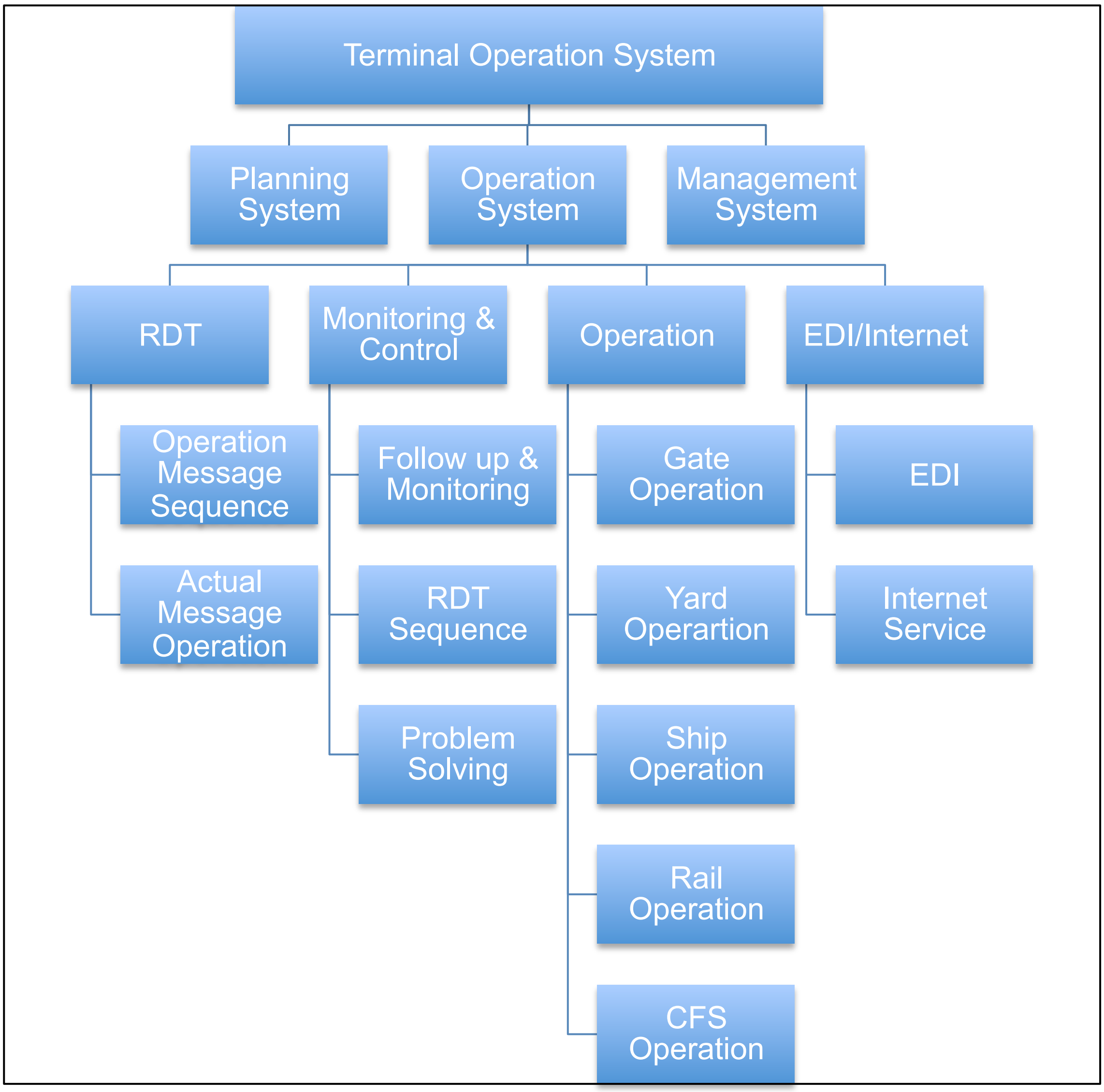


Figure 3.8: Operation system at PSCCHC (Source: PSCCHC, 2015)

Management information system: MIS provides standard reports for daily routine operations such as vessels and yards planning, different containers' reports according to status and/or container type and/or stuffing/and unstuffy dates, different statistics, operations analysis reports and statistics, and special reports and statistics needed (as real time gantry, terminal and berth productivity, stops and failure, berth planning and operation estimations). Classifications of the management system are shown in figure 3.9.

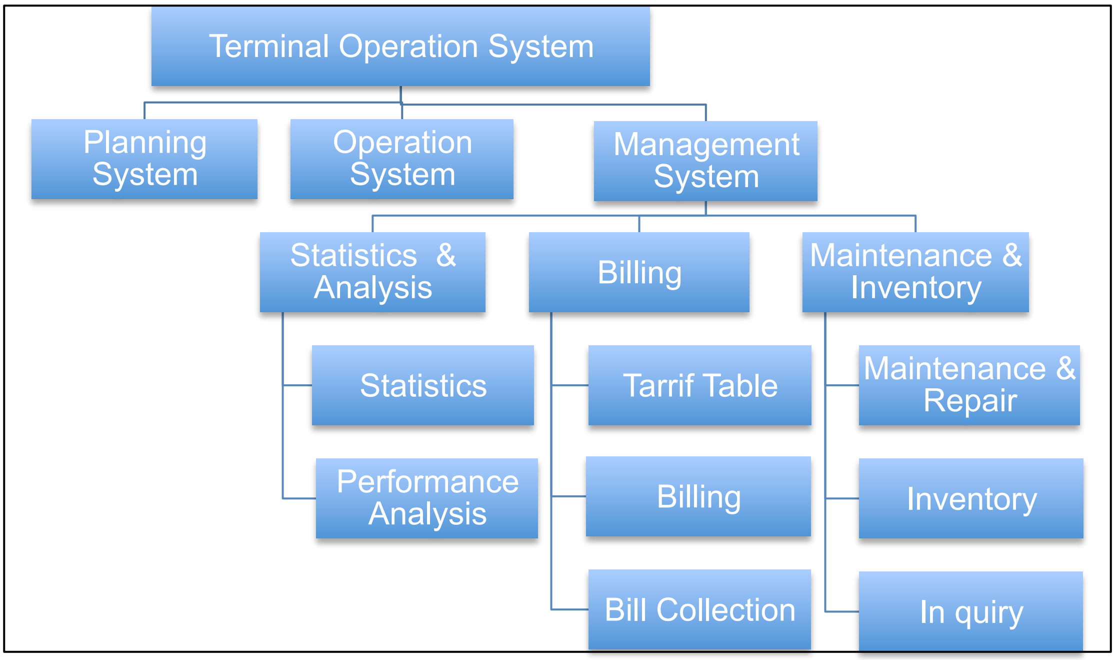


Figure 3.9: Management system at PSCCHC (Source: PSCCHC, 2015)

3.3.3 East Port Said Container Terminal

Suez Canal Container Terminal (SCCT)

East Port Said Port has a distinguished location east of the Northern entrance of the Suez Canal, at the confluence of three continents - the crossroad of the most important world sea trade route between East and West (see figure 3.10). Because of its strategic location, the port is considered as a promising hub centre for international trade between the Europe and Far East. To take advantage of this strategic natural location, the Government of Egypt constructed Port Said East Port on 35 km^2 (Port Said Port Authority, 2010).

Figure 3.10: East Port Said port (Source: Port Said Port Authority, 2010)

In year 2004, SCCT commenced terminal operations. Suez Canal Container Terminal is a private joint venture company which has signed a 30 years concession agreement, with the Egyptian Ministry of Transport, to build, operate, and manage East Port Said terminal. The majority (55%) shareholding of SCCT is held by APM Terminals. The SCCT terminal has been identified as one of the ports, which ideally meets the requirements to cater ultra large container ships (ULCS). Figure 3.11 illustrates the layout of SCCT (SCCT, 2009).

With the completion of a dredging project which deepened the terminal's draft from 13.9 to 14.5 meters, and the expected complement of 24 super-post Panamax cranes at the conclusion of the Phase II expansion (see figure 3.12), SCCT is capable of handling the largest containerships in the global container fleet. Phase II will increase annual capacity at SCCT to 5.4 million TEUs, making it the largest container terminal on the Mediterranean Sea (SCCT, 2013). SCCT specifications are listed in table 3.4. Future development plan expansion for the terminal includes the third and the fourth phases, from 2012 to 2017, involves completing storage, distribution and services' projects and dredging an entrance for the port. Finally, from 2017 to 2020, the utilization phase of precautionary land and completion of the infrastructure network and IT (Port Said Port Authority, 2010).

	Phase I	**Phase I+II**
No. of Cranes	12 Super Post Panamax Cranes	24 Super Post Panamax Cranes
Quay Length	1,200 m	2,400 m
Draft	14.5 m	16 m
Terminal Capacity	2.7 million TEU	5.4 million TEU
Terminal Area	600,000 sqm	1,200,00 sqm
Reefers Plugs	1,716 plugs	2,300 - 2,500 plugs

Table 3.4: SCCT specifications (Source: SCCT, 2015)

Despite its recent entry to the container market, East Port Said Port was able to mark its place among the largest ten Mediterranean container seaports and ranked the third on the list. It realized an impressive growth rate of 101% in the year 2005/2006. It also succeeded to jump from the 67th worldwide to the 35th in year 2006. Figure 3.13 shows that there is a noticed growth in the total containers handled in East Port Said Port from 0.7 million TEUs in year 2005 to 4.5 million TEUs in 2008 and it is also forecasted to increase to reach 10 million TEUs of handling containers in the future (Ministry of Transport, 2008).

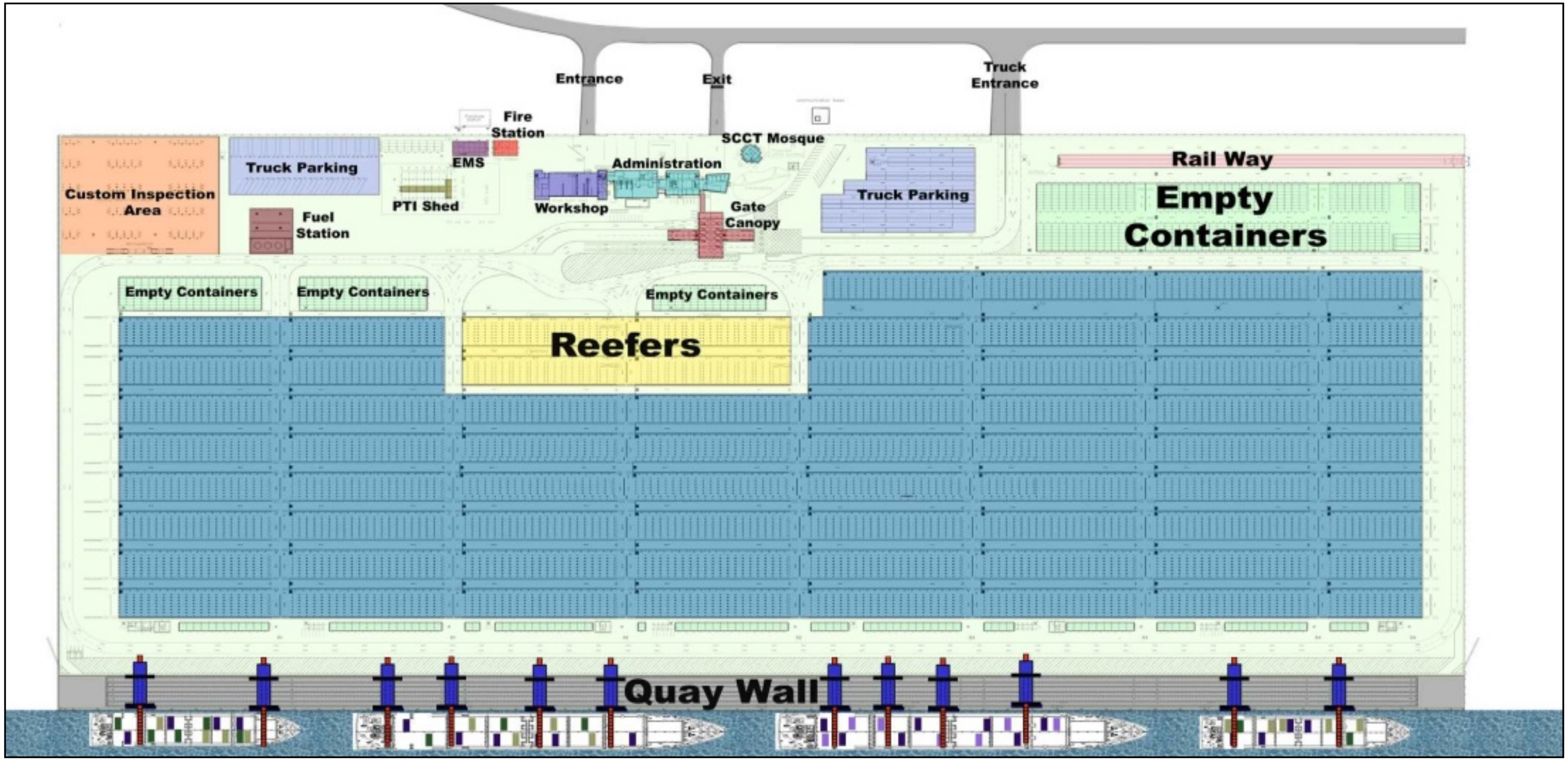


Figure 3.11: SCCT layout (Source: SCCT, 2009)

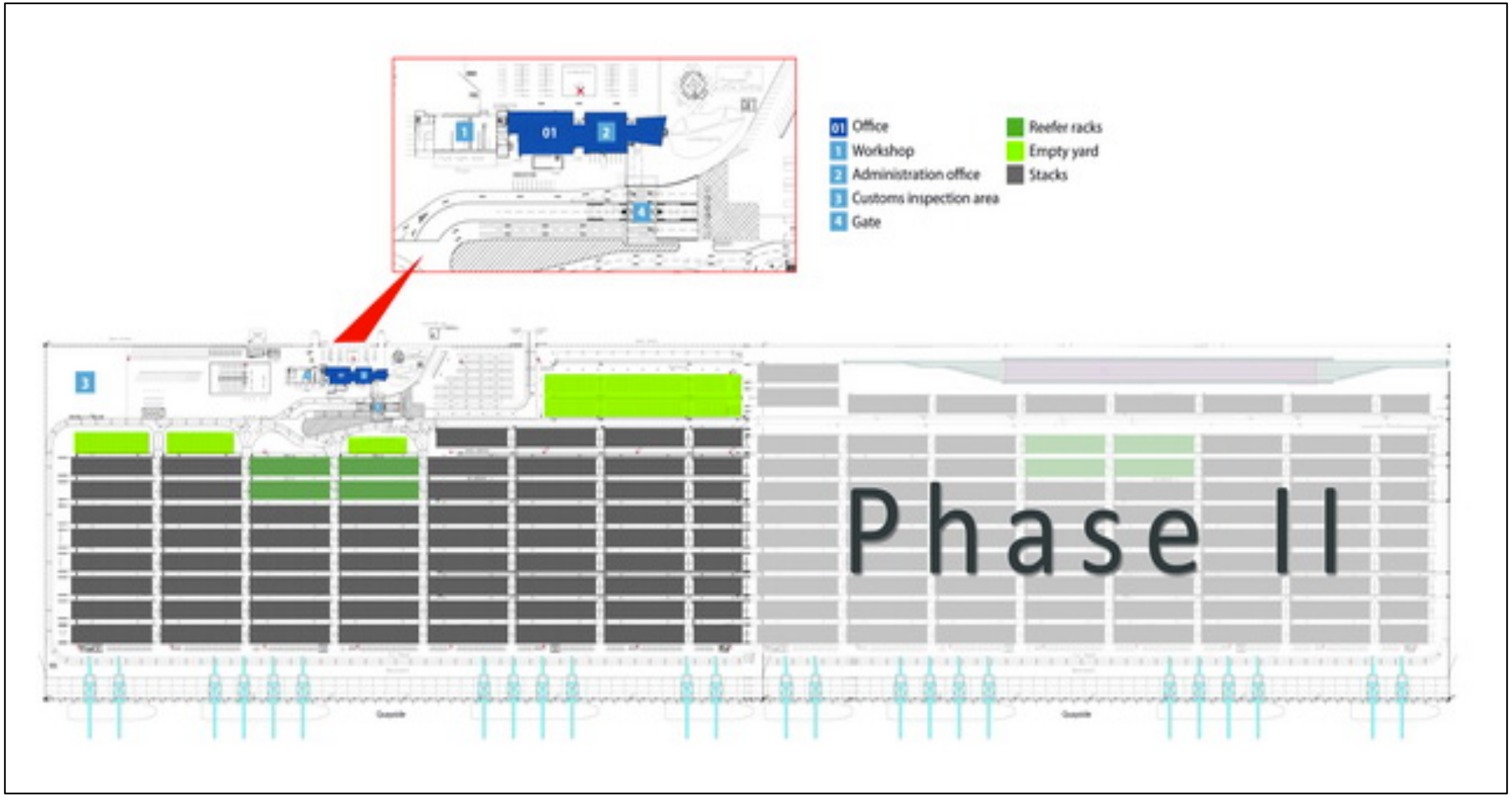


Figure 3.12: SCCT layout phase II (Source: SCCT, 2015)

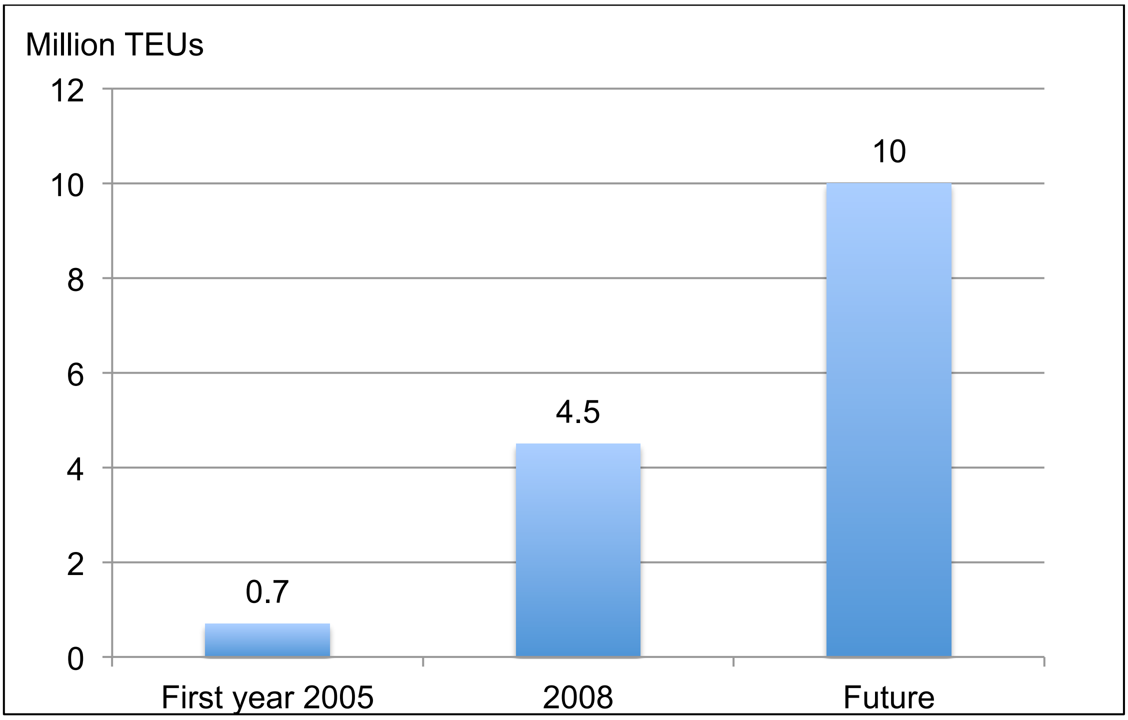


Figure 3.13: Future container handling in East Port Said port (Source: Ministry of Transport, 2008)

3.3.4 Damietta Container Terminal

Damietta Container Handling Company (DCHC)

Damietta Container and Cargo Handling Company is located inside Damietta port which has an unequalled location on the Mediterranean at the crossroads of the Far East and Europe where the main shipping lines operate. Its proximity to the Suez Canal is attractive to transit container vessels. DCHC is located 8 Km from the Nile estuary, and is situated 70 Km to the West of the port facilities at Port-Said, and 185 Km to the East of Alexandria Port. The terminal is connected to the sea through the navigation channel and is connected to the river through another channel of similar nature (DCHC, 2010).

DCHC was established in 1986 is located on the western of the port of Damietta. In 1990 DCHC began commercial operations, becoming one of the most important container terminals in the Mediterranean Sea. DCHC is jointly owned by the holding company for maritime and inland transportation (HCMIT) (42%), Damietta port Authority (25.0%), the Canal Company for Shipping Agency (20.0%), Port Said Container and Cargo Handling Company 3% and private sector/individuals (10.0%). DCHC has excellent road and rail links to the main industrial centers of Egypt. DCHC also benefits from its close proximity to the Nile River, which enables cargo to be transported by barge from hinterland. An overview of Damietta container terminal layout is shown in figure 3.14 (DCHC, 2015).

The terminal uses a variety of programs and software including a highly advanced and secured database system for a faster and more accurate flow of processes in all the terminal operations, i.e. loading and discharging operations. An overview of Damietta terminal yard is shown in figure 3.15.

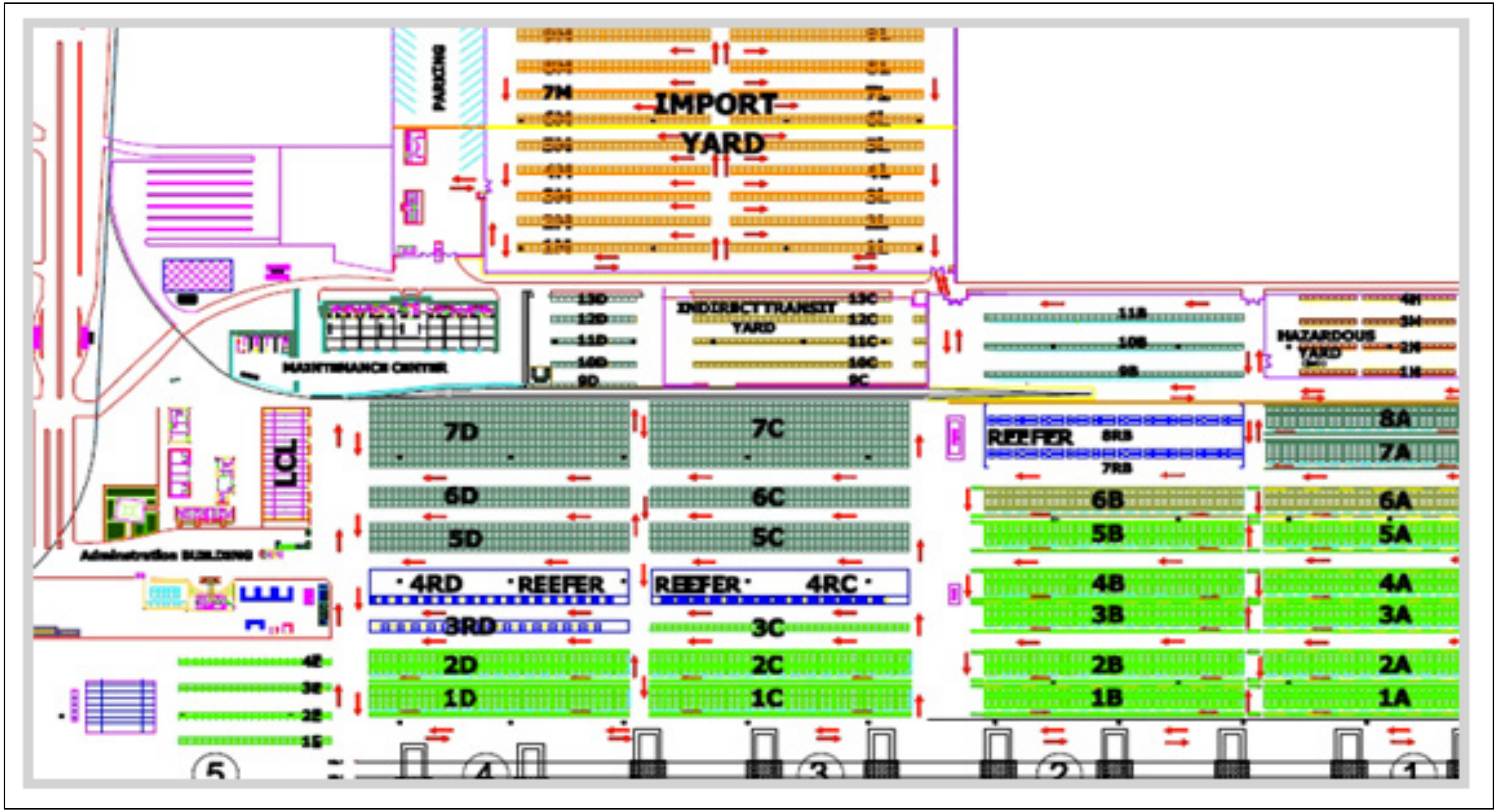


Figure 3.14: Damietta container terminal layout (Source: DCHC, 2015)

Figure 3.15: Damietta terminal yard overview (Source: DCHC, 2010)

The following table 3.5 shows the main specifications of Damietta container terminal.

No. of Cranes	10 Super Post Panamax Cranes
Quay Length	1,050 m
Draft	14 m Save Allowed Ships Draft
Terminal Capacity	1.5 million TEU
Terminal Area	600,000 sqm
Reefers Plugs	750 plugs

Table 3.5: Damietta container terminal specifications (Source: DCHC, 2015)

Figure 3.16 shows the growth increase in container handling at DHCH from the year 2006 to reach its peak in 2009 with 1262700 TEUs, followed by a decline in volume of container handling since 2010.

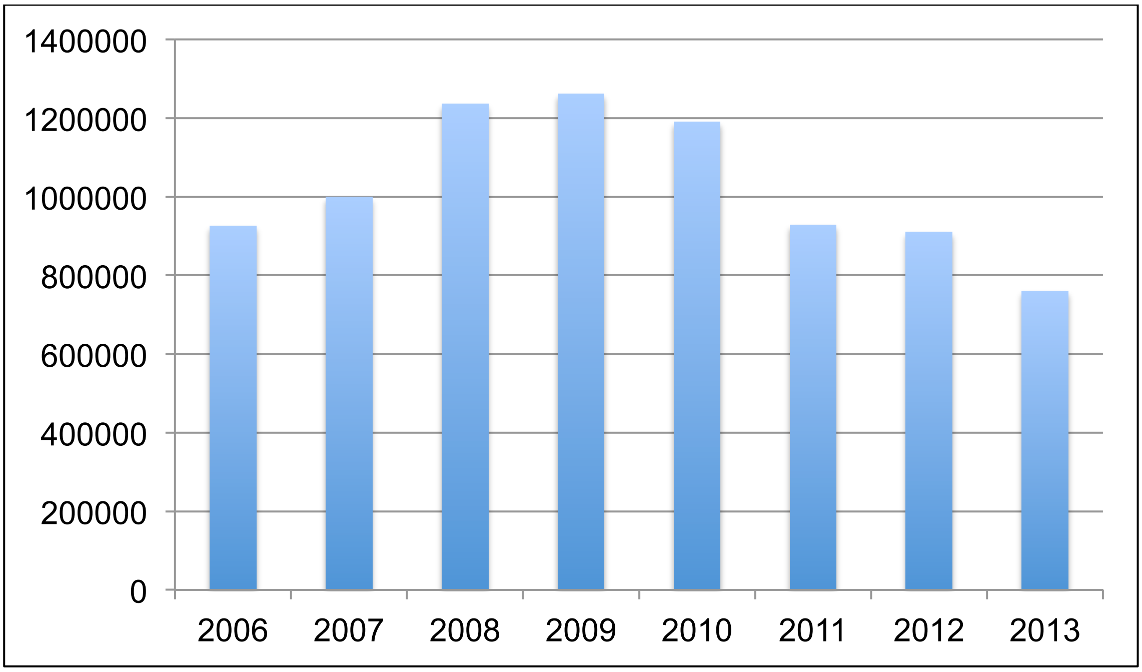


Figure 3.16: Container handling in TEU at DCHC (Source: DCHC, 2015)

3.4 Executed, Current, and Future Investments in Egyptian Ports and Terminals

Despite the unrest, however, there are still several active investments in the various Egyptian ports. The following sub-sections will highlight the main executed investments in selected Egyptian ports as well as the future investment opportunities that can be implemented as pointed out by the Maritime Transport Sector (2015) and CI Capital Research (2012).

3.4.1 Alexandria Port

3.4.1.1 Executed Investments

1. The general cargo, containers, and touristic links.
2. The development of the trucks' entrance and linking the Eastern district with the international road.
3. The construction of logistics centers and electronic department buildings.

4. In September 2007, Alexandria International Container Terminals, a subsidiary of Hutchison Port Holdings, inaugurated two new terminals in Alexandria & El Dekheila seaports.

3.4.1.2 Current Investment Projects

1. The project of establishing the container terminal CT3 at berth 100 (the project was presented for a world public bidding on 29/3/2014).
2. The project of establishing, operating, and administrating a grain terminal (berths- suction equipment - silos) (the project was presented for a world public bidding on 20/4/2014).
3. The project of establishing, operating and administrating the unclean bulk terminal by a world environmental treatment, and transferring the coal terminal of Alexandria Port into it (the project was presented for a world public bidding on 20/4/2014).

3.4.1.3 Medium-Term Investment Projects

1. The project of establishing, operating, and administrating a multipurpose terminal (containers – general cargo).

3.4.1.4 Long- Term Investment Projects

1. The project of establishing the middle port (a future strategic project).
2. Terminals proposed to be established within the middle port are:
   - Service Terminal of the Hydrocarbon liquid bulk.
   - Container Handling Terminal.
   - Agricultural Products Handling Terminal 1,2.
   - Dry Bulk Terminal 1,2.
   - Multipurpose Handling Terminal 1,2.
   - Establishing, operating, and administrating a world marina for yachts

and a special logistics zone.

3.4.2 Damietta Port

3.4.2.1 Executed Investments

1. Importing two tugboats with a pull power of 50 tons per each in addition to a guidance boat. The total investment cost amounted EGP13.3mn and EUR11.9mn, respectively.
2. Completion of the infrastructure related to the seaport development.
3. Exporting the LNG.
4. In November 2007, China Shipping Group acquired a 20% stake in Damietta container seaport with total investments of USD200mn.

3.4.2.2 Current Investment Projects

1. The project of establishing a terminal dedicated to the storage and handling of grains, supplied with the related silos and suction equipment.

3.4.2.3 Long- Term Investment Projects

1. Project of establishing a multipurpose cargo terminal.
2. Grains & food stuffs projects.
3. River transport projects.

3.4.3 Port Said Port

3.4.3.1 Executed Investments

1. Pacific had acquired a 20% stake in Suez Canal Container Terminal, which already started the construction on phase 2 of the East Port Said sea terminal.

3.4.3.2 Current Investment Projects

East Port Said Port:

1. Establishing, operating and administrating the first phase of the multipurpose terminal no.1.
2. Agricultural bulk terminal.
3. Establishing logistics centers.

West Port Said Port:

1. Developing, operating, and administrating a cruise terminal for giant cruise vessels.

3.4.3.3 Medium-Term Investment Projects

East Port Said Port:

1. Establishing storage yards and silos.
2. Establishing the second phase of container berths.
3. Establishing, operating and administrating the second phase of the multipurpose terminal no.1.

West Port Said Port:

1. Establishing a container terminal dedicated to exporting the agricultural products.
2. Establishing yards for ship maintenance.
3. Upgrading and developing port berth.
4. Upgrading and developing hinterland of the port.

3.4.3.4 Long- Term Investment Projects

East Port Said Port:

1. Establishing container berths.
2. Establishing Ro-Ro berths.

3.4.4 Red Sea Port

3.4.4.1 Executed Investments

1. In February 2008, DP World, a UAE based terminal operator, acquired a 90% stake the Egyptian Containers Handling Company (ECHCO) the operator of El Sokhna seaport terminal in a deal worth USD670m.

3.4.4.2 Current Investment Projects

1. Establishing a multipurpose terminal at the Adabia Port.
2. Establishing, operating and administrating the dry bulk terminal (grains) at the Adabia Port, supplied with the related silos and suction equipment.
3. Establishing, operating, and administrating the main container terminal to serve the southern region of Safaga.
4. Establishing, operating, and administrating the general cargo terminal at Portawfik Port.
5. Establishing, operating, and administrating the cruise terminal and the world Marina of yachts at Sharm El Sheikh Port.
6. Utilizing, operating, and marketing the World Trade Center at Hurgada Port.
7. The development project of El-tur Port.
8. Establishing a container terminal at the Adabia Port.

3.4.4.3 Medium-Term Investment Projects

1. The project of establishing the Fifth Dock at Sukhna Port.
2. The project of establishing a berth at the back of the northern berth at the Suez Port.

3.4.4.4 Long- Term Investment Projects

1. The sixth dock project at the Port of Sukhna.

3.5 Developing the Suez Canal

The Suez Canal region has a unique location, as it is a strategic area where continents, markets, and global trade routes can meet. However, Egypt did not utilize this to its full capacity. This location of the Suez Canal makes the cost of transportation and security low for major world markets. Existing free trade zones between Egypt and Europe, the Arab World, East and South Africa exempt commodities produced there, with the required percentage of Egyptian components, from tariffs when they are sent to these markets. This allows it to attract industrial investments from export countries of this type of investment, especially faraway places such as Japan, China, Korea, and the Americas, to take advantage of low wages in Egypt and its proximity to the European market, which is the largest in the world.

The new Suez Canal is a huge project for the Egyptian economy that could give it a strong push to end recession and its inability to take off for many years and motivate its launch. The infrastructure of the project includes the digging of a new canal and six tunnels that will link the east and west banks of the canal and two railway tunnels. This new project is not just a parallel canal to the existing one, it is an entire new link that includes 35 km of dry digging, and 37 km of expansion and deep digging. This will let big ships sail through the Canal in both directions, allowing ships coming from the north and south to cross simultaneously without stopping instead of the current wait that can reach up to eight hours. This non-stop navigation will reduce the voyage through the canal to eleven hours instead of nearly 20 hours, and will increase the number of vessels passing through the canal. About 18,000 ships sail through the canal every year, a figure that could double after the new project increases the number of giant vessels passing through, raises revenues and the canal's share of world trade. This project will generate a large number of jobs that will improve unemployment rates that have become the most persistent and complicated economic, social and political problem nowadays. Moreover, industrial and service projects that will be established will create many more job opportunities because of the size of these projects and their need for labour (Ahram online, 2014).

The new project truly safeguards the Suez Canal from regional and international threats. The prominence of the Suez Canal was indeed under threat if Egypt did not improve its handling of the canal, and develop its potential to serve the quantity, quality and cost of global traffic. The new project can become a massive jump for Egypt's economy and its regional and international role in transit industry and services. It would also contribute to a vital change in the distribution of the population by transferring large sectors of the population to the region of the Canal and Sinai.

Numerous projects could be the main pillars for development in the Suez Canal region, whether they are linked to the Suez Canal itself or the natural resources available in surrounding governorates. These development projects may include (Ahram online, 2014):

- Developing, expanding and establishing ports to receive and store goods north of the Suez Canal (Port Said, East of Tafria, Damietta, and Arish Port under construction), and to the south of the Canal (Ain Shokhna, Safaga and Al-Adbiya).
- Constructing railroads west of the Suez Canal connecting Red Sea ports south of the Canal with Mediterranean ports north of the Suez

Canal, to directly transport back and forth vessels between them without going through the Suez Canal.

- More than 18,000 vessels pass through the Suez Canal and this figure is expected to double when the new project starts operations. This increasing number of vessels requires maintenance and repair, which means building dry basins for working on these ships. This would be a great source of income and a new branch of transit industry to diversify and develop the economy, increase revenues, improve living standards and create jobs.

3.6 A SWOT Analysis for the Maritime Transport and Logistics Industry in Egypt

From the previous discussion, and as concluded by CI Capital Research (2012), a SWOT analysis is made to the industry of maritime transport and logistics in Egypt with a view to identifying the points of strength to be optimally utilized, the weaknesses points in order to be improved or even avoided. It also points out the opportunities that can be exploited, and finally the threats that may face Egypt in this sector.

3.6.1 Strengths

- The strategic location of Egypt at the heart of World's maritime trade routes enhances local and transit foreign trade.
- Suez Canal has a market share of 15% of the global maritime trade traffic. The canal has a fundamental role in linking Asia with Europe and vice versa, and used for the oil delivery from Asia to Europe.
- A broad range of required facilities exists in the Egyptian seaports and terminals to serve almost all types and sizes of vessels.

3.6.2 Weaknesses

- Still more development and advanced technology are needed in Egyptian seaports and terminals to satisfy all clients' needs.
- An improvement is required as regards seaport congestions in order to save the time consumed in waiting before entering the port, especially in busy periods.
- Upgrading the relatively obsolete merchant fleet is necessitated.

3.6.3 Opportunities

- Faster than expected global economic recovery.
- There is a space for potential growth as seaports and terminals are still not fully utilized.
- The long-term investments announced by the private terminal operators in their controlled seaports.
- Dredging activities implemented in Suez Canal in order to widen and deepen its draught are crucial to receiving the giant generation of fully loaded VLCCs and ULCCs vessels, thus increasing the canal's traffic.

3.6.4 Threats

- A longer than expected global economic recovery.
- Piracy operations in the Gulf of Aden (the main portal to Suez Canal) is considered one of the major risks that face the canal's traffic and the maritime industry in general, as it leads the ship owners to shift their waterway to the Cape of Good Hope as safe route, particularly in the time of low oil prices.
- Egypt's political and economic unrest and instability.
- The frequent labour strikes might adversely affect seaports and terminals operations.

3.7 Summary

This chapter represented the second part of the literature review. It gives an overview on the major Egyptian container terminals, along with their main specifications. The chapter also presented the executed, current, and future investments in these ports and terminals either on the medium term or on the long term. The new Suez Canal project was also discussed as a major investment in Egypt, and its potential benefits are emphasized. At the end of the chapter, a SWOT analysis for the maritime transport and logistics sector in Egypt was presented.

This intensive review reveals the worthiness of studying Egyptian container terminals as an emerging industry that involves several opportunities to achieve a better future. As previously mentioned in chapter two, this research adds its contribution by defining the research problem, setting its aim and objectives in an attempt to fill in the main research gaps identified from the literature review.

The next chapter will deal with the methodology of the whole thesis. It will present the different methodology approaches that can be conducted in a research study, and then the framework of the methodology applied in this research will be further explained.

Chapter 4

Research Methodology

This chapter deals with the methodology of the research. It starts with introducing the scope of research and presents its framework process. Section two discusses the research philosophy as found in the literature. The research approaches that are followed in this research are explained in section three. Section four reviews the different research strategies, focuses on the main strategy selected for this study, and justifies the reasons behind this selection. Section five illustrates how the different research methods are incorporated throughout this study. It also specifies the techniques and procedures used in the subsequent stages of the research process, mainly data collection and data analysis stages. The last section of the chapter demonstrates the logistics processes that take place in the case company.

4.1 Scope and Framework of Research

The scope of this research is primarily reflected in linking the research problem (stated in chapter two) to its set objectives (mentioned in chapter one). This encompasses a sequence of activities and tasks that should be carried out in order to fulfil the main target of the study. The following figure shows the overall framework of the research process that relates the undertaken activities and tasks to the desired research objective(s).

As the figure indicates, the study starts with reviewing literature related to container terminal operations, logistics control issues, and logistics processes performed within container terminals, then surveying Egyptian container terminals to decide on a specific case study. This step was carried out and well acknowledged through reviewing relevant literature in chapters two and three with a view to achieving the first two objectives of the research. The second step is dedicated to the selected Egyptian container terminal as the case study of the research to describe in detail the import and export logistics processes performed in the company and then to identify the key issues that affect the performance. This step will be addressed in the last section of this chapter. The following steps will be sequentially carried out in the remaining chapters of the thesis.

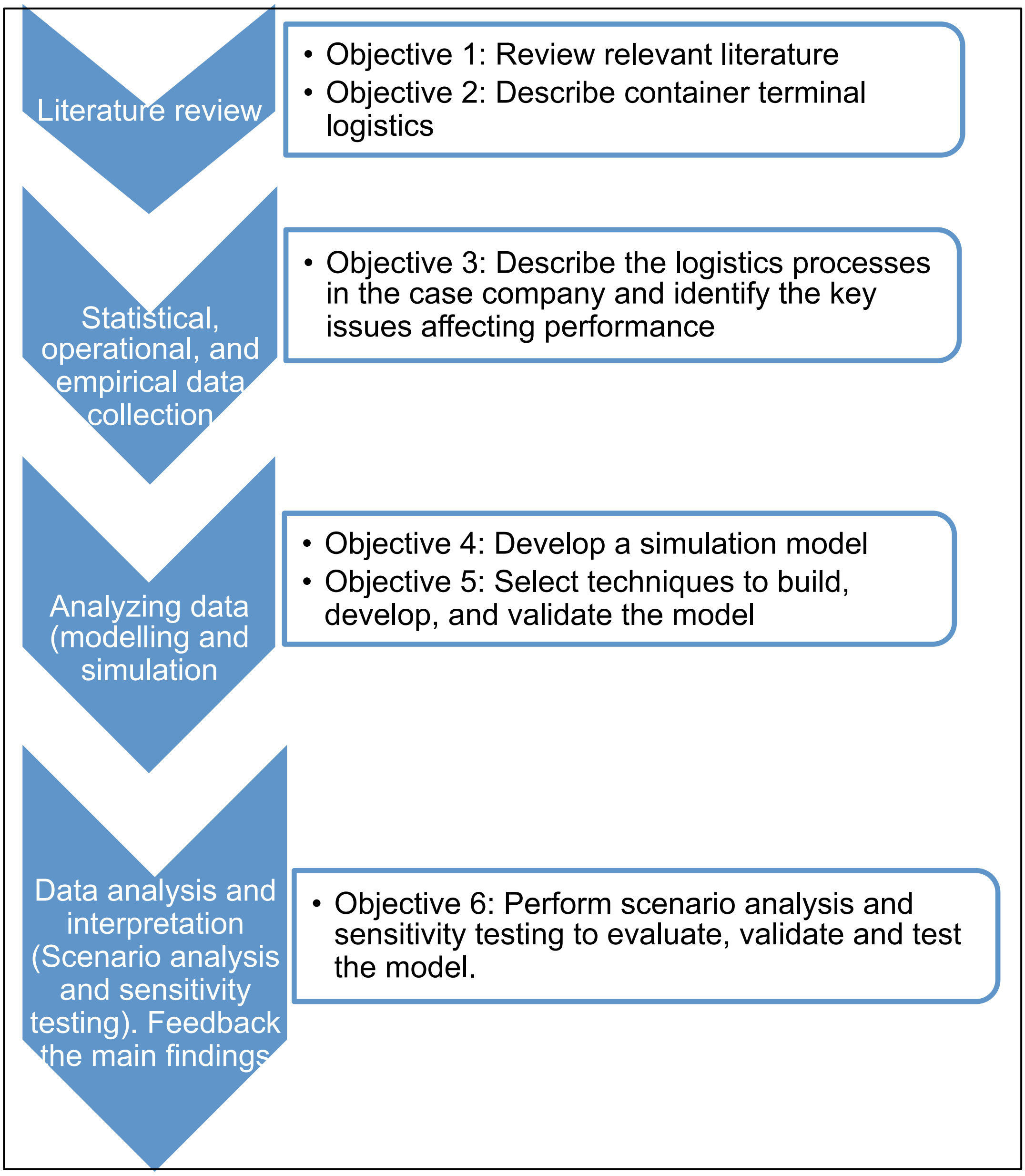


Figure 4.1: Framework of the research process

According to Saunders et al. (2009), the research process looks like an onion with several layers as shown in figure 4.2. The outer layer represents the philosophical perspectives of business research. The second layer shows the research approaches. Layer three involves the various research strategies, followed by the layer of choices that includes the research methods that can be used to conduct any research. The inner layer of the research onion incorporates the techniques and procedures that can be employed throughout the research, especially at the stages of data collection and data analysis. Based on this classification, the research philosophy, approach, strategy, methods, and techniques will be discussed in the following sections.

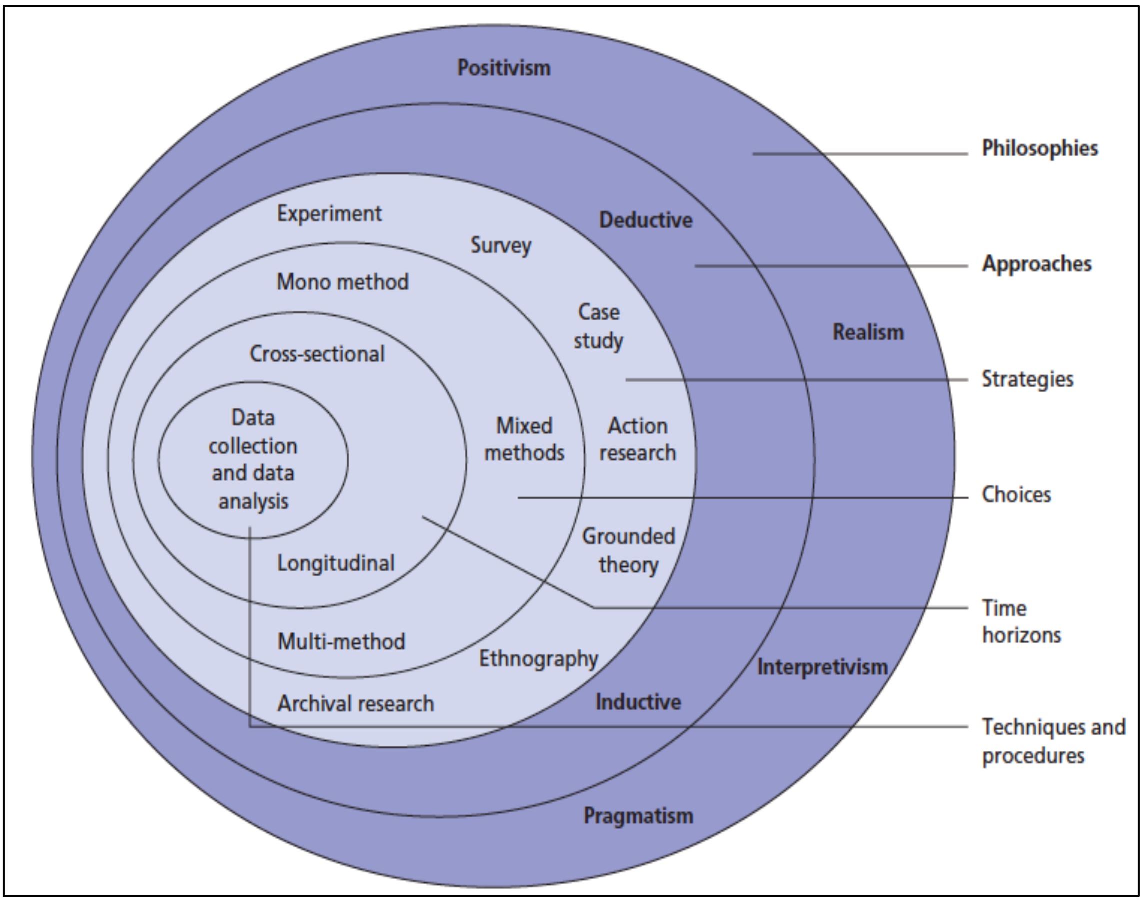


Figure 4.2: The research onion (Source: Saunders et al, 2009, p. 108)

4.2 Research Philosophy

Research philosophy relates to the development of knowledge and its nature. Saunders et al. (2009) explain four philosophies for business research. They include: positivism, realism, pragmatism, and interpretivism. Pragmatism argues that the research question is the key determinant of adopting one's philosophical position. They define three positions or ways of thinking. First, ontology, which is concerned with nature of reality and raises the questions of researchers concerning the assumptions they make about the way by which the world operates. Two aspects of ontology are discussed: objectivism and subjectivism. Objectivism holds that social entities exist independent of social actors, for example, societies, organizations, and teams have an existence that is separate from the individuals involved (Greener, 2008). On the contrary, subjectivism views that actions and perceptions of social actors create the social phenomena. This is related to constructionism, which implies that organizations have no independent reality but it is socially constructed in individuals' minds (Saunders et al, 2009 and Greener, 2008).

The second philosophical position is epistemology. It is concerned with what forms acceptable knowledge in a field of study. Two types of researchers are involved: the resources researcher, usually natural scientist, considers data on resources; and feelings researcher, who considers feelings and attitudes. The resources researcher embraces the philosophy of positivism. This philosophy entails empirical testing and hypothesis testing leading to generating laws or developing theory. Positivists undertake research in a value free way and they are likely to use a highly structured methodology in order to facilitate replication (Saunders et al, 2009 and Gill and Johnson, 2002). Another branch of epistemology is realism. The philosophy of realism is similar to positivism in that it assumes a scientific approach to knowledge development. The essence of realism, as opposed to idealism, is that what the senses show us is reality, is the truth: that objects have an existence independent of the human mind. Direct realism is a type of realism that states that we get what we see. This contrasts the critical realism, which argues that we experience sensations not the direct things, i.e. the images of the things in the real world. In relation to business and management, both types are essential although direct realism suggests that business operates at one level whereas critical realism admits the necessity of multi-levels study. On the other hand, feelings researchers adopt the interpretivism philosophy. This philosophy supports the necessity for the researcher to understand the differences between humans as social actors. Interpretivism is common and appropriate in social sciences including business and management research. Interpretivists adopt an empathetic stance, in a way that they see the world through the eyes of studied people. This allows them several reality perspectives (Saunders et al, 2009 and Greener, 2008).

Moving to another philosophical position that studies judgements about value, which is axiology. As an example, conducting a study using data collected through interviews reflects that personal interaction with respondents is more highly valued than questionnaire responses. Table 4.1 compares the four research philosophies in management research.

Based on the previous discussion and linking it to the research problem, objectives, and questions, it can be said that this research encounters more than one philosophy. It also incorporates different philosophical positions or ways of thinking.

	Positivism	Realism	Interpretivism	Pragmatism
Ontology: *the researcher's view of the nature of reality or being*	External, objective and independent of social actors	Is objective. Exists independently of human thoughts and beliefs or knowledge of their existence (realist), but is interpreted through social conditioning (critical realist)	Socially constructed, subjective, may change, multiple	External, multiple, view chosen to best enable answering of research question
Epistemology: *the researcher's view regarding what constitutes acceptable knowledge*	Only observable phenomena can provide credible data, facts. Focus on causality and law like generalisations, reducing phenomena to simplest elements	Observable phenomena provide credible data, facts. Insufficient data means inaccuracies in sensations (direct realism). Alternatively, phenomena create sensations which are open to misinterpretation (critical realism). Focus on explaining within a context or contexts	Subjective meanings and social phenomena. Focus upon the details of situation, a reality behind these details, subjective meanings motivating actions	Either or both observable phenomena and subjective meanings can provide acceptable knowledge dependent upon the research question. Focus on practical applied research, integrating different perspectives to help interpret the data
Axiology: *the researcher's view of the role of values in research*	Research is undertaken in a value-free way, the researcher is independent of the data and maintains an objective stance	Research is value laden; the researcher is biased by world views, cultural experiences and upbringing. These will impact on the research	Research is value bound, the researcher is part of what is being researched, cannot be separated and so will be subjective	Values play a large role in interpreting results, the researcher adopting both objective and subjective points of view
Data collection techniques most often used	Highly structured, large samples, measurement, quantitative, but can use qualitative	Methods chosen must fit the subject matter, quantitative or qualitative	Small samples, in-depth investigations, qualitative	Mixed or multiple method designs, quantitative and qualitative

Table 4.1: A comparison of the four research philosophies in management research (Source: Saunders et al, 2009, p.119)

4.3 Research Approaches

According to Saunders et al. (2009), there are two research approaches: deduction and induction. Research philosophies can be related to research approaches as stated by Saunders et al. (2009) and Greener (2008), as they related the deduction research approach to the philosophy of positivism and the induction approach to interpretivism philosophy. Generally the deduction approach is concerned with theory testing whereas the induction approach considers generating theory. Deduction is the prominent approach in natural sciences as it starts with identifying the theory, deducing a hypothesis from theory, expressing hypothesis in operational terms, seeking evidence to prove or disprove hypothesis through testing, examining the outcomes and modifying the theory based on the finding if necessary (Collis and Hussey, 2009, Saunders et al, 2009, Greener, 2008, and Robson, 2002). This relates to objectivity particularly when experimenting one group and having a control group of similar subjects for comparison is possible (Greener, 2008).

Induction, as an alternative approach, involves understanding a problem, collect then analyse data, and generate a theory. The strength of this approach is developing an understanding of the way in which humans interpreted their social world. Another merit for the inductive approach over the deductive approach is that it better suits research questioning why something is happening rather than just describing what is happening (Easterby-Smith et al, 2008). The major differences between induction and deduction approaches are presented in table 4.2.

Deciding upon the research approach to be followed mainly depends on the emphasis of the research and the nature of its topic (Creswell, 2002). However it can be beneficial to combine both approaches within the same research

(Saunders et al, 2009). As a conclusion, it is vital to determine the approach adopted in the research for following reasons as suggested by Easterby-Smith et al. (2008):

- Researchers will be able to make informed decision about their research design such as data collection techniques, kinds and sources of data, and interpretation of findings.
- Researchers will be capable of selecting the research strategies that fit their research.
- The knowledge of the diverse research backgrounds allows researchers to adjust their research design to cater for constraints.

Deduction emphasises	Induction emphasises
• scientific principles • moving from theory to data • the need to explain causal relationships between variables • the collection of quantitative data • the application of controls to ensure validity of data • the operationalisation of concepts to ensure clarity of definition • a highly structured approach • researcher independence of what is being researched • the necessity to select samples of sufficient size in order to generalise conclusions	• gaining an understanding of the meanings humans attach to events • a close understanding of the research context • the collection of qualitative data • a more flexible structure to permit changes of research emphasis as the research progresses • a realisation that the researcher is part of the research process • less concern with the need to generalise

Table 4.2: Major differences between inductive and deductive approaches to research (Source: Saunders et al, 2009, p.127)

Considering this research topic and nature of its study, this research follows a combination of both approaches. It firstly employs the deduction approach as regards the formulation of the research problem, the collection of quantitative (statistical and operational) data, and validation of data. The induction approach mainly assists in understanding the cause- effect relationships between variables (why rather than what). This appears in the data analysis stage and the scenarios suggested and tested.

Although the previous discussion addressed only two forms of logical arguments, but there is another form of reasoning named as abduction. The philosopher Peirce defined it as inferring a premise from a conclusion. He identified abduction with the scientific method of hypothesis-deduction-observation-experiment. In this case, various hypotheses are assumed to explain some observations. Once the hypothesis is formed, deduction is used to predict other logical consequences. Experiments then establish the truth or falsity of these consequences (the information philosopher, 2015). Abductive reasoning yields the kind of daily decision-making that does its best with the information at hand, which is often incomplete (Butte College, 2015).

4.4 Research Strategies

A number of factors can imply the selection of research strategies. These include the research objectives and questions, the level of existing knowledge, the amount of available resources and time, and the philosophical foundations. Saunders at al. (2009) indicated that these strategies are not mutually exclusive, which means that one strategy may be used as a part of another strategy. They can also be linked to the deductive and inductive approaches. This section discusses some of these strategies and focuses on the strategy employed in this particular research.

4.4.1 Experiment

Experiment is a form of research that mainly belongs to the natural sciences, although it strongly fits in much social science research, particularly psychology. The purpose of an experiment is to study causal links and whether a change in one independent variable creates a change in another dependent variable. The simplest experiments are concerned with whether there is a link between two variables. More complex experiments also consider the size of the change and the relative importance of two or more independent variables. Thus experiments can be used in exploratory and explanatory research to answer 'how' and 'why' questions (Saunders et al, 2009). Experiments normally involve:

- Identifying a hypothesis from theory.
- Selecting individual samples from populations.
- Assigning samples to experimental conditions.
- Introducing a manipulation to one or more variables.
- Measuring a small number of dependent variables.
- Controlling other variables.

4.4.2 Action Research

Literature reveals four themes for action research, illustrated as follows:

- The first theme highlights the purpose of the research: research in action rather than research about action (Coghlan and Brannick, 2005).
- The second theme relates to the envelopment of practitioners in the research. The researcher is part of the organization within which the research and the change process are taking place (Coghlan and Brannick, 2005).
- The third theme emphasizes the iterative nature of the process of diagnosing, planning, taking action and evaluating.
- The fourth theme indicates that action research should have implications beyond the instant project; in other words, the results could inform other frameworks.

Thus the explicit focus on action, specifically promoting change within organizations, is what differs action research from other research strategies. In particular, it is convenient to answer 'how' questions.

4.4.3 Archival Research

Archival research considers the use of administrative records and documents as the principal source of data. This strategy can be exploratory, descriptive, or explanatory. It allows answering research questions that focus on the past and change over time, but this will certainly be constrained by the nature of the administrative records and documents. Records may exist but without the exact information that answers the research questions or achieves its objectives.

4.4.4 Grounded Theory

This strategy focuses on developing and building theory. It helps researchers predict and explain behaviour, so that it can be used in a variety of business and management subjects. It combines both induction and deduction research approaches (Collis and Hussey, 2009). Grounded theory does not consider the formulation of a theoretical framework in the data collection. Rather, theory is developed from data generated by a series of observations, leading to creating predictions to be tested by additional observations in order to finally prove or disprove these predictions (Saunders et al, 2009).

Suddaby (2006) identified a few common misconceptions about grounded theory listed as follows:

- Grounded theory is not an excuse to ignore the literature.
- Grounded theory is not presentation of raw data.
- Grounded theory is not theory testing, content analysis, or word counts.
- Grounded theory is not simply routine application of formulaic technique to data.
- Grounded theory is not perfect.

- Grounded theory is not easy.
- Grounded theory is not an excuse for the absence of a methodology.

4.4.5 Survey

Survey is a common strategy that is used in business and management research. It is exploratory, descriptive, and is used to answer who, what, where, how much and how many questions. It is usually associated with the deduction approach. It allows collecting much data from a large population efficiently and also enables researchers to collect quantitative data, which can be analysed quantitatively using descriptive and inferential statistics. It enables the researcher to control the research process, making it possible to generalize its findings to the whole population if sampling is used. Questionnaires, structured observations, and structured interviews are among the data collection techniques associated with this strategy.

4.4.6 Case Study

The case study research strategy can be defined as an empirical inquiry that investigates a contemporary phenomenon within its real-life context, when the boundaries between phenomenon and context are not clearly evident and in which multiple sources of evidence are used (Robson, 2002 and Yin, 2003). Case studies become mainly useful in explanatory and exploratory research and have been widely used by researchers across a variety of disciplines for many years, particularly social scientists, to understand specific problem or situation in great-depth, and recognize cases rich in information. Thus case study provides a convenient strategy with which to investigate how and why type research questions (Dinwoodie and Xu, 2008). A combination of data collection techniques is likely used under this strategy; this is referred to as triangulation. This combination may include interviews, observation, documentary analysis, and questionnaires (Saunders et al, 2009). Moreover, Berg and Lune (2014) defines triangulation as the use of several lines of sight. They consider that every method reflects a distinctive view towards the same idea, observing certain facets of the social and symbolic reality. The combination of multiple lines of sight enables researchers to acquire a better and more substantive picture of reality, a deeper and a more complete array of symbols and theoretical concepts.

According to Yin (2003), there are four case study strategies that are based on two separate dimensions:

- Single case versus multiple case: this dimension distinguishes between studying a critical or unique case in a single case study strategy or more than one case in the multiple case strategy.
- Holistic case versus embedded case: this dimension considers the unit of analysis. The holistic case study strategy involves only one unit of analysis, for example, an organization as a whole. On the contrary if more than one unit of analysis are examined, such as departments within an organization, then the embedded case study strategy is employed.

4.4.6.1 Advantages of the Case Study Strategy

Case study research excels at bringing an understanding of a complex issue or object and can extend experience or add strength to what is already known through previous research. Case studies emphasize detailed contextual analysis of a limited number of events or conditions and their relationships and provide the basis for the application of ideas and extension of methods. Other advantages are listed below (Noor, 2008, Crowe et al, 2011, and Easton, 2010):

- Good source of ideas about behaviour.

- Good opportunity for innovation.
- Good strategy to study rare phenomena.
- Good strategy to challenge theoretical assumptions.
- Good source of hypotheses.
- Provides in-depth information on individuals.
- Unusual cases can shed light on situations or problems that are unethical or impractical to study in other ways.
- The case study can be constructive (solve some problem), or confirmatory (test a hypothesis with empirical evidence). The case study can use either primary (the researcher collects the data) or secondary (the researcher uses someone else's data) data collection strategy. Finally, a case study can be either qualitative or quantitative in nature.
- It enables the researcher to gain a comprehensive view of a certain phenomenon or series of events and can provide a round picture since many sources of evidence were used.
- Case studies can be useful in capturing the emergent and immanent properties of life in organizations and the ebb and flow of organizational activity, especially where it is changing very fast.
- Case studies also allow generalizations as that result of findings using multiple cases can lead to some form of replication.
- Case studies allow critical events, interventions, policy developments, and program-based service reforms to be studied in detail in a real-life context.
- Case research allows the researcher the opportunity to tease out and disentangle a complex set of factors and relationships, albeit in one or a small number of instances.

4.4.6.2 Disadvantages of the Case Study Strategy

Critics of the case study method believe that studying a small number of cases provides no grounds for establishing reliability or generality of findings. Others see that the intense exposure to study of the case biases the findings. Some dismiss case study research as useful only as an exploratory tool. However researchers continue to use the case study research method with success in carefully planned and crafted studies of real-life situations, issues, and problems. Further disadvantages include:

- Hard to draw definite cause-effect conclusions.
- Hard to generalize from a single case.
- Possible biases in data collection and interpretation (since a single person gathers and analyses the information).
- Vital information may be missing making the case hard to interpret.
- The person's memories may be selective or inaccurate.
- The individual may not be representative or typical.

4.4.6.3 The Case Study of the Research

There is an increasing implementation of case study strategy in logistics research. Four subcategories, grounded in the database of logistics articles, seek to span and encourage dialogue between both realist and constructionist ontologies, related mainly to exploratory theory building. The first defines attempts to understand a particular process through in-depth study of a specific context such as a particular sector of an industry. The second approach seeks to derive tentative theoretical hypotheses, based on a synthesis of the cases, to enrich existing theory. The third type offers a prototype for an initial theoretical proposition, typically providing an empirical application. The fourth approach involves investigation of a novel industry, network or other appropriate context

(Dinwoodie and Xu, 2008). Some examples of logistics research that adopted the case study strategy, particularly in the field of container terminals (as it relates to the research area of this study) include: Le-Griffen et al. (2010), Arango et al. (2011), Linn et al. (2007), Vacca et al. (2007), Huang et al. (2008), Legato et al. (2009), and Azevedo et al. (2009). Other examples of recent logistics research that adopted the case study strategy, particularly in Egyptian container terminals may include: Said and Elhorbaty (2015), Said et al. (2014), Younis et al. (2010), Elkalla and Elshamy (2012), Elazouny et al. (2011), Elnaggar et al. (2010), and Ragheb et al. (2010).

In this context, this research adds its contribution in this specific research domain. It employs the case study strategy as it meets the research objectives, accompanied by the survey strategy, in studying an Egyptian container terminal in Alexandria for a number of reasons which are listed below:

- The Port of Alexandria still occupies the issues between ports of the Arab Republic of Egypt regarding the volume of traffic, where approximately 60% of Egypt's foreign trade is handled through the port of Alexandria.
- The City of Alexandria is located at the west end of the River Nile between the Mediterranean Sea and Lake Mariot. It is considered the second most important city and the main port in Egypt.
- This company is the leading specialized container handling company in the Egyptian Ports. It performs all activities related to container handling in Alexandria Container Terminal (ACT) and El Dekhiela Container Terminal (DCT) in the custom area. It became a free zone branch in 2004. It is worth mentioning that both ACT and DCT handle more than 60% of the total domestic containers (import/export) and about 2.6% of the total transhipped containers.

- In fact, the company suffers from some problems. These include insufficient storage space for stacking containers which represents a major problem because it has significant consequences as the terminal cannot serve a large number of vessels at the same time because the space is limited to handle a certain level of containers (TEUs). Also congestion and traffic bottlenecks occurs in the terminal when customers collect their containers, the back reach technique as a handling system is inapplicable, and the non-availability of a special yard for customs inspection or for delivery and receiving and collecting containers to prevent the customers from entering the stacking areas and interfering with the terminal traffic is problematic. Other problems facing the company include: the problem of water depth whereby the terminal cannot receive mega carriers with drafts more than 12m; the lack of handling equipment used; and the non-availability of inland transport to deliver containers to their final customers' premises.
- Generally, very little research has been undertaken concerning Egyptian Container Terminals. Also, literature covering and dealing with relevant issues is very limited.
- Finally, as regards the research methodology, the researcher can access this case company's premises. This facilitates data collection, either primary or secondary, and data analysis, which are required to conduct the study.

4.5 Research Methods and Data Collection Techniques

Research choice refers to the way the researcher selects to combine quantitative and qualitative techniques and procedures. This can be shown in figure 4.3. Using a single data collection technique is referred to as mono method. A mix of methods is increasingly adopted and commonly employed in business and management research, this is called multiple methods. (Greener, 2008 and Saunders et al, 2009). A research using various methods that are all either qualitative or quantitative is embracing a multi method choice, whereas a mixed methods research uses both qualitative and quantitative data. This can be done either in parallel or sequential but not combined (mixed method research), or they can be combined at some phases of the research (mixed model research). Dawson (2009) argues that qualitative research explores attitudes, behaviour, and experiences by examining different social settings and groups or individuals who inhabit these settings (Berg and Luce, 2014). Qualitative research uses or produces non-numeric data as stated by Saunders et al. (2009). In contrast, quantitative research generates statistics that are expressed in numeric data (Dawson, 2009 and Saunders et al, 2009).

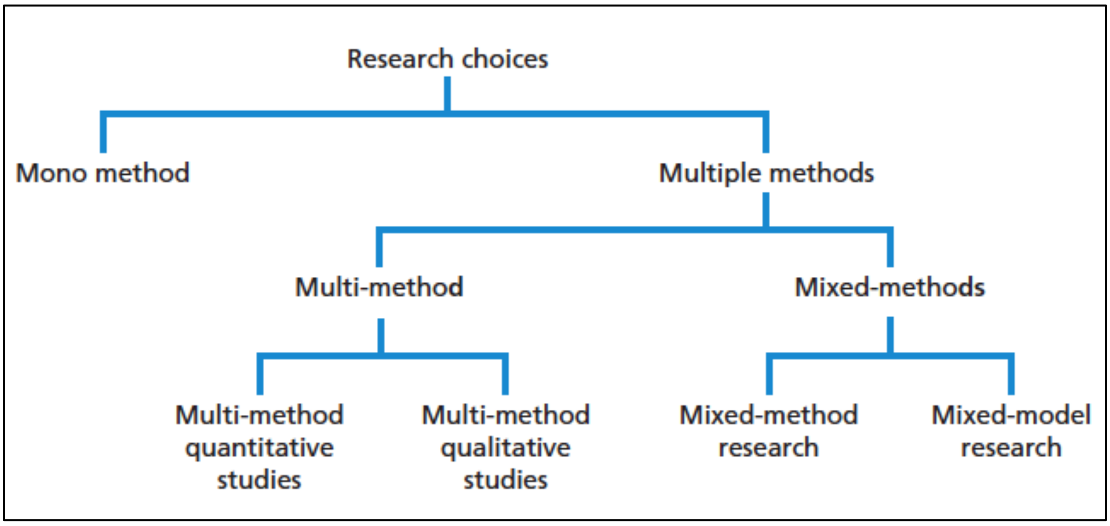


Figure 4.3: Research choices as suggested by Saunders et al. (2009, p. 152)

The following table shows some differences between quantitative and qualitative methods.

Quantitative	Qualitative
Numbers	words
Point of view of researcher	Point of view of participants
distant Researcher	Researcher close
Theory testing	Theory emergent
Static	Process
Structured	Unstructured
Generalisation	Contextual understanding
Hard reliable data	Rich deep data
Macro	Micro
Behaviour	Meaning
Atrificial settings	Natural settings

Table 4.3: Key differences between quantitative and qualitative data (Source: Bryman and Bell, 2003 and Greener, 2008, p.80)

From the above discussion, it can be revealed that this study follows the multiple methods choice, i.e. it uses both qualitative and quantitative data. This will be more illustrated through introducing the data collection techniques employed in the research and the data analysis methods as well in the following sub-sections.

4.5.1 Data Collection Techniques and Tools

Data-collection techniques allow to systematically collect information about the objects of study (people, objects, phenomena) and about the settings in which they occur. Collection of data should be systematic. If data are collected haphazardly, it will be difficult to answer the research questions in a conclusive way. Among the various data collection techniques that can be used (Chaleunvong, 2009 and Dawson, 2009):

- Using available information.
- Observing: It is a technique that involves systematically selecting, watching and recording behaviour and characteristics of living beings,

objects or phenomena. It involves: the systematic observation, recording, description, analysis and interpretation of people's behavior. Two types are engaged: participant observation, which is qualitative and focuses on discovering the meanings that people attach to their actions. The other type is structured observation, which is quantitative and is more concerned with the frequency of those actions (Saunders et al, 2009).

- Interviewing: An interview is a data-collection technique that involves oral questioning of respondents, either individually or as a group. This technique is detailed in the next section.
- Questionnaires: They can be used for descriptive or explanatory research. They can be used as the only data collection technique or they can be combined with other methods. Types of questionnaires include self-administered questionnaires that are usually completed by the respondents, or interviewer-administered questionnaires, where the interviewer records the responses on the basis of each respondent's answers (Saunders et al, 2009).
- Focus group discussions: Where a group of 8 – 12 informants is allowed to freely discuss a certain subject with the guidance of a facilitator or moderator, whose role is to keep the group within the boundaries of the discussed topic and generate interest in the topic and encourage discussion (Saunders et al, 2009).

Table 4.4 shows the most commonly used data collection techniques and the tools used for conducting each technique. It also highlights the advantages and possible constraints associated with each data collection method.

Technique	Data collection tool	Advantages	Possible constraints
Using available information	Checklist: data compilation forms	Inexpensive because data is already there. Permits examination of trends over the past.	Data is not always easily accessible. Information may be imprecise or incomplete.
Observing	Eyes and other senses, pen/paper, watch, scales. Microscope	Gives more detailed information. Permits collection of information on facts not mentioned in an interview. Permits tests of reliability of responses to questionnaires.	Observer bias may occur. The presence of data collector may influence the situation observed. Thorough training of research assistants is required.
Interviewing	Interview guide, checklist, questionnaire, tape recorder	Suitable for use for both literates and illiterates. Permits clarification of questions. Has higher response rate than written questionnaires.	The presences of interviewer can influence responses. Reports of events may be less complete than information gained through observations.
Administering written questionnaire	Questionnaire	Less expensive. May result in more honest responses. Does not require research assistants. Eliminates bias due to phrasing questions differently with different respondents.	Cannot be used with illiterate respondents. Requires some extra training of researches.

Table 4.4: Tools, advantages and constraints of data collection techniques (Source: Chaleunvong, 2009)

4.5.2 Data Collection Techniques Used in the Study

One of the main data collection methods used in conducting this study is interviewing as it helps achieving the objectives of this research (see figure 4.1). As previously mentioned, an interview is a data-collection technique that involves oral questioning of respondents, either individually or as a group. Berg and Lune (2014) simply defines an interview as a conversation with the purpose of collecting information. Answers to the questions posed during an interview can be recorded by writing them down (either during the interview itself or immediately after the interview) or by tape-recording the responses, or by a combination of both. Interviews can be conducted with varying degrees of flexibility. The two extremes are high degree of flexibility and low degree of flexibility (Chaleunvong, 2009). Interviews can be differentiated according to the level of structure and standardization adopted and various types of interviews are beneficial for different research purposes (Saunders et al, 2009). In this regards, Berg and Lune (2014) compares the characteristics of the three basic types of interviews: the standardized (formal or highly structured) interview, the unstandardized (informal or nondirective) interview, and the semistandardized (guided-semistructured or focused) interview. This is represented in figure 4.4.

Structured or standardized interviews are intended to extract information using a set of predetermined or standardized questions that are expected to elicit the subjects' opinions, thoughts, and attitudes about study related issues (Berg and Lune, 2014). Saunders et al. (2009) and Greener (2008) agreed that structured interviews are used to collect quantifiable data, so they are also referred to as quantitative research interviews.

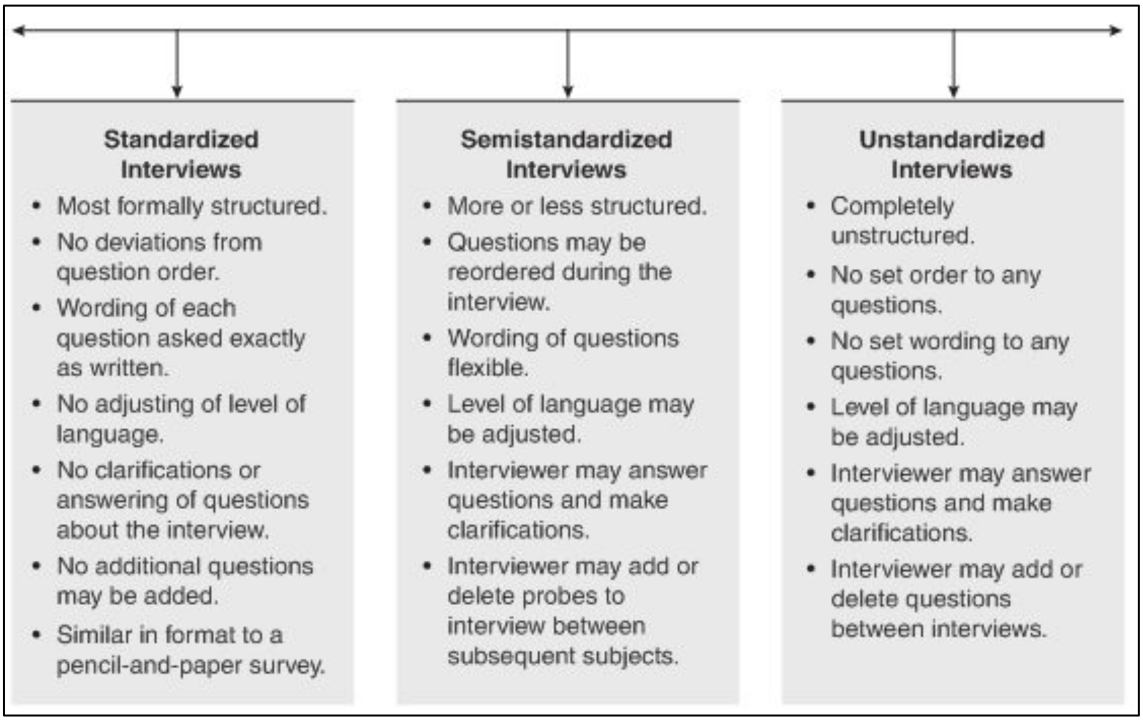


Figure 4.4: Interview structure continuum of formality (Source: Berg and Lune, 2014. p. 109)

Unstructured or unstandardized interviews are informal. They are also called in depth interviews as they are used to explore a general idea of interest in depth, but they can go off the point (Greener, 2008). These interviews are like an improvised performance in which the performers have agreed in advance on the underlying themes and purposes but the details are left to be worked out at the moment (Berg and Lune, 2014).

Semistructured or semistandardized interviews involve the implementation of predetermined questions given a specific context, although they may vary from interview to another. Interviewers are expected to probe beyond the answers to their prepared questions. Skipping questions or adding further ones may be required in some cases (Berg and Lune, 2014 and Saunders et al, 2009).

In structured and semistructured interviews, researchers merge a series of probes elicited by one or another type of response to some crucial questions. In unstructured interviews, researchers are expected to anticipate responses and have in mind the kinds of probes that will encourage further elaboration (Berg and Lune, 2014).

Each form of interview outlined above has a distinct purpose. Standardised interviews are normally used to gather data, which will then be the subject of quantitative analysis, for example as part of a survey strategy. Non-standardised interviews are used to gather data, which are normally analysed qualitatively, for example as part of a case study strategy. These data are likely to be used not only to reveal and understand the 'what' and the 'how' but also to place more emphasis on exploring the 'why'. The following figure shows the various forms of interviews.

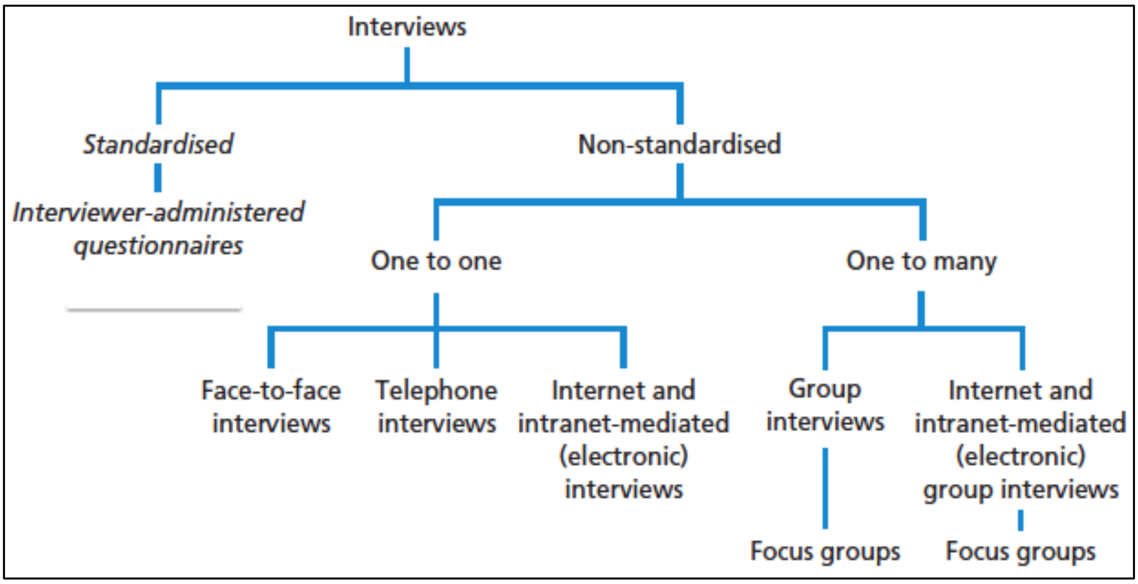


Figure 4.5: Forms of interviews (Source: Saunders et al, 2009, p. 321)

During the course of this study, some visits were made to the case company's premises where a number of interviews were conducted with different personnel in the company. Firstly, a few unstructured interviews were conducted with the chairman of the company to discuss the main operational issues relative to the company and recommend some referrals to be interviewed. This reflects a snowball sampling strategy as the researcher did not know any employees' contacts and required further referrals (of the company's employees from different departments) to be recommended by the chairman of the company. Then, a number of semi-structured interviews were conducted with the referred employees from the operations department, the referred employees from the management department, and referrals from research and development employees. During these interviews, a group of predetermined questions was addressed to the interviewees to form a complete view about the company and its core business. Another group of questions aimed at identifying the key issues that affect the company’s performance and mentioning the performance indicators and the performance measures as well. The last group of questions was related to specifying a certain problem that represents the focus of the research. Some of the prepared questions for the interviews are attached to the appendices.

Based on the main findings of the conducted interviews, in addition to the other collected statistical data, a proposed pipe flow model is developed to identify the main bottlenecks facing the case company to be further analysed using the simulation technique where Simul8 software is employed to build and run the model so as to achieve the set objectives of the research.

4.5.3 Modelling and Data Analysis Methods Used in the Study

Based on the collected data, either primary or secondary, the next stage is to analyse it. The data analysis stage includes different modelling and analysis methods that are used throughout this research, some of which are listed below:

4.5.3.1 Pipe Flow Model

Basically, pipe flow models are common in sectors of engineering and transportation of fluids (particularly oil and gas) to model flow and heat transport in pipe networks. Specialized software for piping design and pipe system modelling are available. In computing and technology, pipeline refers to a chain of processes, while in logistics, pipeline is a type of inventory that is defined as the goods that are in transit between locations i.e. in the distribution chain or distribution pipeline. By integrating these definitions, this study started its first step in analysing the data collected through proposing a pipe flow model based on the container flow as well as the information flow along the entire system with a view to identifying the key processes, activities and resources (dedicated to each flow or shared) either for the import logistics processes or the export logistics processes in the case company. The purpose of this model is to show the sequence of the logistics operations in container terminals and identify the stages where bottlenecks may occur.

4.5.3.2 Simulation Model

A simulation generally refers to a computerized version of the model, which runs over time, to study the implications of the defined interactions. Simulations are generally iterative in their development. Since container terminals operations are characterized by their dynamic processes, therefore developing simulation models that are able to evaluate these processes is crucial. Simulation models allow generating and analysing statistics (for example productivity and average time), and identifying potential bottlenecks. They can be used for developing terminal management as a decision support system either for upgrading existing terminals or while constructing a new terminal, especially when it comes to testing plans that concern the logistics processes before putting them in real implementation. This is because simulation models usually incorporate both the physical resources (such as equipment and storage yards) and the components for control and strategies (Hatrman 2004). In this study, the proposed pipe flow model was used as a guide to build and develop an operational level simulation model that covers the entire logistics processes of import and export container flows and shows, to a great extent, the actual inbound and outbound flows of containers from the entry point to the exit point. In this context, this is a novel study, which simulates the operational level of the entire import and export logistics processes using Simul8 software. To the best of our knowledge, no such model has been reported in the literature. The purpose of this model is to show the interrelations between the various variables, and enable several scenarios to be examined.

4.5.3.3 Scenario Analysis

The developed simulation model is considered as a base model that enables different scenarios to be designed to test and evaluate the impact of various uncertainties in the logistics processes and different combinations of resources on the overall performance of the entire process. These scenarios are mainly suggested for improvement and providing potential solutions for optimizing the overall performance of the case company.

4.5.3.4 Sensitivity Testing

The last data analysis method that is used is the sensitivity testing that aims at evaluating and validating the model. It measures and reports the impact of each suggested scenario on the entire process. It can be also considered as one of the validation techniques that is used to show the impact of changing the value of an input or parameter of a model on the model's output or result (either a certain output parameter or the overall impact). In the simulation model, various kinds of sensitivity were tested, i.e. sensitivity in system analysis.

4.6 Logistics Processes of the Case Company

As for the case company, the company's business involves handling and storage of imported, exported and transit containers. The activities performed by the company are represented in two logistics chains. The first chain describes the process of handling imported containers while the second chain involves handling exported containers. These logistics chains include various activities such as loading and unloading of containers, internal transport to container storage yards, handling of containers, customs procedures, inspection and quality control, and loading containers on customer's vehicles. These logistics chains are described in detail as follows (Abbas and Mokhtar, 2003).

4.6.1 Logistics Activities Involved in Importing Process

The logistics chain for handling imported containers comprises seven main stages listed as (Abbas and Mokhtar, 2003):

1. Ships anchoring at berths.
2. Unloading and loading of containers into tractors or trailers.
3. Moving containers within premises.
4. Unloading, storing, and handling containers as well as conducting relevant inspections to obtain the necessary clearances.
5. Loading and moving inspected containers within premises.
6. Unloading, handling, and stripping cargo from containers.
7. Loading and transporting containers or cargo to customers' warehouses.

The first three stages represent the inbound logistics of the chain. The core process is stage four where containers are stored and handled. The outbound logistics of the chain is represented by stages five and six.

The process begins when the agent of the shipping line informs the company with the expected time of arrival of a vessel loaded with imported or transit containers. The agent also requests from the port authority permission for the vessel to enter the port and anchor at the berth. The terminal performs a discharge plan for the expected vessel and determines the yard that will be used for storing and the equipment will be used for handling. Upon anchorage of the vessel, gantry crane operations start to unload containers from the vessel to the tractors' deck. Close shots of Gantry Cranes in ACCHC are shown in figure 4.6.

Figure 4.6: A close shot of Gantry Crane while handling ship containers at the quay (Source: ACCHC, 2009)

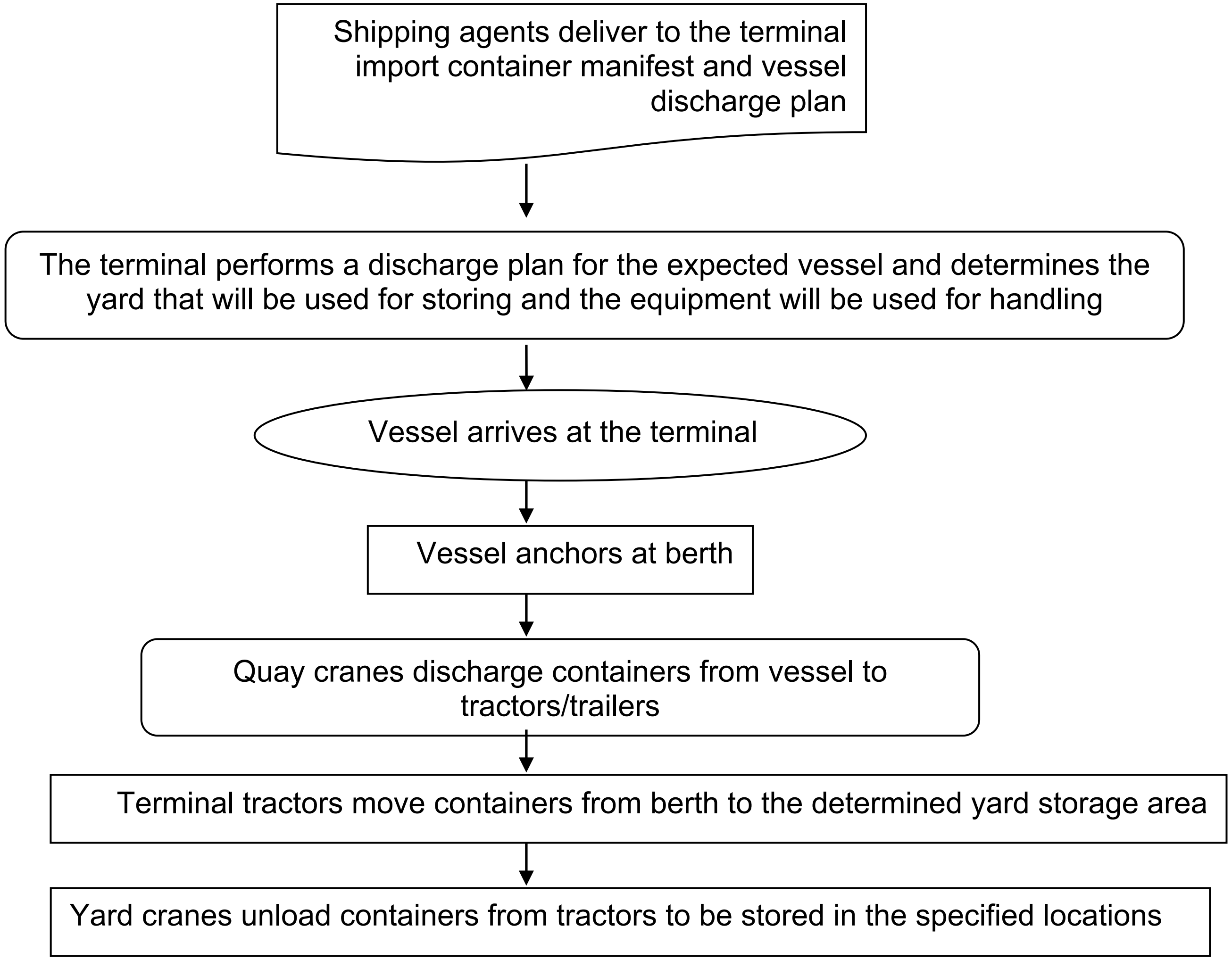
Imported containers are then moved within the company's premises to be stored according to their contents in corresponding yards (figure 4.7) either for refrigerated cargo containers or dangerous cargo containers or imported general cargo containers. Transits and containers with special dimensions are moved to specially allocated yards. Also, containers containing shared cargo are moved to a special depot for unloading shared cargo. When reaching the storage yards, handling equipment as yard cranes are used to stack containers to their exact locations. Equivalent information for each stacked container is then recorded into a computer database. This information covers the name of the shipping line, the name of the vessel, arrival time, container number, storage location, contents...etc.

Figure 4.7: Import yard in Alexandria Terminal at Alexandria port (Source: ACCHC, 2009)

The next step is facilitated by the company but mainly performed by official bodies responsible for conducting the required various forms of inspection (such as customs, agriculture, and radiation inspection), and quality controls and expiry checks as well as checking compliance with technical standards.

Upon the completion of such inspection procedures and the clearance of all the requested permissions, containers can be released and loaded into trucks owned or rented by customers and transported to customers' warehouses. As an alternative, upon customer request, a yard crane handles a container from the yard to be loaded on tractors owned by the company and moved to the stripping yard, then the toplifter handles a container from the terminal tractor to the yard stack where a forklift strips the container depending on its size (20/40) and shape of the commodity (boxes, pallets, bags). A lifter moves cargo to the customer's truck after entering the stripping yard. Finally, the customer's truck exits the yard. Empty containers are loaded on tractors and moved to a yard allocated for empty containers. Figure 4.8 shows the imports logistics processes in the company.

The Logistics processes for handling imported containers by the company



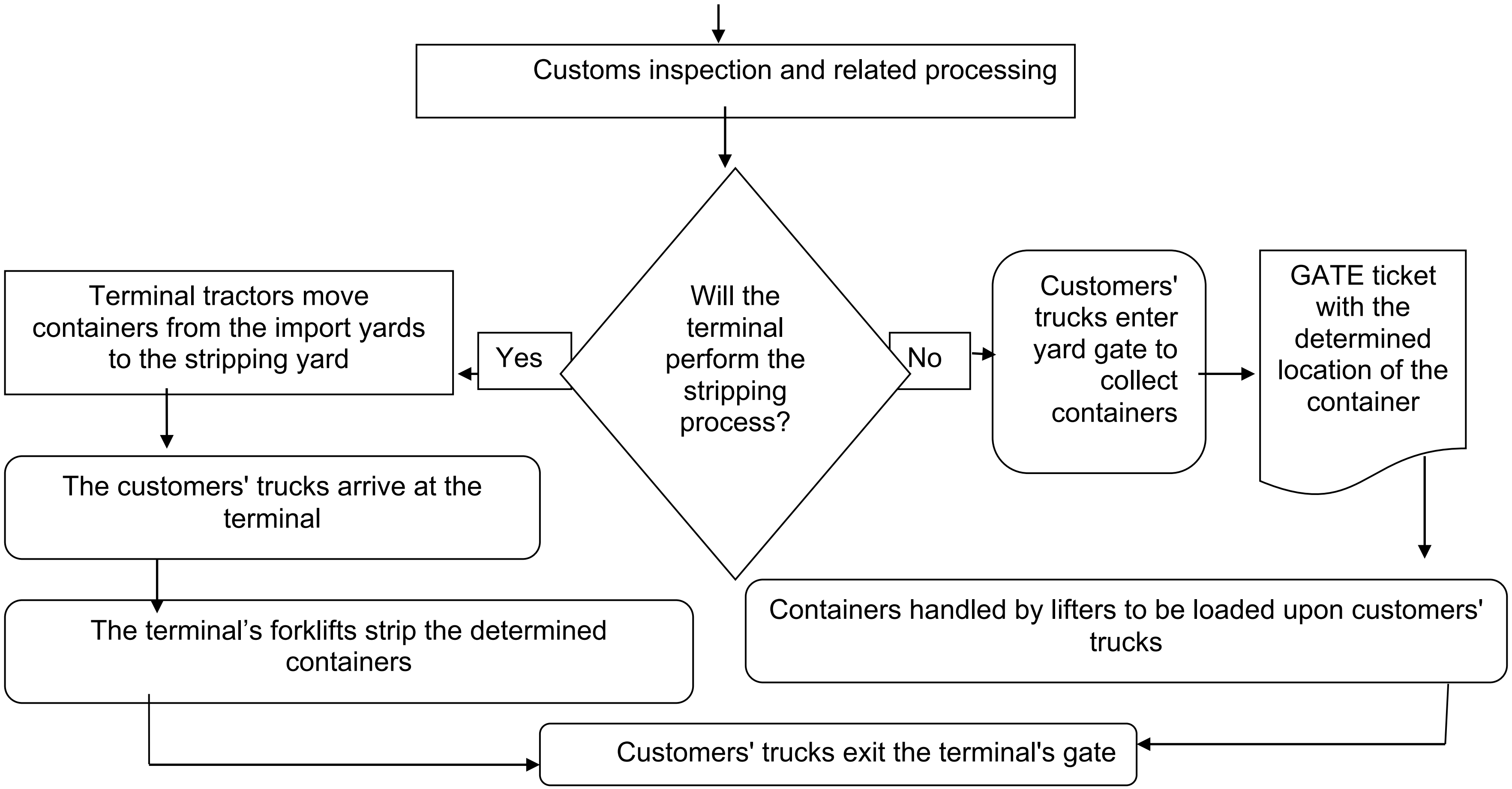


Figure 4.8: The Logistics processes for handling imported containers by the company

4.6.2 Logistics Activities Involved in Exporting Process

The logistics processes for handling exported containers include seven stages:

1. Loading and transporting containers from customers' warehouses.
2. Unloading, handling and stuffing cargo into containers.
3. Loading and moving containers within premises.
4. Unloading, storing, handling, inspections and clearances.
5. Moving inspected containers within premises.
6. Unloading and loading containers into vessels.
7. Vessels depart from berths.

Inbound logistics is represented by stages two and three. Stage four is the core of the process where containers are stored and handled. Stages five and six represent the outbound logistics.

The process begins at the customers' premises, where empty containers and exported cargo containers are loaded into tractors/trailers owned/rented by customers. Loaded containers are transported to yards allocated for the storage of exported containers in the company's premises and also empty containers are transported to special yards for empty containers to be moved by the company's owned tractors/trailers to depots allocated for stuffing containers within Alexandria port. Alternatively, separate cargoes are loaded on HGVs or LGVs owned/rented by customers to be transported from customers' warehouses to the container stuffing depots, where cargo is handled and stuffed into designated containers.

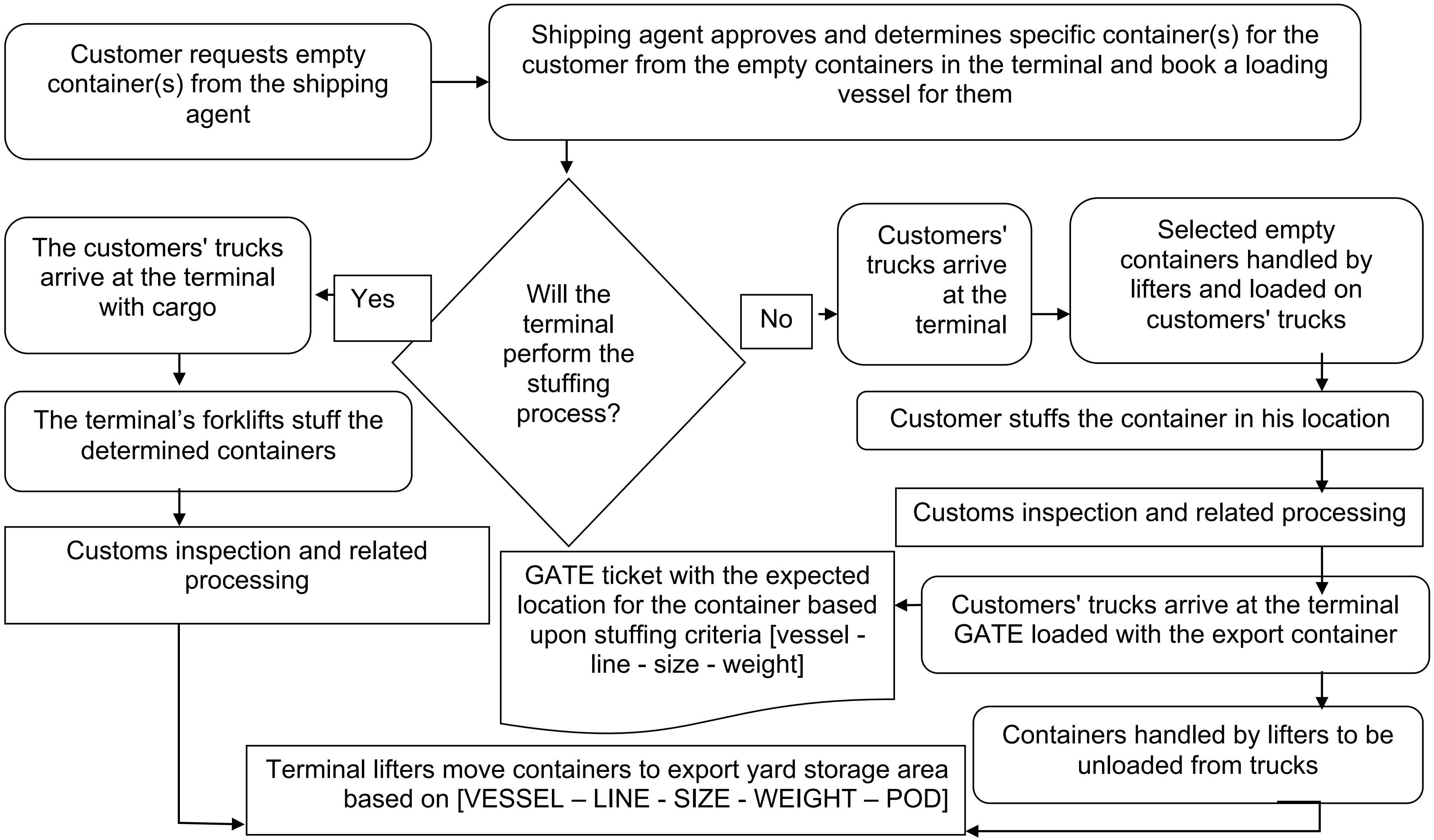
Stuffed containers are then transported to be stored in the export yards by the company's owned/rented trailers/tractors. Refrigerated containers as well as special dimension containers are transported from customers' premises to specially allocated yards.

When the exporter’s truck reaches the company's gates, inspection processes are done by the gate clerk on the container to check that the container seal is valid on the door and the container is without damage. Then, a ticket is printed to determine where to stack the container in the export yard based on the outbound carrier, port of discharge, the weight of the container and the container shipping line.

When reaching the storing yards, handling equipment as telescopic stackers or forklift trucks are used to stack containers to their exact locations.

After these procedures are completed, the company’s owned trailers/tractors are loaded with exported and/or transit containers, which are identified by the shipping line as designated containers for shipping, to be moved to the terminal quay where ships are anchored. Finally, gantry cranes are used to lift containers from the terminal tractors to be loaded upon the anchored ships at the terminal berths. Figure 4.9 shows the exports logistics processes in the company.

The Logistics processes for handling exported containers by the company



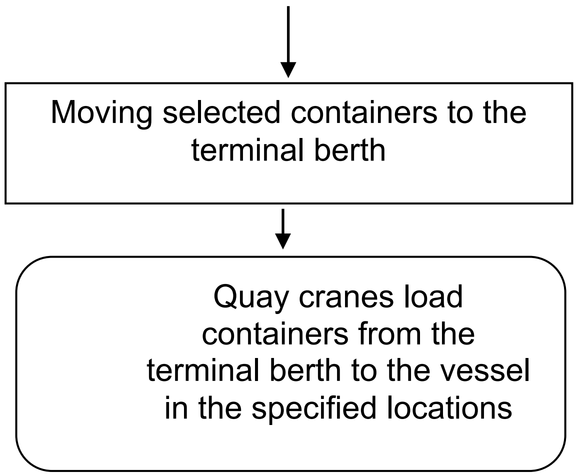


Figure 4.9: The Logistics processes for handling exported containers by the company

4.7 Summary

This chapter has discussed the methodology followed throughout the research. It started by introducing the various research philosophies and showed that more than one philosophy are incorporated in this research. The next section reflected the approach of the research as being deductive-inductive research through illustrating the differences between both approaches. The different research strategies are explained in section three, focusing on the case study strategy as the main strategy implemented in this research in association with the survey strategy. The chapter then clarified that the research follows the multiple methods choice through using both qualitative and quantitative data. It identified the interviewing as the main data collection technique adopted. The research involved several data analysis methods, in particular the modelling and simulation tools embraced, scenario analysis, and sensitivity testing. The chapter also presented an overview of the imports logistics flow and the exports logistics flow of containers in the case company. A graphical illustration for each flow is figured separately.

The next chapter will deal with the modelling and simulation tools employed in this study. It will present the proposed pipe flow model and describe in detail the developed simulation model and its parameters based on the collected data from the case company.

Chapter 5

Modelling and Simulation

This chapter discusses the modelling techniques used throughout this study. In this context, the study involves two main models; the first one represents a pipe flow model that shows the interrelations between the various resources of the case company for both the import process and the export process. Another model was then developed by the means of simulation where Simul8 software was used to build and develop an operational level simulation model that covers the entire logistics processes of import and export container flows and shows, to a great extent, the actual inbound and outbound flows of containers from the entry point to the exit point. The next section introduces the proposed pipe flow model and its analysis, followed by the simulation model and its full description.

5.1 Pipe Flow Model

As previously mentioned in chapter 4, the findings of the conducted interviews were organized and presented into two sets. First, a description of the entire logistics processes that take place in the company for both import and export flows, which were graphically illustrated in chapter 4 (see figures 4.8 and 4.9).

Based on this description, a pipe flow model was proposed to give an overview and identify the key logistical activities and resources for each flow. It also shows the shared resources between the imports and the exports processes with a view to finding the main bottlenecks facing the case company in both processes. Figure 5.1 shows the proposed pipe flow model for the imports process and the export process of the case company. As shown in the figure, the apparent logistics activities may include transportation of containers via various transportation means such as vessels, tractors, and trucks between the different stages of the processes. Another logistics activity is handling of containers, where different types of handling equipment are used to handle containers. For example, quay cranes are used to load and discharge containers to/from vessels. Containers are also moved to/from storage yards using yard cranes and lifters. Storage of containers in the allocated storage yard(s) can be considered as a logistics activity as well.

The pipe flow model identifies the shared resources between both flows. These resources include a variety of equipment and yards. For instance, quay cranes are fixed and they are allocated to vessels to perform the loading/discharging operations of containers for imports and exports. Tractors are also shared between imports and exports, whereby they are used to move containers to/from quayside to landside, i.e. from quay cranes to yard cranes or lifters. Three kinds of yards are shared between imports and exports. They are referred to as mixed yards as they are used for storing imported and exported containers. They involve: one dangerous yard, one reefer yard, and one empty yard.

The main objective of this model is to help identify the areas where bottlenecks are expected. This requires analysing the aggregated flow capacities at the different stages along the pipe. These capacities are stated in the next section and their relevant analysis is followed.

5.1.1 Flow Capacities of Pipe Flow Model

This section contains the required data that is related to the different capacities of handling equipment, storage yards and flows of containers. This is a part of the second set of data referred to at the beginning of section 5.1. This set of capacities data is mainly required to help identify where bottlenecks can occur in the pipe model and also to build and develop a more detailed model later

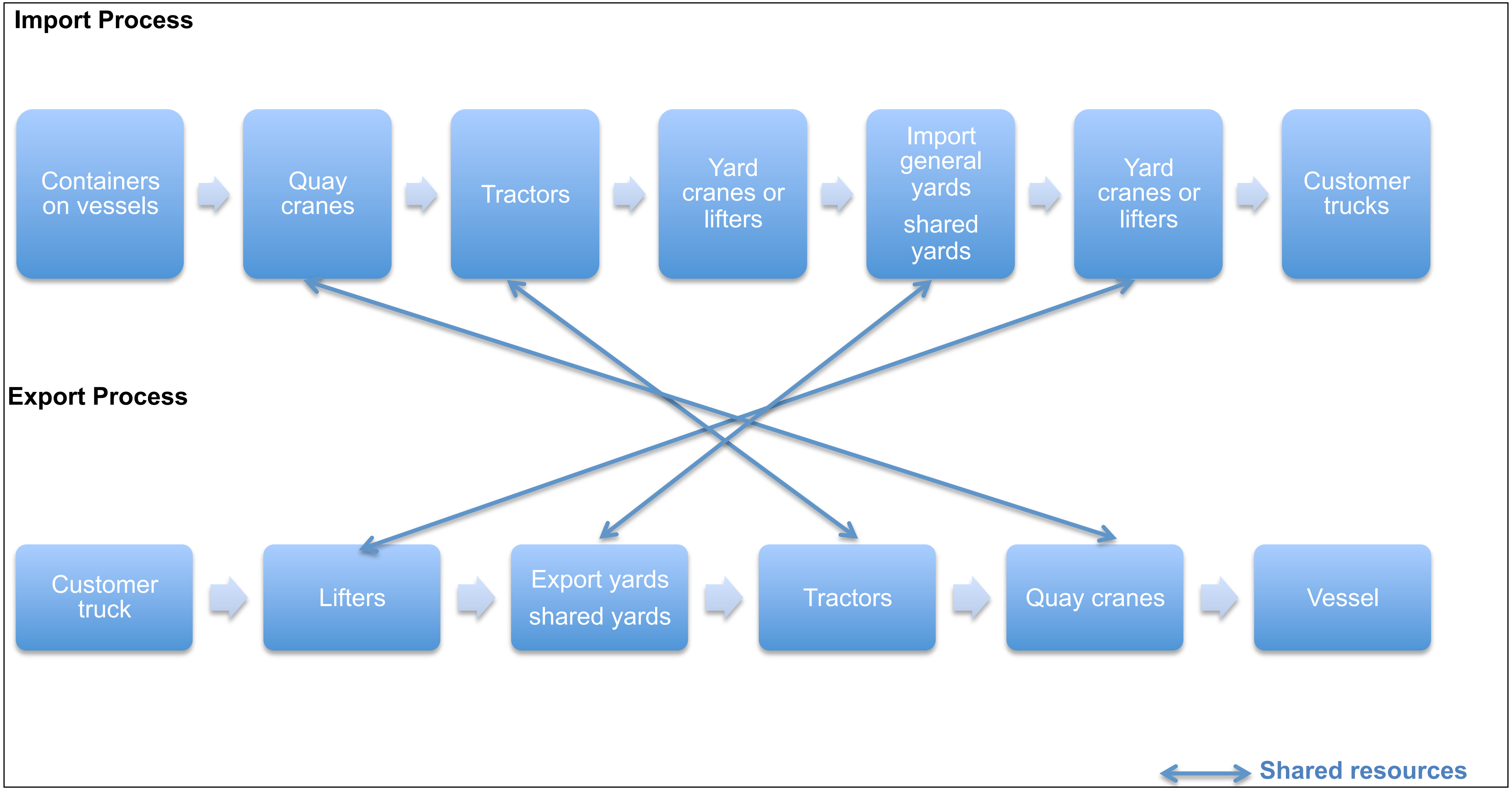


Figure 5.1: A proposed pipe flow model for the import process and the export process of the case company

5.1.1.1 Capacities of Storage Yards

Yard storage capacity: a total of 14000 TEUs classified as follows:

a. The storage capacities of general import yards: imports yard 1: 2280 TEU - imports yard 2: 1820 TEU - imports yard 3: 1870 TEU - imports yard 4: 1820 TEU - imports yard 5: 1240 TEU.
b. Reefer yard capacity is 500 TEU. This yard is mixed.
c. Dangerous yard capacity is 580 TEU. This yard is mixed.
d. Empty yard capacity is 2400 TEU. This yard is mixed.
e. The storage capacities of export yards: exports yard 1: 1240 TEU - exports yard 2: 920 TEU.

It is worth noting that customs clearance takes place within the storage yards. The rate for that may range from one to four days. In general, dwell time (the duration of stay of containers in yards) for imports ranges from nine to twelve days. Dwell time for exports ranges from five to six days.

5.1.1.2 Capacities of Handling Equipment

Handling equipment categories and their related capacities are listed as follows:

a. Five quay cranes (QC). The average daily working hours for quay cranes= 13-15 hours/quay crane/day. Each QC takes an average of two minutes to handle a container.
b. Eight yard cranes (YC RTG). The average daily working hours for yard cranes= 12-14 hours/yard crane/day. Each YC RTG takes an average of five minutes to store a container in its allocated yard and an average of 20 minutes to handle a container and move it out of the yard to the customer truck.

c. 25 tractors. The average daily working hours for tractors= 10-12 hours/tractor/day. A tractor takes an average of five minutes to move a container to/from QC to YC or lifter.
d. Number of total available forklifts = 19; Heavy lifters = 13 and empty lifters = 6. The average daily working hours for lifters= 10-12 hours/lifter/day. Lifters are used beside or instead of YC RTGs, thus the same timing parameters apply.

5.1.1.3 Flow Capacity of Containers

The minimum and maximum number of imported/exported containers per day are estimated as follows:

a. For exports: a minimum of 150 exported containers and a maximum of 350 exported containers are daily expected to enter the terminal, with an average normal rate of 250 – 300 daily exported containers.
b. For imports: a minimum of 200 imported containers and a maximum of 500 imported containers are daily expected to enter the terminal, with an average normal rate of 300 – 400 daily imported containers.

5.1.2 Analysis of the Pipe Flow Model Capacities

Analysing the above given capacities at the different stages of the pipe flow model can reveal the critical stages where bottlenecks may occur. It can be noticed that no bottlenecks are expected at the quayside since there are five cranes available, each working an average of 15 hours/day (equivalent to 900 minutes). This results in about 4500 total daily available minutes for all the QCs, which means that up to about 2300 containers can be handled daily given that each container takes two minutes on average working by a QC. Comparing this number with the average number of imported and exported containers reveals that the available quay cranes can handle the expected containers, resulting in no bottlenecks. The same justification applies to tractors, as 25 tractors are available to handle more than the expected number of containers daily.

When it comes to storage yards, their capacities indicate that mainly general import yards and export yards can only handle a certain number of containers. For example, all the five import yards have a total capacity of about 5000 containers (this is calculated based on a ratio used to convert the TEUs capacity of storage yards into number of boxes, as it was given in the data of the company that the equivalent value of 3000 boxes is 5000 TEUs). This total capacity of yards can be reached within 12 days according to the expected daily number of containers (5000 total capacity/400 average expected daily imported containers). This may reveal expected bottlenecks at this stage, given that the dwell time for imports ranges from nine to twelve days, especially when an increased number of imported containers is to be handled. This may result in congestion at general import yards. This import yards case is similar to the export yards as well. On the other hand, shared yards do not reveal any expected bottlenecks as their total share (30%) of total number of containers is relatively low compared to the total share of import and export yards (70%) as indicated by the company's statistics.

This analysis urges the investigation of the yard side in more details. This includes the previous and the following stages to the storage yards stage, in order to have a comprehensive operational view that enables further studying the cause/impact relationships in the process. Accordingly, developing a simulation model is highly required to achieve the desired objectives.

5.2 Developed Simulation Model

The proposed pipe flow model in addition to the set of collected operational data were used to build a simulation model using the Simul8 software. This dynamic integrated operational simulation model would enable us to evaluate the interacting effect between various activities at a lower planning level.

The model was developed based on the collected operational data in terms of the resources available (e.g. handling equipment, yards and labour) and their specific data (e.g. corresponding number of each type of equipment and its movement time duration, number of import yards, export yards, shared yards and their capacities). Other empirical statistics including the number of vessels, throughput of containers, dwell time for imports and exports and empty containers, customs clearance procedures…etc. were used as input parameters to build the model. Several versions of the model were developed to finally decide on the most reasonable and representative one.

As with any simulation model, this model is built given some facts and upon some assumptions. These facts and assumptions are listed below:

5.2.1 Facts of the Simulation Model

In addition to the previously given set of data in section 5.1, the following facts are also involved:

1. There is no back reach area in the terminal, which implies that there are no buffer areas for quay cranes to store containers temporarily.
2. Average monthly handled imported containers = 17000 TEUs, exported containers = 16000 TEUs.
3. The container categories and the percentage share of each category are listed as follows:
   a. Foreign trade containers represent 98%.

b. FCL 64.9%, LCL 0.5%.
c. Reefer 2.7%.
d. Dangerous 2.1%.
e. Empty 27.5%.

4. The empty imports represent about 5% of total imports, while empty exports represent about 40% of total exports (these percentages are calculated based on real numbers).
5. There are three dwell time distributions; dwell time for imports, dwell time for exports, and dwell time for empty containers. Each distribution includes eight groups of days; 1-5 days, 6 days, 7 days, 8 days, 9 days, 10 days, 11-20 days, and more than 20 days.

5.2.2 Assumptions of the Simulation Model

Based on some of the above facts and according to the current practices that take place in the real operations, here are the main assumptions of the developed model:

1. The average number of vessels that can berth at the same time = three feeder vessels.
2. Since only five QCs are available and three vessels can berth at the same time, it is assumed that two QCs are assigned to two of the vessels and one QC is assigned to the third vessel.
3. Lifters are used as "routing in" & "routing out" in case of "general import yard 5" (as it has no routes for RTG), export yard, dangerous yard, reefer yard, and empty yard. Basically, RTGs are used as "routing out" for other general yards but if all RTGs are unavailable then lifters can replace them.
4. Any RTG can go to any storage yard, but RTGs "routing out priority" are assumed from the nearest yard to each RTG to the farthest.

5. The share of imports & exports in reefer, dangerous and empty yards is estimated based on the percentage share of each yard from the total handled containers as mentioned in fact 3.
6. It is assumed that customs clearance procedures are included in the dwell time of containers in the yards.
7. The dwell time distribution was calculated based on selected monthly statistics of each dwell time group and its associated number of handled TEUs. The dwell time is classified into eight groups starting from one to five days up to more than 20 days.
8. The model considers three sets of lifters; one set for import lifters, one set for export lifters and one set for empty lifters.

It is worth mentioning that due to the unavailability of some specific data, some figures were assumed by estimation.

5.2.3 Description of the Developed Simulation Model

This section includes a detailed description of the simulation model, along with the justification for each parameter introduced to the model. This description follows a sequence starting from the entry point, through the different work centres, resources and storage bins involved, to the exit point.

The model represents the entire logistics processes in the case company, i.e. the flow of imported and exported containers since their arrival till their departure, given all the available resources in terms of yards, handling equipment, labour … etc. Figure 5.2 shows an overview for the entire simulation model. Some pictures for selected equipment are shown in appendix VII.

The simulation model starts with the entry point of the import process (which is the vessel), followed by 3 berths (as a maximum of 3 vessels can berth at the same time), then 1 or 2 quay cranes (a total of 5) is/are allocated to each vessel to unload the containers and load them on the import tractors (25 total tractors). Import tractors move containers to yard cranes (8 yard cranes) or import lifters (total of 13 heavy and 6 empty lifters) according to set percentages of the share of each yard from the total handled containers. Yard cranes only serve the first four general import yards. Other yards are served by lifters. There are 5 general import yards, 1 shared (imports and exports) reefer yard, 1 shared dangerous yard, and 1 shared empty yard (their capacities are considered) where containers have to stay for customs clearance procedures (dwell time is considered as well). When the customer is ready to collect a container, the yard crane or import lifter handles the container from the yard and moves it to the customer truck to exit the terminal (imports exit point). For each item of company-owned equipment, a worker (resource) is assigned.

Simultaneously, the export process starts when a customer's truck enters the gate (exports entry point). The container is taken from the customer's truck by export lifter (total of 13 heavy and 6 empty lifters) to the yard according to the set percentages. There are 2 export yards (capacities, customs clearance, dwell time are considered). Export lifters then move containers out of the yard to the export tractors (25 total tractors) to the quay cranes to be loaded on the vessel (exports exit point). In general, for all shared resources (between exports and imports), each was represented twice, once for imports and once for exports. This is done for the purpose of collecting separate results for each flow. However, both are assigned a single common resource to indicate that both are the same resource and avoid any conflicts. The other objective of this assignment is to measure the utilization of resources.

The model incorporates a number of stochastic decision variables such as the arrivals and batching value of vessels i.e. the numbers of loaded and discharged containers, the numbers of equipment as tractors and lifters that can be used especially in peaks, and capacities of yards i.e. the numbers of handled exported and imported containers.

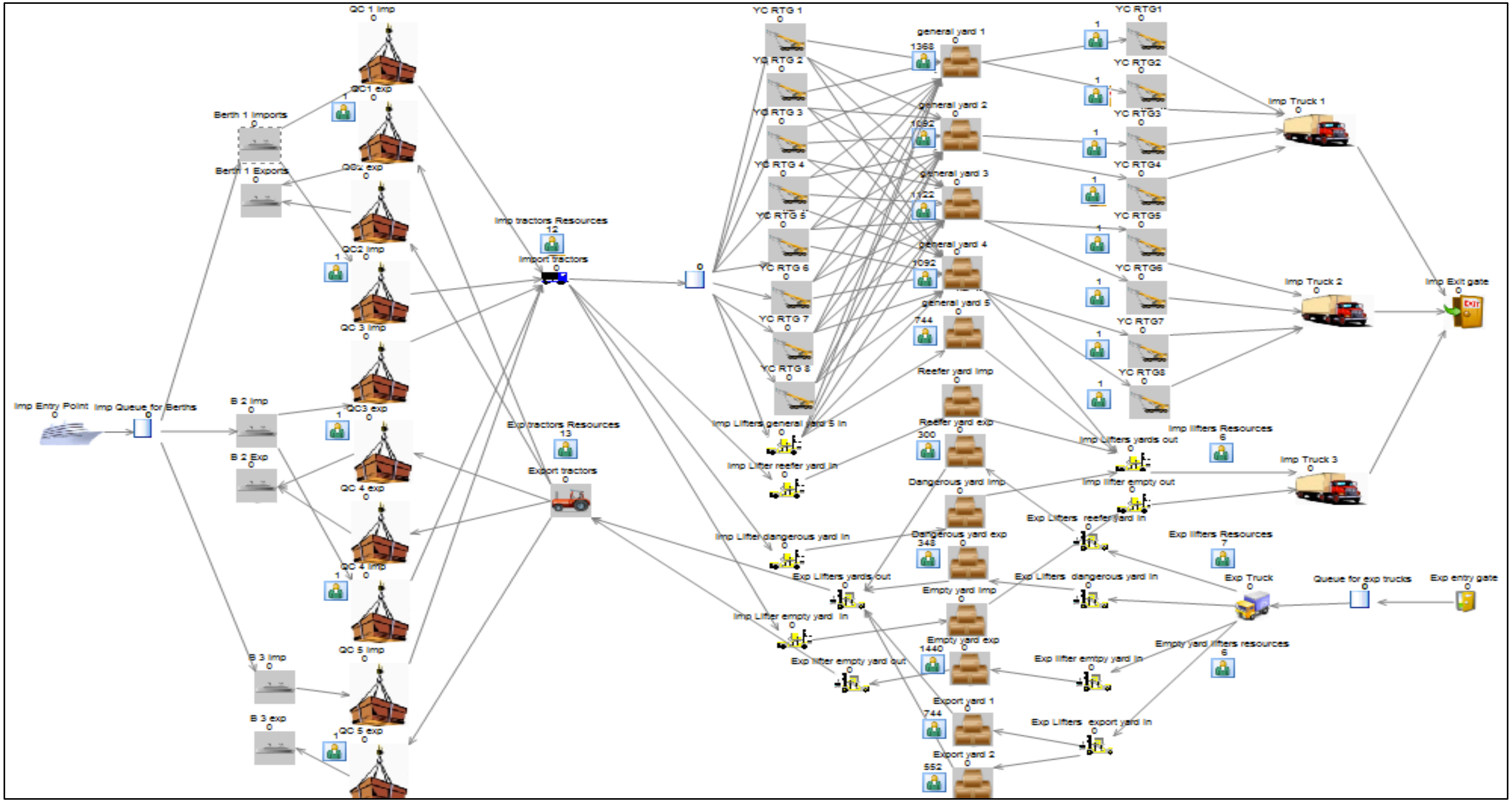


Figure 5.2: An overview for the entire simulation model

Work Entry Point 1 (“Imp entry point”): 

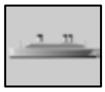
- Interarrival times (minutes):
  - Average:
    - Lower: 7*60=420 ⇒ maximum arrivals of three vessels/day.
    - Mode: 9*60=540 ⇒ the most frequent arrivals of two vessels/day.
    - Upper: 20*60=1200 ⇒ a minimum arrival of one vessel/day.
  - Distribution: Triangular ⇒ arrivals of vessels range from one to three vessels/day.
- √ First at start time ⇒ one vessel arrives as the model starts running.
- Batching:
  - Fixed value: 1 ⇒ one vessel arrives at a time.
  - Distribution: fixed ⇒ the batching distribution rule is fixed.
- Routing out:
  - To: “import queue for berth” ⇒ all arriving vessels are queued for berth allocation.

Storage Bin 1 (“Import queue for berths”):

- Storage bin 1:
  - Capacity: infinite ⇒ an infinite queue for all inbound vessels to facilitate the entry of vessels to the terminal (provided that vessels can be waiting in the sea in case all the berths are occupied).
  - Min wait time: 20 ⇒ a vessel takes 20 minutes to anchor at the terminal's berth.

N.B

- This is a virtual storage area (sea) to manage the entry and anchorage of vessels at the terminal's berths.

Work Center 1 ("Berth 1 imports"): 

- Timing:
  - Average value: 30 ⇒ 30 minutes as an average time for unlashing containers.
  - Distribution: Average ⇒ it takes an average of 30 minutes from anchorage to start unloading containers by QCs.
- Routing Out:
  - Discipline: Passive ⇒ the vessel will wait for a QC to unload the container.
  - To: "QC 1 imp", "QC 2 imp" ⇒ "berth 1" is served by "QC 1 imp" & "QC 2 imp".
  - Batching:
    - Distribution: Boxes ⇒ the distribution of unloaded containers is divided into six classes based on the number of boxes handled per vessel. Figure 5.3 shows the distribution of berths batching. For instance, 30% of total vessels handled are up to 110 boxes and so on. This applies to all "berth 1 imports", "berth 2 imports", and "berth 3 imports".

N.B:

- Based on assumption 1, only three vessels can berth at the same time.

- The average numbers of containers carried by each vessel (batching distribution) are estimated based on a randomly selected monthly reports of the vessels entered the case company.

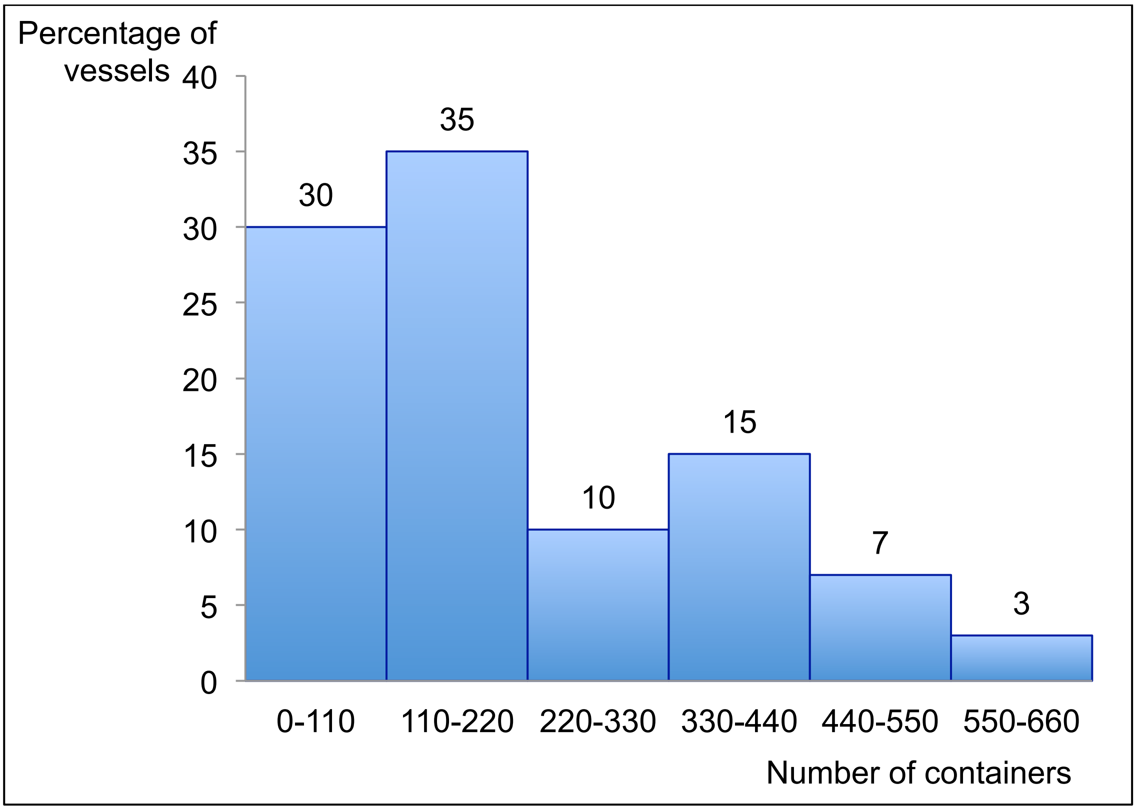


Figure 5.3: Batching distribution of berths routing out

<u>Work Center 2 ("Berth 2 imports"):</u>

All setting of "Work Center 1 (Berth 1 imports)" except:

- Routing Out:
  - To: "QC 3 imp", "QC 4 imp" ⇒ "berth 2" is served by "QC 3 imp" & "QC 4 imp".

<u>Work Center 3 ("Berth 3 imports"):</u>

Same setting of "Work Center 1 (Berth 1 imports)" except:

- Routing Out:
  - To: "QC 5 imp" ⇒ "berth 3" is served by "QC 5 imp".

Work Center 4 (Quay Crane 1 imports “QC 1 imp”): 

- Timing:
    - Average value: 2 ⇒ each container takes an average of two minutes work by a QC.
    - Distribution: Average ⇒ about every two minutes, a container is unloaded from a vessel.
- Resources: “Resource QC1” ⇒ one resource is added to this QC.
    - √ Require resource before collecting any work items ⇒ one worker is required to operate the QC.
- Routing In:
    - Selection Method: 1: “Berth 1 imports”⇒ “berth 1 imports” feeds this QC.
    - Discipline: Priority.
- Routing Out:
    - Discipline: Priority ⇒ “QC 1 imp” feeds import tractors by priority.
    - To: “Imp tractors” ⇒ “import tractors” are allocated to “QC 1 imp”.
    - Batching:
        - Fixed: 1 ⇒ “QC 1 imp” handles one container at each time.
        - Distribution: Fixed ⇒ this applies to all distributions.

Work Center 5 (Quay Crane 1 exports "QC 1 exp"):

- Timing:
  - Average value: 2 ⇒ each container takes an average of two minutes work by a QC.
  - Distribution: Average ⇒ every about two minutes, a container is loaded onto a vessel.
- Resources: "Resource QC1" ⇒ one resource is added to this QC.
  - √ Require resource before collecting any work items ⇒ one worker is required to operate the QC.
- Routing In:
  - Selection Method: 1: "export tractors" ⇒ "export tractors" are allocated to "QC 1 exports".
- Discipline: Passive. ⇒ "QC 1 exp" will accept containers pushed to it from "export tractors".
- Routing Out:
  - Discipline: Priority
  - To: "berth 1 exp" ⇒ "QC1 exports" usually feeds "berth 1 exports".
  - Batching:
    - Fixed: 1 ⇒ "QC 1 exp" handles one container at each time.
    - Distribution: Fixed ⇒ this applies to all distributions.

N.B:

- "QC 1 imports" is the same "QC 1 exports".

- "Resource QC1" is only one resource added to "QC 1 imports" and "QC 1 exports" to avoid loading and unloading at the same time and to indicate that it is only one QC.
- It is assumed that two QCs are assigned to "berth 1".

Work Center 6 (Quay Crane 2 imports "QC 2 imp"):

Same setting of "Work Center 4 (Quay Crane 1 imports)" except:

- ➢ Resources: "Resource QC2" ⇒ one resource is added to this QC.
  - ☑ Require resource before collecting any work items ⇒ one worker is required to operate the QC.

Work Center 7 (Quay Crane 2 exports "QC 2 exp"):

Same settings of "Work Center 5 (Quay Crane 1 exports)" except:

- ➢ Resources: "Resource QC2" ⇒ one resource is added to this QC.
  - ☑ Require resource before collecting any work items ⇒ one worker is required to operate the QC.

N.B:

- "QC 2 imports" is the same "QC 2 exports".
- "Resource QC2" is only one resource added to "QC 2 imports" and "QC 2 exports" to avoid loading and unloading at the same time and to indicate that it is only one QC.
- It is assumed that two QCs are assigned to "berth 1".

Work Center 8 (Quay Crane 3 imports "QC 3 imp"):

Same setting of "Work Center 4 (Quay Crane 1 imports)" except:

- ➢ Resources: "Resource QC3" ⇒ one resource is added to this QC.
  - ☑ Require resource before collecting any work items ⇒ one worker is required to operate the QC.

- Routing In:
  - Selection Method: 1: “Berth 2 imports” ⇒ ”berth 2 imports” feeds this QC.

<u>Work Center 9 (Quay Crane 3 exports):</u>

Same settings of “Work Center 5 (Quay Crane 1 exports)” except:

- Resources: “Resource QC3” ⇒ one resource is added to this QC.
  - [√] Require resource before collecting any work items ⇒ one worker is required to operate the QC.
- Routing Out:
  - To: “berth 2 exp” ⇒ “QC3 exports” usually feeds “berth 2 exports”.

<u>N.B:</u>

- “QC 3 imports” is the same “QC 3 exports”.
- “Resource QC3” is only one resource added to “QC 3 imports” and “QC 3 exports” to avoid loading and unloading at the same time and to indicate that it is only one QC.
- It is assumed that two QCs are assigned to “berth 2”.

<u>Work Center 10 (Quay Crane 4 imports “QC 4 imp”):</u>

Same settings of “Work Center 8 (Quay Crane 3 imports)” except**:**

- Resources: “Resource QC4” ⇒ one resource is added to this QC.
  - [√] Require resource before collecting any work items ⇒ one worker is required to operate the QC.

<u>Work Center 11 (Quay Crane 4 exports “QC 4 exp”):</u>

Same settings of “Work Center 9 (Quay Crane 3 exports)” except:

- Resources: “Resource QC4” ⇒ one resource is added to this QC.

- ☑ Require resource before collecting any work items ⇒ one worker is required to operate the QC.

N.B:

- “QC 4 imports” is the same “QC 4 exports”.
- “Resource QC4” is only one resource added to “QC 4 imports” and “QC 4 exports” to avoid loading and unloading at the same time and to indicate that it is only one QC.
- It is assumed that two QCs are assigned to “berth 2”.

Work Center 12 (Quay Crane 5 imports “QC 5 imp”):

Same settings of “Work Center 8 (Quay Crane 3 imports)” except:

- Resources: “Resource QC5” ⇒ one resource is added to this QC.
  - ☑ Require resource before collecting any work items ⇒ one worker is required to operate the QC.
- Routing In:
  - Selection Method: 1: “Berth 3 imports” ⇒ “berth 3 imports” feeds this QC.

Work Center 13 (Quay Crane 5 exports “QC 5 exp”):

Same settings of “Work Center 9 (Quay Crane 3 exports)” except:

- Resources: “Resource QC5” ⇒ one resource is added to this QC.
  - ☑ Require resource before collecting any work items ⇒ one worker is required to operate the QC.
- Routing Out:
  - To: “berth 3 exp” ⇒ “QC 5 exports” usually feeds “berth 3 exports”.

N.B:

- “QC 5 imports” is the same “QC 5 exports”.

- “Resource QC5” is only one resource added to “QC 5 imports” and “QC 5 exports” to avoid loading and unloading at the same time and to indicate that it is only one QC.
- It is assumed that one QC is assigned to “berth 3”.

Work Center 14 (Import tractors): 

- Timing:
  - Average value: 5 ⇒ each container takes on average five minutes moving by a tractor.
  - Distribution: Average ⇒ about once every five minutes, a container is moved by a tractor.
- Resources: “Import tractors Resources” ⇒ one resource is added to each tractor.
  - [√] Require resource before collecting any work items ⇒ one worker is required to operate the tractor.
- Routing In:
  - Selection Method: 1: “QC 1 imp”, 2: “QC 2 imp”, 3: “QC 3 imp”, 4: “QC 4 imp”, 5: “QC 5 imp”.
  - Discipline: Passive. ⇒ “import tractors” will accept containers pushed to them by QCs.
- Routing Out:
  - Discipline: Percent ⇒ containers are moved to queue for “general yards” or “import lifter reefer yard in” or “import lifter dangerous yard in” or “import lifter empty yard in”, according to the set percentages.

- To: 90.5% Queue for general yards ⇒ 90.5% of the containers moved by each tractor go to "RTGs 1 to 8" or "lifters general yard 5 in" (when a general yard is targeted).

  2.5% import lifter reefer yard in ⇒ based on fact 3, the share of reefer containers is 2.7% from total handled containers.

  2% import lifter dangerous yard in ⇒ based on fact 3, the share of dangerous containers is 2.1% from total handled containers.

  5% import lifter empty yard in ⇒ based on facts 3 & 4, the share of empty containers is 27.5% from total handled containers, where imported empty containers account for 5% of total imports.

- Replicate: 12 ⇒ 12 replicates to represent 12 import tractors.

<u>N.B:</u>

- It is assumed that tractors move containers to general import yards or reefer yard or dangerous yard or empty yard.

<u>Work Center 15 (Export tractors):</u> 

- Timing:
  - Average value: 5 ⇒ each container takes on average five minutes moving by a tractor.
  - Distribution: Average ⇒ about once every five minutes, a container is moved by a tractor.
- Resources: "Export tractors Resource" ⇒ one resource is added to each tractor.
  - √ Require resource before collecting any work items ⇒ one worker is required to operate the tractor.

- Routing In:
  - Selection Method: 1: “Export lifters yard out”.

    2: “Export lifter empty yard out”.
  - Discipline: Passive ⇒ “export tractors” will accept containers pushed to it from “export lifters yard out” or “export lifter empty yard out”.
- Routing Out:
  - Discipline: Uniform. ⇒ containers are moved from export tractors to QCs with an equal chance of going to each QC.
    - To: 1: “QC 1 exp”, 2: “QC 2 exp”, 3: “QC 3 exp”, 4: “QC 4 exp”, 5: “QC 5 exp”.
- Replicate: 13 ⇒ 13 replicates to represent 13 export tractors.

N.B:

- Since all the available tractors are 25, it is assumed that 13 of them are allocated to exports and 12 are allocated to imports.

Storage Bin 2 (Queues for general import yards):

- Capacity: 1 ⇒ each queue has the capacity of one container that will be moved to the following YC RTG or lifter.

N.B:

- This is a virtual queue to manage the flow of containers from tractors to YC RTGs or lifters.
- Based on assumption 3, “general yard 5”, “reefer yard”, “dangerous yard”, & “empty yard” are all served by lifters rather than RTGs.
- This queue serves “YC RTGs 1 to 8 in” and “Imp lifter general yard 5 in”, in case any of the “general yards 1 to 5” is targeted.

Work Center 16 (Yard Crane "YC RTG 1" in): 

- Timing:
  - Average value: 5 ⇒ each container takes on average five minutes moving by an RTG.
  - Distribution: Average ⇒ every about five minutes, a container is moved by an RTG.
- Resources: "Resource YC RTG1" ⇒ one resource is added to "YC RTG 1".
  - ☑ Require resource before collecting any work items ⇒ one worker is required to operate the crane.
- Routing In:
  - Selection Method: 1: "Queue for general yards".
  - Discipline: Priority.
- Routing Out:
  - Discipline: Priority ⇒ "YC RTG 1 in" always goes to destination 1 firstly (the nearest yard).
  - To: general yards 1 to 4 ⇒ "YC RTG 1 in" always goes to "general yard 1", then "general yard 2", then "general yard 3", then "general yard 4".

Work Center 17 (Yard Crane "YC RTG 2" in):

Same settings of "Work Center 16 (Yard Crane YC RTG 1 in)" except:

- Resources: "Resource YC RTG2" ⇒ one resource is added to "YC RTG 2".
  - ☑ Require resource before collecting any work items ⇒ one worker is required to operate the crane.

Work Center 18 (Yard Crane "YC RTG 3" in):

Same settings of "Work Center 16 (Yard Crane YC RTG 1 in)" except:

- Resources: "Resource YC RTG3" ⇒ one resource is added to "YC RTG 3".
  - √ Require resource before collecting any work items ⇒ one worker is required to operate the crane.
- Routing Out:
  - To: general yards 2, 3, 1, 4 ⇒ "YC RTG 3 in" always goes to "general yard 2", then "general yard 3", then "general yard 1", then "general yard 4".

Work Center 19 (Yard Crane "YC RTG 4" in):

Same settings of "Work Center 18 (Yard Crane YC RTG 3 in)" except:

- Resources: "Resource YC RTG4" ⇒ one resource is added to "YC RTG 4".
  - √ Require resource before collecting any work items ⇒ one worker is required to operate the crane.
- Routing Out:
  - To: general yards 2, 3, 4, 1 ⇒ "YC RTG 4 in" always goes to "general yard 2", then "general yard 3", then "general yard 4", then "general yard 1".

Work Center 20 (Yard Crane "YC RTG 5" in):

Same settings of "Work Center 18 (Yard Crane YC RTG 3 in)" except:

- Resources: "Resource YC RTG5" ⇒ one resource is added to "YC RTG 5".
  - √ Require resource before collecting any work items ⇒ one worker is required to operate the crane.
- Routing Out:
  - To: general yards 3,4,2,1 ⇒ "YC RTG 5 in" always goes to "general yard 3" then "general yard 4", then "general yard 2" then "general yard 1".

Work Center 21 (Yard Crane "YC RTG 6" in):

Same settings of "Work Center 18 (Yard Crane YC RTG 3 in)" except:

- Resources: "Resource YC RTG6" ⇒ one resource is added to "YC RTG 6".
  - √ Require resource before collecting any work items ⇒ one worker is required to operate the crane.
- Routing Out:
  - To: general yard 3,4,2,1 ⇒ "YC RTG 6 in" always goes to "general yard 3" then "general yard 4", then "general yard 2" then "general yard 1".

Work Center 22 (Yard Crane "YC RTG 7" in):

Same settings of "Work Center 18 (Yard Crane YC RTG 3 in)" except:

- Resources: "Resource YC RTG7" ⇒ one resource is added to "YC RTG 7".
  - √ Require resource before collecting any work items ⇒ one worker is required to operate the crane.
- Routing Out:
  - To: general yard 4,3,2,1 ⇒ "YC RTG 7 in" always goes to "general yard 4" then "general yard 3", then "general yard 2" then "general yard 1".

Work Center 23 (Yard Crane "YC RTG 8" in):

Same settings of "Work Center 21 (Yard Crane YC RTG 7 in)" except:

- Resources: "Resource YC RTG8" ⇒ one resource is added to "YC RTG 8".
  - √ Require resource before collecting any work items ⇒ one worker is required to operate the crane.

Work Center 24 ("Import Lifter general yard 5 in"): 

- Timing:
  - Average value: 5 ⇒ each container takes on average five minutes moving by a lifter.

- Distribution: Average ⇒ about once every five minutes, a container is moved by a lifter.

- Resources: “Import lifters Resources” ⇒ one resource is added to “import lifter general yard 5 in”.
  - [√] Require resource before collecting any work items ⇒ one worker is required to operate the lifter.
- Routing In:
  - Selection Method: 1: “Queue for general yards”.
  - Discipline: Priority.
- Routing Out:
  - Discipline: Priority ⇒ “Import lifter general yard in” always goes to “general yard 5” firstly.
  - To: general yards 5,4,3,2,1 ⇒ “import lifter general yard in” always goes to “general yard 5” then “general yard 4” then “general yard 3” then “general yard 2” then “general yard 1”.
- Replicates: 6 ⇒ 6 lifters are assigned for imports.

N.B:

- Since all the heavy lifters are 13, it is assumed that 6 lifters are assigned to imports and 7 are assigned to exports.
- Based on assumption 3, “general yard 5”, reefer yard, dangerous yard, & empty yards are all served by lifters rather than RTGs.
- Export yards are served by lifters, so that more lifters are assigned to exports.

Work Center 25 ("Import Lifter reefer yard in"):

- Timing:
  - Average value: 5 ⇒ each container takes on average five minutes moving by a lifter.
  - Distribution: Average ⇒ every about five minutes, a container is moved by a lifter.
- Resources: "Import lifters Resources" ⇒ one resource is added to "Import Lifter reefer yard in".
  - [√] Require resource before collecting any work items ⇒ one worker is required to operate the lifter.
- Routing In:
  - Selection Method: 1: "import tractors".
  - Discipline: Passive. ⇒ "imp lifter reefer yard in" will accept containers pushed to it by "imp tractors".
- Routing Out:
  - Discipline: Priority ⇒ "import lifter reefer yard in" always goes to "reefer yard".
  - To: "reefer yard imp" ⇒ "import lifter reefer yard in" always goes to "reefer yard imp".
- Replicates: 6 ⇒ 6 lifters are assigned for imports.

Work Center 26 ("Import Lifter dangerous yard in"):

Same settings of "Work Center 23 (Import Lifter reefer yard in)" except:

- Routing Out:
  - To: "dangerous yard" ⇒ "import lifter dangerous yard in" always goes to "dangerous yard imp".

Work Center 27 ("Import Lifter empty yard in"):

Same settings of "Work Center 23 (Import Lifter reefer yard in)" except:

- Routing Out:
  - To: "empty yard" ⇒ "import lifter empty yard in" always goes to "empty yard imp".

N.B:

- Empty lifters are 6 lifters other than the imports lifters. Imp lifters resources are set as 6 and empty lifters resources are set as 6.

Work Center 28 ("Export Lifter yards out"): 

- Timing:
  - Average value: 5 ⇒ each container takes on average five minutes moving by a lifter.
  - Distribution: Average ⇒ about once every five minutes, a container is moved by a lifter.
- Resources: "Export lifters Resources" ⇒ one resource is added to "export lifter yards out".
  - [√] Require resource before collecting any work items ⇒ one worker is required to operate the lifter.
- Routing In:
  - Selection Method: 1: "export yard 1", 2: "export yard 2", 3: "dangerous yard", 4: "reefer yard".
  - Discipline: Priority ⇒ "exp lifter yards out" will take containers from "export yard 1" then "export yard 2", then "dangerous yard", then "reefer yard".

- Routing Out:
  - Discipline: Priority ⇒ “export lifter yards out” feeds “exp tractors”.
  - To: “export tractors” ⇒ “export lifter yards out” move containers to “exp tractors”.
- Replicates: 7 ⇒ 7 lifters are assigned for exports.

<u>Work Center 29 (“Export Lifter empty yards out”):</u>

- Timing:
  - Average value: 5 ⇒ each container takes on average five minutes moving by a lifter.
  - Distribution: Average ⇒ about once every five minutes, a container is moved by a lifter.
- Resources: “Empty lifters Resources” ⇒ one resource is added to “exp lifter empty yards out”.
  - √ Require resource before collecting any work items ⇒ one worker is required to operate the lifter.
- Routing In:
  - Selection Method: 1: “empty yard exp”
  - Discipline: Priority ⇒ “exp lifter empty yards out” will take containers from “empty yard exp”.
- Routing Out:
  - Discipline: Priority ⇒ “export lifter empty yards out” feeds “exp tractors”.
  - To: “export tractors” ⇒ “export lifter empty yards out” move containers to “exp tractors”.

Work Center 30 (“general yard 1”): 

- Timing:
    - Distribution: dwell time imp ⇒ dwell time for imports is classified into eight groups as shown in figure 5.4. It shows that 31% of handled containers stay in yard from 2 – 5 days, 7% of containers stay six days, 6% of containers stay seven days, 4% of containers stay eight days, 5% of containers stay nine days, 5% of containers stay ten days, 29% of containers stay from 11-20 days, and 13% of containers stay more than 20 days.

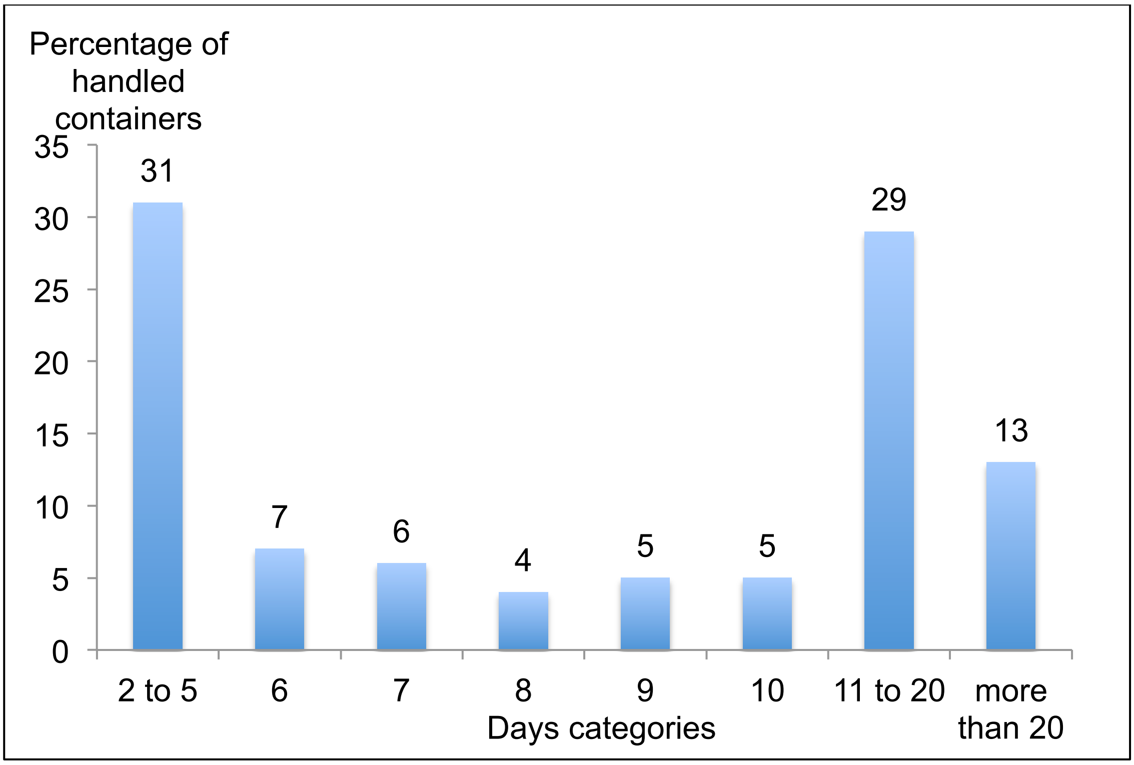


Figure 5.4: Dwell time categories for imports

- Resources: “General yard 1” ⇒ the purpose of adding this resource is to measure the utilization of the yard.

- Routing In:
  - Selection Method: 1: “YC RTG 1” in, 2: “YC RTG 2” in, 3: “YC RTG 3” in, 4: “YC RTG 4” in, 5: “YC RTG 5” in, 6: “YC RTG 6” in, 7: “YC RTG 7” in, 8: “YC RTG 8” in, 9: “imp lifters general yard 5 in”.
  - Discipline: Priority.
- Routing Out:
  - Discipline: Passive ⇒ a container stays in yard until pulled by a YC RTG.
    - To: YC RTG 1, 2 ⇒ a container can be moved by “YC RTG1” out or “YC RTG2” out.
- Replicate: 1368 ⇒ based on section 5.1.1.1(a), the capacity of “general import yard 1”= 2280 TEUs, which is equivalent to 1368 container boxes.

N.B:

- The distribution of “Dwell time for imports” was calculated based on fact 5 & assumption 7.

Work Center 31 (“general yard 2”):

- Timing: Same as Work Center 28 (general yard 1).
- Resources: “General yard 2” ⇒ the purpose of adding this resource is to measure the utilization of the yard.
- Routing In:
  - Selection Method: 1: “YC RTG 3” in, 2: “YC RTG 4” in, 3: “YC RTG 2” in, 4: “YC RTG 1” in, 5: “YC RTG 5” in, 6: “YC RTG 6” in, 7: “YC RTG 7” in, 8: “YC RTG 8” in, 9: “imp lifters general yard 5 in”.
  - Discipline: Priority.

- Routing Out:
  - Discipline: Passive ⇒ a container stays in yard until pulled by a YC RTG.
  - To: YC RTG 3, 4 out ⇒ a container can be moved by "YC RTG3" out or "YC RTG4" out.
- Replicate: 1092 ⇒ based on section 5.1.1.1(a), the capacity of "general import yard 2" = 1820 TEUs, which is equivalent to 1092 container boxes.

Work Center 32 ("general yard 3"):

- Timing: Same as Work Center 28 (general yard 1).
- Resources: "General yard 3" ⇒ the purpose of adding this resource is to measure the utilization of the yard.
- Routing In:
  - Selection Method: 1: "YC RTG 5" in, 2: "YC RTG 6" in, 3: "YC RTG 4" in, 4: "YC RTG 3" in, 5: "YC RTG 2" in, 6: "YCRTG 7" in, 7: "YC RTG 1" in, 8: "YC RTG 8" in, 9: "imp lifters general yard 5 in".
  - Discipline: Priority.
- Routing Out:
  - Discipline: Passive ⇒ a container stays in yard until pulled by a YC RTG.
  - To: YC RTG 5, 6 out ⇒ a container can be moved by "YC RTG5" out or "YC RTG6" out.
- Replicate: 1122 ⇒ based on section 5.1.1.1(a), the capacity of "general import yard 3" = 1870 TEUs, which is equivalent to 1122 container boxes.

<u>Work Center 33 ("general yard 4"):</u>

- Timing: Same as Work Center 28 (general yard 1).
- Resources: "General yard 4" ⇒ the purpose of adding this resource is to measure the utilization of the yard.
- Routing In:
  - Selection Method: 1: "YC RTG 7" in, 2: "YC RTG 8" in, 3: "YC RTG 6" in, 4: "YC RTG 5" in, 5: "imp lifters general yard 5 in", 6: "YC RTG 4" in, 7: "YC RTG 3" in, 8: "YC RTG 2" in, 9: "YC RTG 1" in.
  - Discipline: Priority.
- Routing Out:
  - Discipline: Passive ⇒ a container stays in yard until pulled by a YC RTG or a lifter.
    - To: YC RTG 7, 8 out, imp lifters yards out ⇒ a container can be moved by "YC RTG7" out or "YC RTG8" out or "imp lifters yards out".
- Replicate: 1092 ⇒ based on section 5.1.1.1(a), the capacity of "general import yard 4" = 1820 TEUs, which is equivalent to 1092 container boxes.

<u>Work Center 34 ("general yard 5"):</u>

- Timing: Same as Work Center 28 (general yard 1).
- Resources: "General yard 5" ⇒ the purpose of adding this resource is to measure the utilization of the yard.
- Routing In:
  - Selection Method: 1: "imp lifters general yard 5 in".
  - Discipline: Passive.

- Routing Out:
  - Discipline: Passive ⇒ a container stays in yard until pulled by a lifter.
  - To: “import lifters yards out”. ⇒ a container can be moved by “imp lifter yard out”.
- Replicate: 744 ⇒ based on section 5.1.1.1(a), the capacity of “general import yard 5” = 1240 TEUs, which is equivalent to 744 container boxes.

<u>Work Center 35 (“reefer yard imports”):</u>

- Timing: Same as Work Center 28 (general yard 1).
- Resources: “reefer space” ⇒ the purpose of adding this resource is to measure the utilization of the yard.
- Routing In:
  - Selection Method: 1: “imp lifter reefer yard in”.
  - Discipline: Passive. ⇒ an import container is moved to the reefer yard by “import lifter reefer yard in”.
- Routing Out:
  - Discipline: Priority. ⇒ containers are moved from “reefer yard” by “imp lifter yards out”.
  - To: “import lifter yards out”.
- Replicate: 300 ⇒ based on section 5.1.1.1(b), the capacity of “reefer yard” = 500 TEUs, which is equivalent to 300 container boxes.

Work Center 36 ("reefer yard exports"):

- Timing:
  - Distribution: dwell time exp ⇒ dwell time for exports is classified into eight groups as follows: 64.5% of handled containers stay in yard from 1 – 5 days, 12% of containers stay six days, 8% of containers stay seven days, 5% of containers stay eight days, 3% of containers stay nine days, 2% of containers stay ten days, 5% of containers stay from 11-20 days, and 0.5% of containers stay more than 20 days. This is shown in figure 5.5.

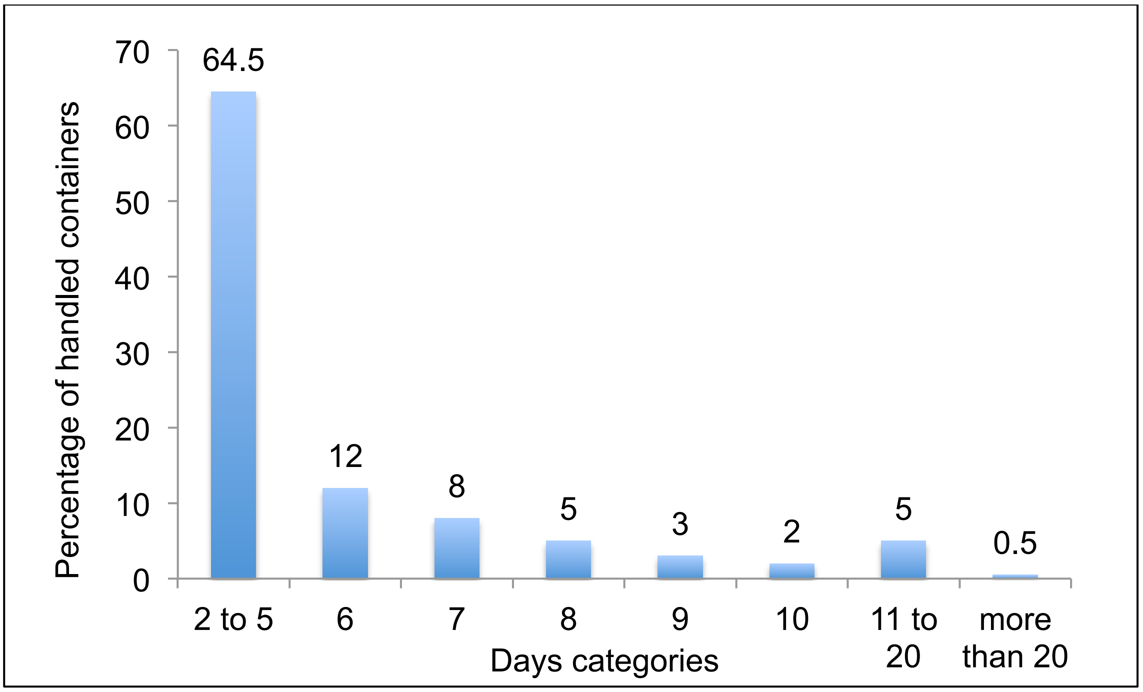


Figure 5.5: Dwell time categories for exports

- Resources: reefer space ⇒ the purpose of adding this resource is to measure the utilization of the yard.
- Routing In:
  - Selection Method: 1: "exp lifter reefer yards in".

- Discipline: Passive. ⇒ an export container is moved to the "reefer yard exp" by an "export lifter reefer yard in".

➢ Routing Out:
  - Discipline: Priority. ⇒ containers are moved from "reefer yard exp" by an "exp lifter yards out".
  - To: "export lifter yards out".

➢ Replicate: 300 ⇒ based on section 5.1.1.1(b), the capacity of "reefer yard" = 500 TEUs, which is equivalent to 300 container boxes.

N.B:

- "Reefer yard imports" and "reefer yard exports" are the same yard. They are assigned the same resource "reefer space" with a number of resources limited to 300 (which is the maximum capacity of reefer yard for both exports and imports).

Work Center 37 ("dangerous yard imports"):

➢ Timing: Same as Work Center 28 (general yard 1).

➢ Resources: "dangerous space" ⇒ the purpose of adding this resource is to measure the utilization of the yard.

➢ Routing In:
  - Selection Method: 1: "imp lifter dangerous yard in".
  - Discipline: Passive. ⇒ an import container moved is moved to the "dangerous yard imp" by an "import lifter dangerous yard in".

➢ Routing Out:
  - Discipline: Priority ⇒ containers are moved to dangerous yard imp.
  - To: "import lifters yards out". ⇒ containers are moved from "dangerous yard imp" by an "import lifter yard out".

- Replicate: 348 ⇒ based on section 5.1.1.1(c), the capacity of “dangerous yard” = 580 TEUs, which is equivalent to 348 container boxes.

<u>Work Center 38 (“dangerous yard exports”):</u>

- Timing: Same as Work Center 34 (reefer yard exports).
- Resources: “dangerous space” ⇒ the purpose of adding this resource is to measure the utilization of the yard.
- Routing In:
  - Selection Method: 1: “exp lifters dangerous yards in”.
  - Discipline: Passive. ⇒ an export container moved is moved to the “dangerous yard exp” by an “export lifter dangerous yard in”.
- Routing Out:
  - Discipline: Priority ⇒ containers are moved to dangerous yard exp.
  - To: “export lifters yards out”. ⇒ containers are moved from “dangerous yard exp” by an “export lifter yards out”.
- Replicate: 348 ⇒ based on section 5.1.1.1(c), the capacity of “dangerous yard” = 580 TEUs, which is equivalent to 348 container boxes.

<u>N.B:</u>

- “Dangerous yard imports” and “Dangerous yard exports” are the same yard. They are assigned the same resource “Dangerous space” with a number of resources limited to 348 (which is the maximum capacity of dangerous yard for both exports and imports).

Work Center 39 (“empty yard imports”):

- Timing:
  - Distribution: dwell time empty ⇒ dwell time for empty containers is classified into eight groups as follows: 65% of handled containers stay in yard from 2 – 5 days, 6% of containers stay six days, 5% of containers stay seven days, 3% of containers stay eight days, 2% of containers stay nine days, 1% of containers stay ten days, 10% of containers stay from 11-20 days, and 8% of containers stay more than 20 days. Figure 5.6 shows the dwell time for empty containers.

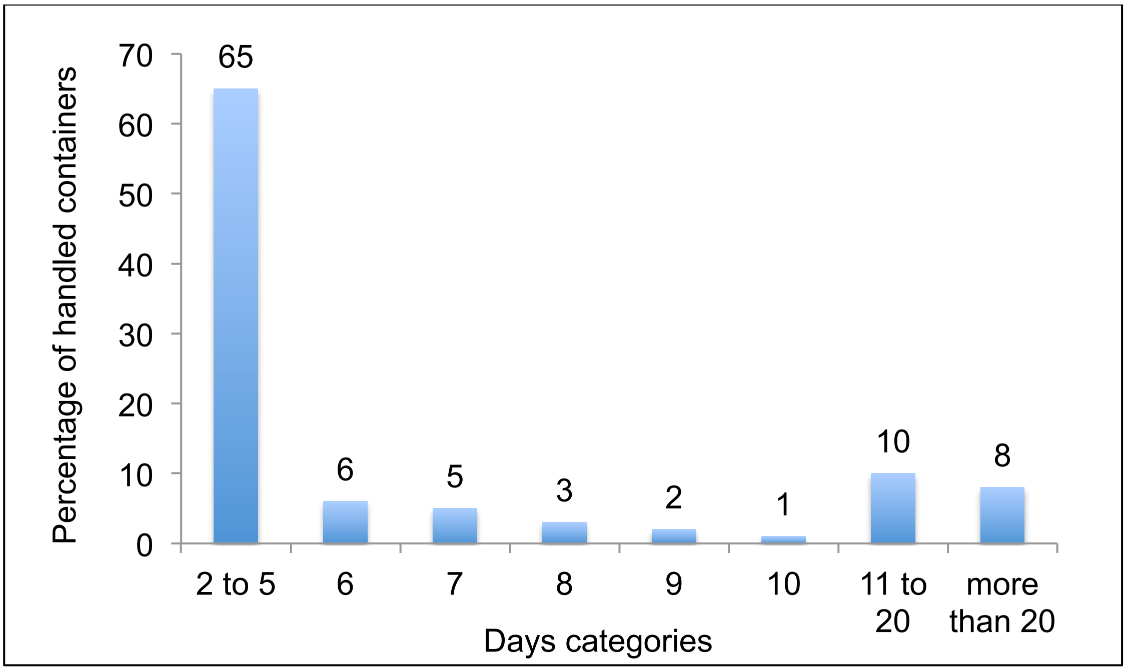


Figure 5.6: Dwell time categories for empty containers

- Resources: “empty space” ⇒ the purpose of adding this resource is to measure the utilization of the yard.
  - Routing In:
  - Selection Method: 1: “imp lifter empty yard in”.
  - Discipline: Passive. ⇒ an import container is moved to the “empty yard imp” by “import lifter empty yard in”.

- Routing Out:
  - Discipline: Priority. ⇒ containers are moved to “empty yard imp”.
  - To: “import lifters empty yard out”. ⇒ containers are moved from “empty yard imp” by an “import lifter empty yard out”.
- Replicate: 1440 ⇒ based on section 5.1.1.1(d), the capacity of “empty yard” = 2400 TEUs, which is equivalent to 1440 container boxes.

<u>Work Center 40 (“empty yard exports”):</u>

- Timing:
  - Distribution: dwell time empty ⇒ dwell time for empty containers is classified into eight groups as follows: 65% of handled containers stay in yard from 2 – 5 days, 6% of containers stay six days, 5% of containers stay seven days, 3% of containers stay eight days, 2% of containers stay nine days, 1% of containers stay ten days, 10% of containers stay from 11-20 days, and 8% of containers stay more than 20 days.
  - Resources: “empty space” ⇒ the purpose of adding this resource is to measure the utilization of the yard.
  - Routing In:
  - Selection Method: 1: “exp lifters empty yard in”.
  - Discipline: Passive. ⇒ an export container is moved to the “empty yard exp” by an “export lifter empty yard in”.
  - Routing Out:
  - Discipline: Priority. ⇒ containers are moved to “empty yard exp”.

- To: export lifters empty yard out. ⇒ containers are moved from “empty yard exp” by an “export lifter empty yard out”.

- Replicate: 1440 ⇒ based on section 5.1.1.1(d), the capacity of “empty yard” = 2400 TEUs, which is equivalent to 1440 container boxes.

N.B:

- “Empty yard imports” and “empty yard exports” are the same yard. They are assigned the same resource “Empty space” with a number of resources limited to 1440 (which is the maximum capacity of empty yard for both exports and imports).

Work Center 41 (“export yard 1”):

- Timing: Same as Work Center 34 (reefer yard exports).
  - Resources: “export yard 1” ⇒ the purpose of adding this resource is to measure the utilization of the yard.
  - Routing In:
  - Selection Method: 1: “export lifter export yards in”.
  - Discipline: Passive.
  - Routing Out:
    - Discipline: Priority
    - To: “export lifter yards out”. ⇒ a container can be moved from “export yard 1” to an “export lifter yards out”.
- Replicate: 744 ⇒ based on section 5.1.1.1(e), the capacity of “export yard 1” = 1240 TEUs, which is equivalent to 744 container boxes.

Work Center 42 (“export yard 2”):

- Timing: Same as Work Center 34 (reefer yard exports).
  - Resources: “export yard 2” ⇒ the purpose of adding this resource is to measure the utilization of the yard.
  - Routing In:
  - Selection Method: 1: “export lifter export yards in”.
  - Discipline: Passive.
  - Routing Out:
    - Discipline: Priority
    - To: “export lifter yards out” ⇒ a container can be moved from “export yard 2” to an “export lifter yards out”.
- Replicate: 552 ⇒ based on section 5.1.1.1(e), the capacity of “export yard 2” = 920 TEUs, which is equivalent to 552 container boxes.

Work Center 43 (“YC RTG1” out):

- Timing:
  - Average value: 20 ⇒ each container takes on average 20 minutes moving to “import truck”.
  - Distribution: Average ⇒ about once every 20 minutes, a container is moved to “import truck”.
- Resources: “Resource YC RTG1” ⇒ one resource is added to “YC RTG 1” out.
  - [√] Require resource before collecting any work items ⇒ one worker is required to operate the crane.
  - Routing In:
  - Selection Method: 1: “general yard 1”.

- Discipline: Priority.

➢ Routing Out:

- Discipline: Priority ⇒ "YC RTG1" out, always goes to "import truck 1".
- To: "Import truck1". ⇒ "YC RTG1" out, always goes to "import truck 1".

N.B:

- The same "resource YC RTG1" is added to "YC RTG 1" in and "YC RTG"1 out, to avoid working in & out at the same time.

Work Center 44 ("YC RTG2" out):

Same settings as "Work Center 41 (YC RTG1 out)" except**:**

➢ Resources: "Resource YC RTG2" ⇒ one resource is added to "YC RTG2" out.

- ☑ Require resource before collecting any work items ⇒ one worker is required to operate the crane.

N.B:

- The same "resource YC RTG2" is added to "YC RTG 2" in and "YC RTG2" out, to avoid working in & out at the same time.

Work Center 45 ("YC RTG3" out):

Same settings as "Work Center 41 (YC RTG 1 out)" except:

➢ Resources: "Resource YC RTG3" ⇒ one resource is added to "YC RTG3" out.

- ☑ Require resource before collecting any work items ⇒ one worker is required to operate the crane.

➢ Routing In:

- Selection Method: 1: "general yard 2".

N.B:

- The same “resource YC RTG3” is added to “YC RTG 3” in and “YC RTG3” out, to avoid working in & out at the same time.

Work Center 46 (“YC RTG4” out):

Same settings as “Work Center 43 (YC RTG 3 out)” except:

- Resources: “Resource YC RTG4” ⇒ one resource is added to “YC RTG4” out.

N.B:

- The same “resource YC RTG4” is added to “YC RTG 4” in and “YC RTG4” out, to avoid working in & out at the same time.

Work Center 47 (“YC RTG5” out):

Same settings as “Work Center 44 (YC RTG 4 out)” except:

- Resources: “Resource YC RTG5” ⇒ one resource is added to “YC RTG 5 out”.
  - Routing In:
    - Selection Method: 1: “general yard 3”.
  - Routing Out:
    - Discipline: Priority ⇒ “YC RTG5” out, always goes to “import truck 2”.

N.B:

- The same “resource YC RTG5” is added to “YC RTG 5” in and “YC RTG5” out, to avoid working in & out at the same time.

Work Center 48 (“YC RTG6” out):

Same settings as “Work Center 45 (YC RTG 5 out)” except:

- Resources: “Resource YC RTG6” ⇒ one resource is added to “YC RTG6” out.

N.B:

- The same “resource YC RTG6” is added to “YC RTG 6” in and “YC RTG6” out, to avoid working in & out at the same time.

Work Center 49 (“YC RTG7” out):

Same settings as “Work Center 46 (YC RTG 6 out)” except:

- Resources: “Resource YC RTG7” ⇒ one resource is added to “YC RTG7” out.
  - Routing In:
    - Selection Method: 1: “general yard 4”.

N.B:

- The same “resource YC RTG7” is added to “YC RTG 7” in and “YC RTG7” out, to avoid working in & out at the same time.

Work Center 50 (“YC RTG8” out):

Same settings as “Work Center 47 (YC RTG 7 out)” except:

- Resources: “Resource YC RTG8” ⇒ one resource is added to “YC RTG 8 out”.

N.B:

- The same “resource YC RTG8” is added to “YC RTG 8” in and “YC RTG8” out, to avoid working in & out at the same time.

Work Center 51 (“Imp Lifter yards out”):

- Timing:
  - Average value: 20 ⇒ each container takes on average 20 minutes moving to truck.
  - Distribution: Average ⇒ about once every 20 minutes, a container is moved to an import truck.

- Resources: “Imp lifters Resources” ⇒ one resource is added to “imp lifter yards out”.
  - [√] Require resource before collecting any work items ⇒ one worker is required to operate the lifter.
- Routing In:
  - Selection Method: 1: “general yard 5”, 2: “reefer yard imp”, 3: “dangerous yard imp”, 4: “general yard 4”.
  - Discipline: Priority. ⇒ containers are taken from “general yard 5”, then “reefer yard imp”, then “dangerous yard imp”, then “general yard 4”.
- Routing Out:
  - Discipline: Priority ⇒ “imp lifters yard out” always goes to “imp truck 3”.
  - To: imp truck 3. ⇒ “imp lifters yard out” always goes to “imp truck 3”.
- Replicates: 6 ⇒ it is assumed that 6 lifters out of 13 heavy lifters will be allocated to imports.

<u>Work Center 52 (“Imp Lifter empty yard out”):</u>

Same settings as “Work Center 49 (Imp Lifter yards out)” except:

- Resources: “empty yard lifters resources” ⇒ one resource is added to “imp lifter empty yard out”.
- Routing In:
  - Selection Method: 1: “empty yard imp”.
- Replicates: 6 ⇒ there are 6 empty lifters for imports and exports.

Work Center 53 ("Exp Lifters reefer yard in"):

- Timing: Same as "Work Center 49 (Imp Lifter yards out)".
- Resources: "Exp lifters Resources" ⇒ one resource is added to "exp lifters reefer yard in".
  - Routing In:
    - Selection Method: 1: "export truck".
- Routing Out:
    - To: "reefer yard exp".
- Replicates: 7 ⇒ it is assumed that 7 lifters out of 13 heavy lifters will be allocated to exports as export yards can be only accessed by lifters.

Work Center 54 ("Exp Lifters dangerous yard in"):

Same settings as "Work Center 51 (Exp Lifters reefer yard in)" except:

- Routing Out:
    - To: "dangerous yard exp".

Work Center 55 ("Exp Lifters empty yard in"):

Same settings as "Work Center 51 (Exp Lifters reefer yard in)" except:

- Resources: "empty lifters Resources"⇒ one resource is added to "exp lifters empty yard in".
- Routing Out:
    - To: "empty yard exp".
- Replicates: 6 ⇒ there are 6 empty lifters for imports and exports.

Work Center 56 (“Exp Lifters export yards in”):

Same settings as “Work Center 51 (Exp Lifters reefer yard in)” except:

- Routing Out:
    - To: 1: “export yard 1”, 2: “export yard 2”.

Work Center 57 (“Imp truck 1”): 

- Timing:
    - Average value: 5 ⇒ each container takes on average five minutes moving to exit gate.
    - Distribution: Average ⇒ about once every five minutes, a container is moved to the gate.
- Routing In:
    - Selection Method: 1: “YC RTG1” out, 2: “YC RTG2” out, 3: “YC RTG3” out, 4: “YC RTG4” out.
    - Discipline: Priority. ⇒ containers are taken from the “YC RTG1” out then “YC RTG2” out then “YC RTG 3” out then “YC RTG4” out to the trucks.
- Routing Out:
    - Discipline: Priority ⇒ “imp truck 1” always goes to “exit gate”.
    - To: exit gate ⇒ “imp truck 1” always goes to “exit gate”.
- Replicates: 4 ⇒ 4 trucks will take the containers from the YC RTGs.

Work Center 58 ("Imp truck 2"):

Same settings as "Work Center 55 (Imp truck 1)" except:

- Routing In:
  - Selection Method: 1: "YC RTG5" out, 2: "YC RTG6" out, 3: "YC RTG7" out, 4: "YC RTG8" out.

Work Center 59 ("Imp truck 3"):

Same settings as **"**Work Center 55 (Imp truck 1)" except:

- Routing In:
  - Selection Method: 1: "imp lifters yards out", 2: "imp lifters empty yard out".
- Replicates: 5 ⇒ 5 trucks will take the containers from the lifters.

Work Center 60 ("Exp trucks"): 

- Timing:
  - Average value: 5 ⇒ each container takes on average five minutes moving to exp lifters.
  - Distribution: Average ⇒ about once every five minutes, a container is moved to exp lifters.
- Routing In:
  - Selection Method: 1: "Queue for export trucks".
  - Discipline: priority. ⇒ containers are pulled from the "queue for export trucks" to be moved to export lifters in.
- Routing Out:
  - Discipline: Percent.
  - To: 55.5% of the total exported containers go to export yards.

2.5% import lifter reefer yard in ⇒ based on fact 3, the share of reefer containers is 2.7% from total handled containers.

2% import lifter dangerous yard in ⇒based on fact 3, the share of dangerous containers is 2.1% from total handled containers.

40% import lifter empty yard in ⇒based on facts 3 & 4, the share of empty containers is 27.5% from total handled containers, where exported empty containers account for 40% of total exports.

- Replicates: 3 ⇒ 3 trucks can enter the export gate at the same time.

Storage Bin 3 ("Queue for export trucks"):

- Capacity: infinite.

- N.B
  - This is a virtual queue to organize the flow of trucks entering the export gate.

Work Entry Point 2 ("Exp entry gate"): 

- Interarrival times (minutes):
  - Average: 4 ⇒ a customer truck enters the terminal every an average of four minutes.
  - Distribution: exponential ⇒ arrival of trucks is independent.
- √ First at start time ⇒ one truck enters the gate as the model starts running.
- Batching:
  - Fixed value: 1 ⇒ one truck arrives at a time.
  - Distribution: fixed ⇒ the batching distribution rule is fixed.

- Routing out:
  - To: “queue for exp trucks”⇒ all arriving trucks are queued for export trucks.

Clock Properties:

- Time units: minutes.
- Time format:
  - Time & day.
  - Digital.
  - HH:MM:SS.
- Days:
  - Day, week.
  - Mon, Tues, Wed.
  - Days per week: 7.
- Running time:
  - Start time each day: 00:00.
  - Duration of the day: 24:00. ⇒ working hours per day = 24 hrs/day.
- Travel time:
  - Zero.

5.3 Summary

In this chapter, the modelling and simulation approaches used in this study were discussed. The chapter proposed the pipe flow model for both the imports and the export processes of containers in the case company, followed by the analysis of its aggregated flow capacities based on the data collected from the case company. The analysis identified the stages along the pipe where bottlenecks may appear. This in turn initiated the need to develop a more detailed model that enables investigating these expected bottlenecks and the relevant impacts on the entire process. The chapter also described in detail the operational simulation model that was built to cover the logistics activities and resources, and their interaction, throughout the entire container logistics process (both flows) in the case company. The main purpose of this developed simulation model is to be a base model that reflects the company's current situation, and enables different situations to be tested and help overcome the expected problems.

The next chapter will show the results of running this base simulation model. It will include the verification and validation process of the model to ensure that it reproduces the historical data of the case company and can be considered as a reasonable, responsive and representative base simulation model on which further investigations and scenarios can be suggested.

Chapter 6

Simulation Model Validation and Verification

In the previous chapter, a detailed description of the developed simulation model was given. The next step is to verify and validate this model. Sargent (2013) and Law (2005) agreed that the more time it takes to develop numerous versions of a model, the more satisfactory the valid model would be. This chapter represents the validation and verification process of the simulation model. It shows how the model is validated and verified to ensure that it reproduces the historical data of the case company. The chapter starts with an introduction that defines model validation and model verification. Then it overviews some approaches to model validation and verification in section 2. Relating validation and verification to the model development process is presented in section 3. In section 4, various verification and validation techniques are listed. Finally, section 5 discusses the main validation techniques used in this study and how they are applied to the developed base simulation model.

6.1 Introduction

Current research indicates that simulation models play a vital role in system analysis. This noticeable increase in the use of simulation models as a tool that can help in the decision-making process and problem solving necessitates validating and verifying the model to ensure its reliability. Ensuring that models are correct is an issue that is related to model verification and validation techniques (Min et al, 2010). Model verification and validation is considered as a part of the model development process (Sargent, 2013). Researchers have presented several definitions for model validation and model verification, from which the following definitions are derived.

Model validation refers to the process by which the simulation model is assured to represent a real system as accurately as possible within the scope of its intended objectives. Model verification refers to the process by which the simulation model is assured to be reasonable and correct in accordance with its description, specifications and assumptions. Another relevant issue is model credibility. It refers to the degree to which potential users and decision makers are confident to use the model and its derived information (Sargent, 2013 and Kutluay and Winner, 2014).

6.2 Model Verification and Validation Approaches

Generally, all models can be validated (Law, 2005). However, validation is not an absolute and there is no perfect validation or verification to a model (Carson, 2002). The following section highlights some approaches of verification and validation of models as reflected by a literature survey.

Sargent (2013) proposed three decision approaches. First, the model development team decides on model validity. Second, it is the decision of the model user whether the simulation model is valid. Third, the model validity is decided by a third party.

Carson (2002) suggested a simple framework for validation and verification that starts with testing the model for face validity, then testing it over a range of input parameters, and finally compares the model's forecasts with previous performance of the real system if existing or compare the model's behaviour to its assumptions if a new system is to be designed. He also stated that there are two types of performance measures for models. Firstly, primary measures e.g. throughput, response time and work in process. The other type of performance measures is called secondary measures such as resource utilization and size of local buffers.

Min et al. (2010) developed a sophisticated knowledge-based system for the validation of complex simulation models. In this study, the simulation behaviour was classified as five types, and then a knowledge system is designed based on the domain knowledge about real system, which was used for validation task.

Rehmen and Pedersen (2012) mentioned three existing validation approaches. Firstly, confirmative validation, where observations from empirical knowledge confirm the model. Secondly, subvalidation, whereby confirmative validation of small models are used to validate larger models. Thirdly, reference validation, which can be defined as the measure of accuracy of a model benchmarked to the determined model possibility.

Dridi (2012) used different methods for validation and calibration of simulation tools. These methods include comparison of simulation results with video recording, comparing the results of the simulation model to the results of other models, and using sensitivity analysis to determine the model behavior under different input values.

According to Romero (2008), model and data conditioning can be used to incorporate system uncertainties in the simulation model, which is considered as an important step to validate models.

Liu and Yang (2005) presented a validation approach for complex system models that includes three steps; sensitivity analysis, uncertainty analysis, and output validation.

Table 6.1 shows some examples of research contributions in the area of verification and validation of simulation models and the approach followed by each one.

Year	Author(s)	Title	Approach
2009	MM Tiller	Verification and validation of physical plant models	Validation through conserved quantities during operation times throughout the system.
2006	WL Oberkampf and MF Barone	Measures of agreement between computation and experiment: validation metrics	Developing a quantitative validation metric based on confidence intervals, constructing two specific metrics, and applying them to three example problems.
2010	Fu Y, Zhan Z, Yang R	A study of model validation method for dynamic systems	The Bayesian hypothesis testing is used to quantitatively assess the quality of a multivariate dynamic system.
2006	RW Logan and CK Nitta	Comparing 10 Methods for Solution Verification, and Linking to Model Validation	Providing methods to supply the quantitative terms for solution verification error and uncertainty estimates needed for inclusion into subsequent model validation, confidence, and reliability analyses.
2009	X Jiang, R Yang, and P Barbat S,Weerappuli	Bayesian Probabilistic PCA Approach for Model Validation of Dynamic Systems	The probabilistic principal component analysis approach is developed to address multivariate correlation, data uncertainty, and dimensionality reduction.
2008	H Sarin et al.	A comprehensive metric for comparing time histories in validation of simulation models with emphasis on vehicle safety applications	Defining a comprehensive metric that summarizes the essential aspects of time history comparison that can be combined with ratings from subject matter experts to build regression-based validation models.

Table 6.1: Some examples of research contributions in the area of verification and validation of simulation models

6.3 Relating Validation and Verification to the Model Development Process

Sargent (2010, 2013) discussed two paradigms that represent this relation: the simple view and the complex view. The simplified version of the model development process includes: the problem entity which is the system to be modelled; the conceptual model which is the representation of the problem of the study in a mathematical, logical or graphical form; and the computerized model which is the computer implementation of the conceptual model. Within this framework, three phases are involved. First, the analysis and modelling phase, through which the conceptual model is developed. The computerized model is developed through the second phase, which is the computer programming and implementation phase. During the last phase, experimentation phase, experiments on the computerized model are conducted. This is illustrated by figure 6.1.

Sargent stated four steps for the verification and validation of the model. Deciding that the model is reasonable for its intended purpose is referred to as conceptual model validation. This is followed by computerized model verification, through which the correctness of the computer programming and the conceptual model implementation are guaranteed. Operational validation involves determining that the model's output has a satisfying accuracy range for its intended purpose. Finally, data validity, which means that the data used for building, evaluating, and testing the model is assured to be accurate and sufficient.

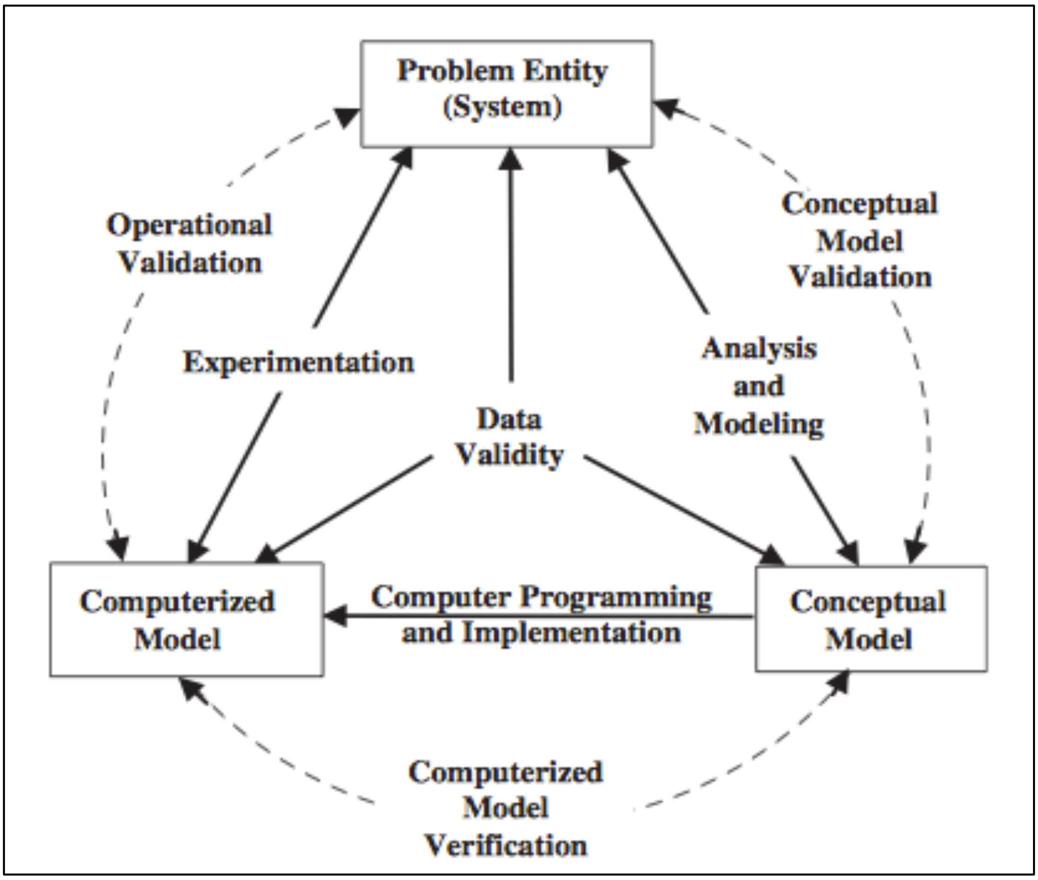


Figure 6.1: The simple view of model development process (Source: Sargent, 2010, 2013)

The complex view is more applicable on this study as it relates the validation and verification to the process of developing simulation models, which is the core of this research. The next section includes the description of the complex view and its applicability on this study.

Figure 6.2 shows the relationships between validation and verification and developing simulation models and system theories (Sargent, 2010, 2013). It shows a real world and a simulation world. The real world includes:

1. The system or problem entity in the real world that needs to be studied. In this research, it is represented by the import/export flows of containers in the case container terminal.
2. System theories that illustrate the properties or behaviour of the system. These are illustrated through the description of the entire logistics

processes, including import and export process, which take place in the terminal, as well as the related activities.

3. System data and results that can be acquired through experimenting with the system. In the study, statistical and empirical data was collected for various months to reflect several situations of the real system.

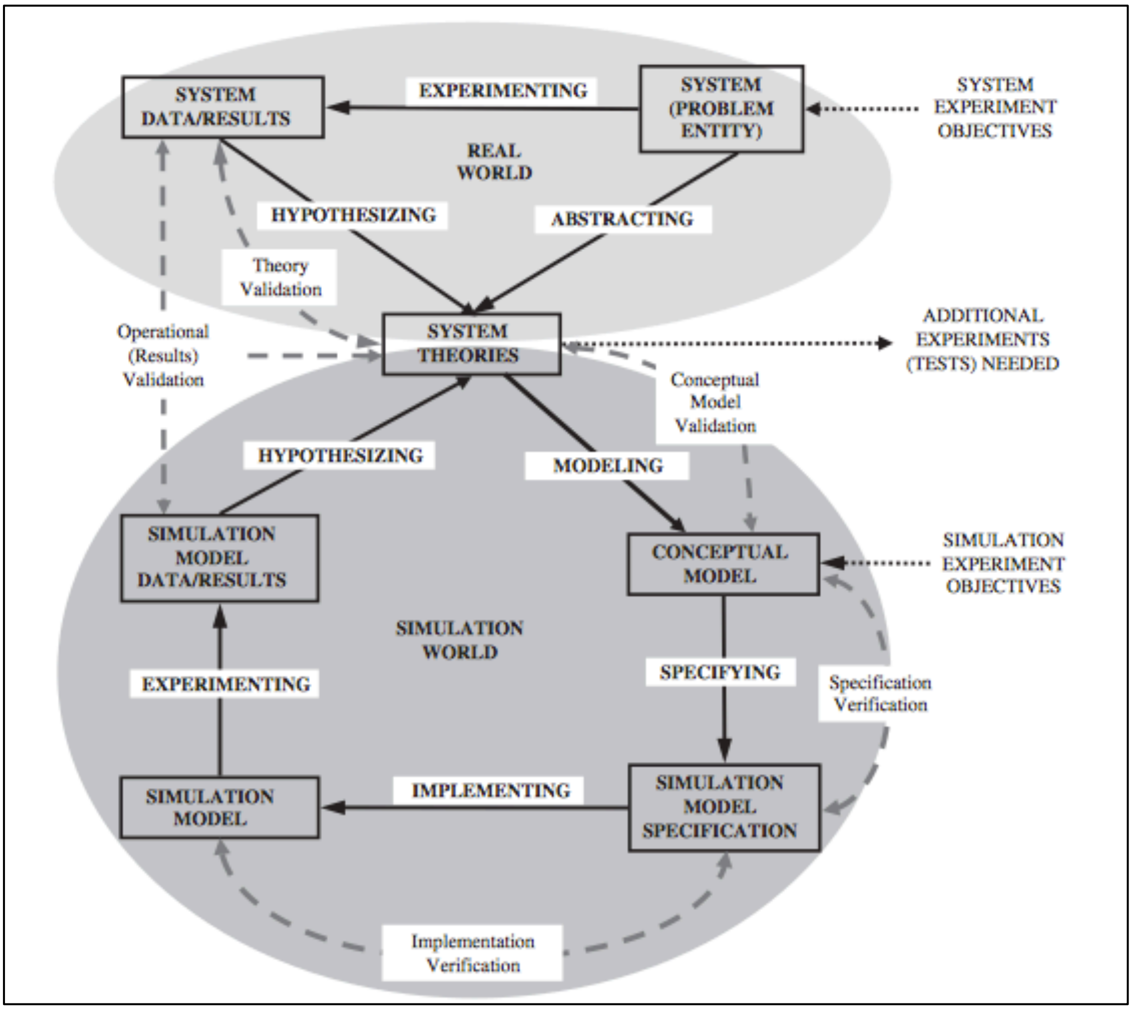


Figure 6.2: Real world and simulation world relationships with validation and verification (Source: Sargent, 2010, 2013)

Moving to the simulation world, it involves:

1. The conceptual model which is a representation of a real system developed for certain purposes. The developed operational level simulation model for the entire logistics processes is the conceptual model of this study.

2. The simulation model specification which is the written description of the software design and the implementation of the conceptual model on the computer system. The simulation model was developed using Simul8 software and a complete description for the model was explained in detail (see chapter five).
3. Simulation model data and results are the data and results obtained from conducting several trials of the simulation model. During the course of this study, multiple versions were developed to decide on the most representative, reliable, and reasonable version of the simulation model. Besides, numerous trials were conducted to obtain various output performance measures and relevant results. That is, several trials of one month were conducted to the base simulation model and their results were revealed, other trials for 12 months were conducted to assure the results of the one month trials and obtain more statistically accurate results.
4. Conceptual model validation is to ensure that the conceptual model assumptions are consistent with the system theories and the model is reasonable in accordance with its set objectives. The simulated model was mainly developed in compliance with the characteristics of the real system and the final model was generally reasonable as regards its throughput when compared to the real data.
5. Specification verification is to ensure that software and its convenience to the implementation of the conceptual model is satisfactory. Simul8 is suitable for the study and the implementation of the simulation model.
6. Implementation verification is to ensure that the simulation model was implemented in accordance with its specifications. This can be reflected

through running the developed simulation model and assuring the consistent flow during the runs.

7. Operational validation is to ensure that the model's results meet its objectives. The main objective of the model is to simulate the container flows in the terminal from entry to exit. The base simulation model reasonably achieves this objective. This base model enables different scenarios to be tested, which is considered as another objective to the model. In addition, the results of the developed simulation model are so far accurate when compared to the operational data of the company and this is the main aim of the model.

6.4 Verification and Validation Techniques

There are several techniques that can be used to validate and verify models; some of them are listed below as found in the literature (e.g. Sargent, 2010, 2013 and Dridi, 2012). This is followed by defining the main techniques that are used throughout this study and explaining how they are applied to the case study of the research.

1. Animation: where the model's objects are shown graphically as it runs over time.
2. Comparison to other models: where the model's output is compared to the output of other models such as famous empirical or analytical models or other validated models with similar characteristics.
3. Degenerate tests: where input parameters are selected to test the model's degeneracy.
4. Event validity: this technique is used to compare some occurrences of the simulation model with those of the real system to test their similarity.

5. Extreme condition tests: the design and results of the model should be reasonable for any extreme combinations of factors levels in the system.
6. Face validity: this is used to test whether the model is correct and the relation between its inputs and outputs is reasonable. This validity level is commonly used especially when validating a model is difficult because of its complexity, or in cases of limited time and money (Liu and Yang, 2005).
7. Historical data validation: whereby part of the obtained historical data is used to develop the simulation model and another part is used to test whether the model behaves like the real system.
8. Historical methods.
9. Internal validity: where multiple runs are conducted to the model to determine its internal variability.
10. Multistage validation: three stages are involved. First, to develop the model in accordance with the theory and observations. Second, to validate the model against the empirical data. Third, to compare the model's results to a real system.
11. Operational graphics: where some values are shown graphically during the model runs, i.e. a visual display of performance indicators while running the simulation.
12. Predictive validation: comparing the system's behaviour to the model's prediction to test their similarity.
13. Traces: determining whether the model's logic is accurate by using the model to trace the behaviour of a certain object.
14. Turing tests: asking experienced persons (i.e. those who know about the operations of the system that is being modelled) if they can distinguish between the system and the model outputs.

15. Parameter variability – sensitivity analysis: this technique is used to show the impact of changing the value of an input or parameter of a model on the model's output or result. This technique can be used to verify qualitative (output directions) and quantitative outputs (output directions and values). These sensitive parameters significantly affect the model's output. This also leads to the scenario analysis stage where the sensitivity analysis is tested for each suggested scenario. Law (2005) gave some examples of the factors that can be tested using this technique like the value of a parameter and the entity moving through the simulated system. He mentioned that a simulation model can be considered valid if its results are as close as possible to the actual system. The process of comparing these outputs is referred to as results validation.

    Sensitivity analysis is the study of how can the uncertainty in the inputs of a model affect the uncertainty in its outputs. It can be valuable for some purposes such as (Wikipedia, 2015):

    - Testing the robustness of the results of a model's results under uncertainty.
    - Better understanding of the inputs/outputs relations in the model.
    - Providing credible and compelling recommendations to decision makers.
    - Model simplification by removing redundant parts of the model or parts that are not significant to the results of the model.
    - Identifying significant input factors that can maximize, minimize, or optimize the model output.

In addition, other validation techniques are shown in table 6.2. They are categorized under four main categories as classified by Hu et al. (2001).

6.5 Validation Techniques Applied to the Developed Simulation Model

The next section shows how the base simulation model developed in this study is verified and validated. It identifies the main techniques used and explains how they are applied to the simulated model.

6.5.1 Animation

The developed simulation model is mainly a graphical representation of a real system (see figures 6.3 and 6.4). While running the simulation model, all its objects are shown graphically over the run time. This includes resources, equipment, and relevant queues.

6.5.2 Event Validity

This technique was used to validate the model in terms of comparing some occurrences of the model with the real system to assure their similarity. Starting from the flow of containers, related activities, and sequence of stages from entry to exit for both imports and exports. Also the available number of equipment in each stage was considered i.e. total available quay cranes, yard cranes, tractors, and lifters. Moreover, capacities of yards (general imports, exports, and shared) are checked for similarity.

6.5.3 Face Validity

The model was validated to assure that it is correct and the relation between its inputs and outputs is reasonable. For example, the number of completed exported containers (i.e. exported containers handled and loaded aboard vessels via terminal berths) is reasonable when compared to the number of exported containers entered the terminal.

Verification and validation			
Informal	**Static**	**Dynamic**	**Formal**

Audit
Desk checking
Face validation
Inspections
Reviews
Walkthroughs
	Cause-effect graphing
	Control analysis
	  Calling structure
	  Concurrent process
	  Control flow
	  State transition
	Data analysis
	  Data dependency
	  Data flow
	Fault/failure analysis
	Interface analysis
	  Model interface
	  User interface
	Semantic analysis
	Structural analysis
	Symbolic evaluation
	Syntax analysis
	Traceability assessment
		Acceptance testing
		Alpha testing
		Assertion checking
		Beta testing
		Bottom-up testing
		Comparison testing
		Compliance testing
		  Authorization
		  Performance
		  Security
		  Standards
		Debugging
		Execution testing
		  Monitoring
		  Profiling
		  Tracing
		Fault/failure insertion testing
		Field testing
		Functional testing
		Graphical comparisons
		Interface testing
		  Data
		  Model
		  User
		Object flow testing
		Partition testing
		Predictive validation
		Product testing
		Regression testing
		Sensitivity analysis
		Special input testing
		Statistical techniques
		Structural (white-box)
		  Branch
		  Condition
		  Data flow
		  Loop
		  Path
		  Statement
		Submodel/Module testing
		Symbolic debugging
		Top-down testing
		Visualization/animation
			Induction
			Inference
			Logical deduction
			Inductive assertions
			Lambda calculus
			Predicate calculus
			Predicate transformation
			Proof of correctness

Table 6.2: Taxonomy of verification and validation techniques (Source: Hu et al, 2001)

Another illustration that ensures a reasonable input - output relationship of the model is reflected by the maximum use of yards during the runs, where the results of the maximum numbers of containers handled by yards do not exceed their maximum capacities that were set as input parameters to the model.

6.5.4 Historical Data Validation of the Simulation Model

In order to validate the simulation model, two runs were conducted; one of them was conducted for a period of approximately one month, which is considered as a short results collection period but it was conducted to verify the company's available monthly data to the model results. A snapshot for the results of running the base simulation model for one short run is shown in figure 6.3. Another run was conducted for a period of about eight months as a longer and accepted results collection period for the simulation model. A snapshot for the results of running the base simulation model for one long run is shown in figure 6.4. The purpose of that is to compare the model results with the collected data form the case company to verify the extent to which the model represents the real system. Parameters of the "results collection period" and "warm up period" as entered in the simulation model are as follows:

- Results collection period:
    - Short results collection period of 41000 minutes equivalent to four weeks (24*60*4*7).
    - Accepted results collection period of 322500 minutes equivalent to 32 weeks (1440*32*7).
- Warm up period:
    - 20160 ⇒ 14 days, which is the most reasonable period that Simul8 should ignore before conducting the results to avoid starting from zero.

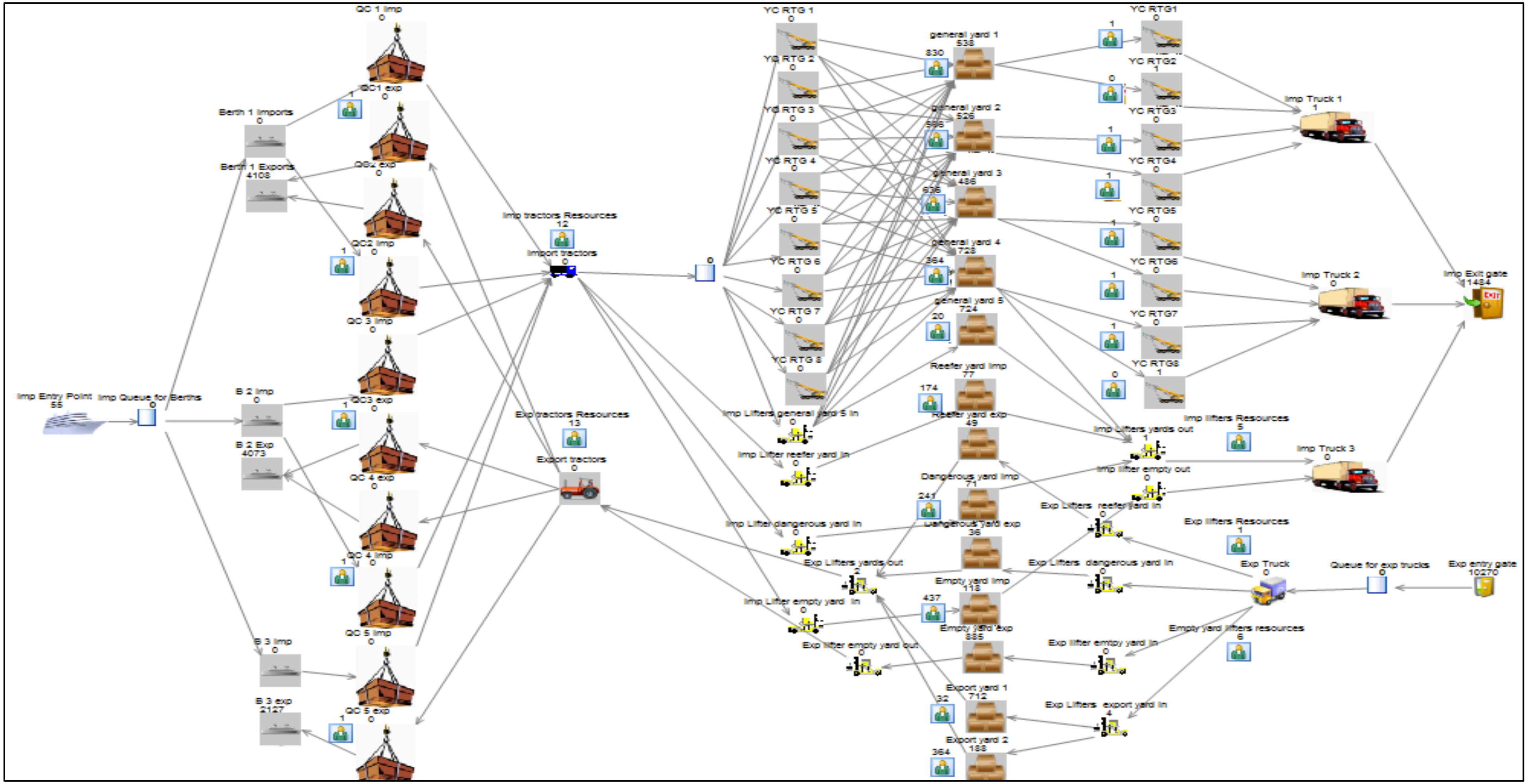


Figure 6.3: A snapshot for the results of one short run under the base model

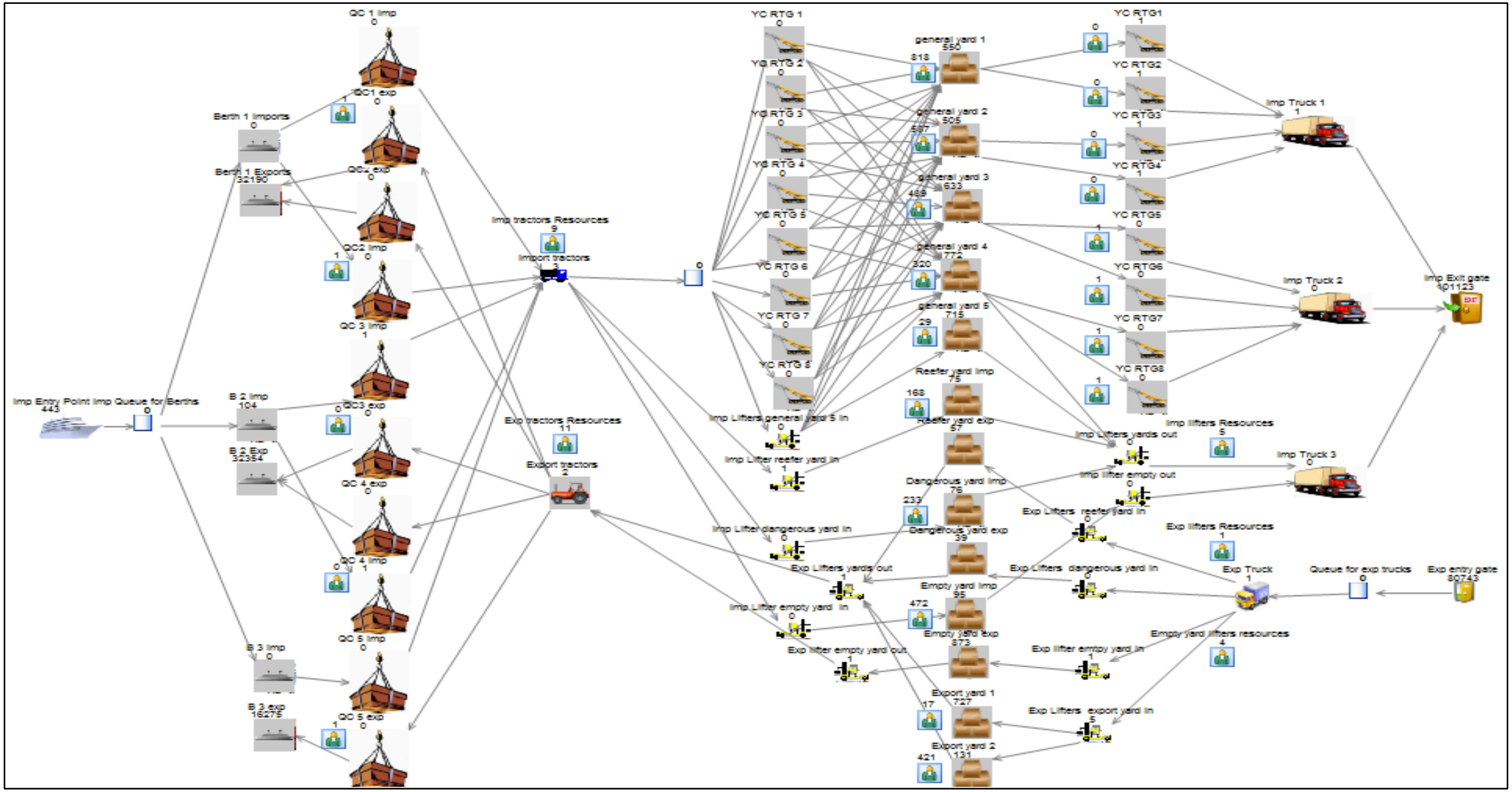


Figure 6.4: A snapshot for the results of one long run under the base model

6.5.4.1 Validation of the Main Performance Measures

The main performance measures are those that are included as the most important measures in the company's monthly report to its board of directors. This mainly covers the throughput of imported and exported containers.

Table 6.3 illustrates the main performance measures conducted from two runs for the base simulation model (one run with a short results collection period for one month and one run for a long results collection period for eight months). As shown in the table, most of the performance measures resulting from the simulation model are very close to the real data of the case company which implies that the model is reasonable, representative, and can be reliable for further investigation. For instance, the model results regarding the number of entered vessels are 55 vessels in the short run and 443 vessels in the long run (equivalent to 55 vessels per month). The number of handled imported containers equals 11500 boxes during the short run and 101000 boxes in the long run, which is equivalent to 12000 boxes per month. The historical data of the company shows an average number of 55 – 60 vessels entering the terminal monthly with an average number of imported containers of about 11000 boxes. The same illustration applies to exports.

Considering the time factor, the results show that every imported container stays an average of 13000 minutes in the system under both runs and each exported container takes an average of 7500 minutes from entry to exit. These results match the empirical data of the average dwell time of containers in the company. This means that the model gives similar results compared to the real data and is able to reproduce its historical data. Note that all the performance measures (column 1) represent the output data (results of the runs) in columns 3 & 4), for which the input data is also expressed in the tables (column 2).

Main Performance Measure	Input data	1 run (short RCP = 1 month) Figure 6.3	1 run (RCP = 8 months) Figure 6.4	Company's Real Data
Imports entry Number completed	Batching value distribution, dwell time distribution, and yard capacities	11500 containers	101000 (About 12000/month)	Average monthly imports 17000 TEUs (equivalent to 11000 boxes)
Imports exit gate. Number completed	Interarrival times of vessels	55 vessels	443 (About 55/month)	Average number of vessels per month = 55-60
Imports exit gate. Average time in System	Travel times of equipment and dwell time distribution	13000 minutes/container	13500 (About 9.5 days)	Average dwell time for imports = 9-12 days
Export entry Number entered	Interarrival times of vessels	10300 containers	81000 (About 10100/month)	
Berth 1 exports Average time	Travel times of equipment and dwell time distribution	7400 minutes	7600 (About 5.5 days)	Average dwell time for exports = 5-8 days
Number Completed	Dwell time distribution, and yard capacities	4100 containers	32000 (About 4000/month)	
Berth 2 exports Average time	Travel times of equipment and dwell time distribution	7500 minutes	7600	
Number Completed	Dwell time distribution, and yard capacities	4100 containers	32000 (About 4000/month)	
Berth 3 exports Average time	Travel times of equipment and dwell time distribution	7800 minutes	7600	
Number Completed	Dwell time distribution, and yard capacities	2100 containers	16000 (About 2000/month)	
Total exports Number completed	Dwell time distribution, and yard capacities	10200 containers	80000 (About 10000/month)	Average monthly exports = 16000 TEUs (equivalent to 10000 boxes)

All numbers are rounded

Table 6.3: Historical data validation of the main performance measures of the simulation model

6.5.4.2 Validation of Resources' Performance Measures

Another set of performance measures is also validated. These are relative to the resources included in the simulation model in terms of the handling equipment (quay cranes, yard cranes, tractors, and lifters) and the storage yards. The validation of resources' performance measures is summarized in table 6.4. The table shows the results of one short run (with a short collection period) and the historical data for the resources' performance measures. The utilization percentages of equipment reveal credible results. To illustrate this, results show that the average utilization percentage per yard crane ranges between 50 - 55%, whereas the company's records indicate about 58% utilization for yard cranes.

As regards any of the mixed (shared) yards, for example, the dangerous yard's result shows a utilization percentage of about 30% over the run total time. It also shows an output of about 450 containers. This accounts for about 2% as its share from the total throughput of containers (450 containers out of a total throughput of about 21700 containers). The historical data recorded that the share of dangerous yards equals to 2.1%. Also the same applies for the rest of yards, and accordingly validates the simulation model.

6.5.5 Internal Validity

This technique implies conducting several runs to the model to validate it. As mentioned in the previous technique, numerous runs were conducted to the model to firstly decide on the final accepted version for the base model and then to validate it. These runs included short collection period runs, long collection period runs, and trials of several runs in some cases.

Performance Measure	Input data	1 short run (RCP = 1 month) Figure 6.3	1 long run Figure 6.4	Company's Real Data
Utilization % of quay cranes	Travel time and distribution settings	5 quay cranes are utilized, each working an average of 20% - 35%	20%- 30%	5 quay cranes, average daily working hours of QC = 13 working hrs/day, i.e. 54%
Utilization % of yard cranes	Travel time and distribution settings	8 yards are utilized for imports, each working an average of 50% - 55%	45%-65%	8 yard cranes, average daily working hours of YC = 14 working hrs/day, i.e. 58%
Number of tractors	Travel time and distribution settings	25 tractors are utilized, 12 for imports and 13 for exports	25 tractors are utilized	25 tractors
Utilization % of lifters	Travel time and distribution settings	19 lifters are utilized, 6 for imports, 7 for exports and 6 for empty. Each working an average of 40% - 55%	43%- 53%	19 lifters divided as 13 heavy and 6 empty, average daily working hours of lifters = 12 working hrs/day, i.e. 50%
Utilization % of yard space General import yards	Capacities of yards, dwell time distribution, and routing out of previous work centers	40% - 98%	47% - 97%	
Export yards		40% - 99%	32% - 99%	
Empty yard		70% - 75% utilization, 27% of total handled containers About 5500 containers.	72%	28% of total handled TEUs
Reefer yard		45% - 55% utilization, 2.65% of total handled containers About 580 containers.	49%	2.7% of total handled TEUs
Dangerous yard		30% - 35% utilization, 2% of total handled containers About 450 containers.	34%	2.1% of total handled TEUs

All numbers are on average

Table 6.4: Historical data validation of the resources' performance measures of the simulation model

6.5.6 Multistage Validation

The three stages of this technique were followed in this study, whereby the model was developed in accordance with the collected data then it was validated against the company's empirical statistics, and finally its results were compared to the actual system.

6.5.7 Operational Graphics

As shown in figures 6.3 and 6.4, most of the results are displayed while the model is running such as the number of entering vessels, number of entering and leaving exported containers, number of imported handled containers, and number of containers currently in yards. All these values are visually displayed during the model runs.

6.5.8 Sensitivity Analysis

In the developed base simulation model, various kinds of sensitivity can be tested, i.e. sensitivity in system analysis to ensure that the model is reasonable, sensitive and responsive to changes. Some examples are as follows:

- The impact of increasing the number of entering vessels (as an input parameter), on the throughput of containers (an output of the model).
- The impact of increasing the numbers of handled containers (as another input parameter), on the yard utilization percentages.
- The impact of handling more containers, either imports or exports, on the utilization percentages of equipment.
- The impact of adding more equipment on the utilization percentages.

- The impact of reducing dwell time on the utilization percentages of storage yards.

6.6 Summary

This chapter has represented the verification and validation process for the base simulation model. It highlighted some validation approaches reviewed in the literature, and addressed the various validation techniques found. The chapter then discussed how the main techniques were used to validate the developed base simulation model. It focused on the historical data validation of the model through conducting runs, with different lengths, to the model to achieve the objective of validating a reasonable, reliable, sensitive and responsive base simulation model. The chapter ended by identifying some examples of sensitivity tests. This guides the selection of a few scenarios to be examined in order to enable these sensitivity tests to be measured.

The next two chapters will apply the suggested scenarios to the base simulation model. This involves adopting some changes to the base model, measuring the effect of such changes on the entire system, and interpreting their results in an attempt to offer decision makers potential tools for improvement and better performance.

Chapter 7

Scenario Analysis

After building and validating the base simulation operational model, scenarios are suggested for improving the terminal's performance. Every scenario addresses a certain change to the model parameters to test its impact on the overall process through analyzing its results. This chapter deals with the first scenario (scenario "1") of the study that represents an efficiency change to the model. The chapter starts with an introduction followed by an explanation of the scenario and the change it suggests, then a representation of its results including the results' analysis and its interpretation. It ends with some concluding remarks on scenario "1".

7.1 Introduction

As discussed in earlier chapters, the interviews conducted in the case company to collect data as well as the proposed pipe flow model revealed that one of the main problems that is facing the case company is the lack of storage yard space. This leads to congestion in the storage yards. Scenario "1" attempts to provide a potential solution for this problem.

Since customs clearance procedures take place in the storage yards, this lengthens the stay of containers in yards. This stay of containers in the storage yards is referred to as "dwell time". In general, dwell time can be influenced by a number of factors such as:

- Time for documents to be linked with customs.
- Time for import licenses to be issued.

- Time for documents to be processed by customs.
- Time for customs to inspect the contents of containers.
- Time for the consignee to be contacted.
- Time for consignee to organize transport.
- Time spent awaiting arrival of transport.
- For export, consolidation, marshalling and time waiting document clearance.

According to UNCTAD (2012), dwell times range from four to seven days depending on the port, the type of container (import or export) and the mode of transport the container uses to enter or leave the port. The target average time in most terminals is three or four days with most terminals allowing importers this time until storage charges are initiated. In practice typical averages of between five and seven days are usually considered reasonable (Container Port Conference, 2003). Dwell time in ports is normally somewhat less in the case of export containers than for import containers.

As an example, the Gioia Tauro terminal is experiencing high congestion of the yard (utilization of about 90%) due to a lengthening of the average dwell time, which is currently 8 days (Vacca et al, 2007).

Dwell time is inversely proportional to capacity (UNCTAD, 2012). This means that if average dwell time is reduced, yard capacity is likely to increase. In the case study of this research, the average dwell time for imports ranges from nine to twelve days and the dwell time for exports ranges from five to six days. This is considered a relatively long time that can be reduced to increase the yard capacity and avoid congestion of yards. Besides, dwell time is considered as one of the main performance measures that are represented in the monthly report of the company issued to its board of directors. This means that dwell time is a key to decision-making process in the company. Therefore, any change in the strategy of this performance measure can have its impact on the overall performance of the company and can give managerial insights for better improvements. Thus, scenario “1” handles the suggestion of reducing dwell time and tests its impact on the whole simulation model.

7.2 Scenario “1”: Reducing Dwell Time by 30%

Generally, the dwell time in the entire logistics processes of the company is grouped into three categories: dwell time for imports, dwell time for exports and dwell time for empty containers. Each of these categories is classified into eight classes that range from one or two days to more than twenty days. These classes of dwell time are determined and collected among the data of the case company.

Due to the high importance of dwell time as a key performance measure, scenario “1” suggests a decrease in the dwell time by 30%. This is a suggested percentage to represent a reasonable change in the number of days of each class in order to match the typical averages, which are considered reasonable as previously mentioned. A lower percentage implies a very slight change in the number of days (in some classes, the difference may be less than half a day) and consequently would not have a significant result, whereas a higher percentage is unreasonable and difficult to implement. This scenario aims to test the impact of this change in dwell time on the overall performance of the logistics process.

The table below (table 7.1) shows the categories of the dwell time as determined by the case company in the first column; under each category the percentage share of each class in terms of the total number of containers handled is given. The second column represents the number of days of each class that is applied in the base simulation model. The third column shows the change as suggested by scenario “1” after reducing the number of days of each class by 30%. To illustrate this more, the first category is dwell time for imports, under this category there are eight classes, the first one is 31% with corresponding number of days of 2-5 days under the base model and 2-3.5 days under scenario “1”, this means that 31% of the total imports stay from 2 to 5 days in the yard as a current practice. Scenario “1” suggests reducing this duration by 30% to be from 2 to maximum 3.5 days rather than 5 days. This illustration is applied to all the following classes of each category.

Dwell time category	Number of days under base model (in days)	Scenario “1” (30% decrease in dwell time) (in days)
Imports		
31%	2-5	2-3.5
7%	6	4
6%	7	5
4%	8	5.5
5%	9	6
5%	10	7
29%	11-20 (16 days)	11
13%	More than 20 (22 days)	15
Exports		
64.5%	1-5	2-3.5
12%	6	4
8%	7	5
5%	8	5.5
3%	9	6
2%	10	7
5%	11-20 (16 days)	11
0.5%	More than 20 (22 days)	15
Empty		
65%	1-5	2-3.5
6%	6	4
5%	7	5
3%	8	5.5
2%	9	6
1%	10	7
10%	11-20 (16 days)	11
8%	More than 20 (22 days)	15

Table 7.1: Dwell time categories under the base model and scenario “1”

7.3 Scenario “1” Results and Analysis

A trial of 12 runs was conducted to the base simulation model and another trial was conducted for the model under the settings of scenario”1”. As mentioned in earlier chapters, each run is set for a results collection period of about one month i.e. the total time per run is 41000 minutes. Also a warm up time of about two weeks is included in the run (about 20000 minutes), which is a reasonable period according to the average total time in system of a container from entry to exit. The clock runs 24 hours a day, 7 days a week. The results of both trials were displayed, filtered, summarized, and presented in the forms of tables and graphs to facilitate their interpretations. These results include the main performance measures relative to the overall time and throughput of both imports and exports such as:

- Imp exit gate average time in system: average time of the process of an imported container since the vessel enters the terminal till the container leaves the terminal gate. This result is displayed in minutes.
- B1 exp average time in system: average time of the process of an exported container leaving from berth 1. The same applies for berth 2 (B2) and berth 3 (B3). This result is displayed in minutes.
- Imp entry point number entered: the number of vessels entered the system during the whole run.
- Exp entry point number entered: the number of exported containers entered the system during the whole run.
- Imp exit gate number completed: the total number of imported containers handled during the run (imports throughput).
- B1 exp number completed: the total number of exported containers handled during the run via berth 1 (exports throughput). The same applies for berth 2 (B2) and berth 3 (B3).

Other performance measures reflect the utilization percentages of the different resources as equipment and yards. For each yard (import, export, and shared), the following can be shown:

- Number completed: the total number of containers handled by the yard.
- Utilization %: this shows the overall percent utilization of a particular resource, i.e. the percentage of the yard's occupancy over the total time of

the run. This percentage is automatically calculated by Simul8 software.

- Maximum use: the maximum number of containers stored in the yard during the run.

On the other hand, equipment includes quay cranes, yard cranes, lifters and tractors:

- For all cranes, number of containers handled and the utilization percentage over time of each crane can be displayed.
- For pools of lifters and tractors (grouped as a pool for imports and a pool for exports), the utilization percentage over time, the average use and the maximum use of each pool can be presented.

The following sections address the main results of the trials conducted under the base model and under scenario “1” and present the analysis and interpretation of these results. Some results are presented as an average of all the runs if the individual runs’ results are similar. A sample of the detailed results of one trial will be attached to the appendices.

7.3.1 Results Relative to the Total Time in System

The most significant change is represented in the total time of the entire process where the average time in system for imports decreased from about 13000 minutes (about 9 days) under the base model to about 9500 minutes (about 6.5 days) under scenario “1”. The average time in system for exports also has decreased from about 7500 minutes (about 5 days) under the base model to about 5500 minutes (about 4 days) under scenario “1”, as shown in figure 7.1. This reflects that the model is generally reasonable, sensitive and responsive to changes, i.e. by decreasing the dwell time (which represents the longest time in the whole process), the total time of the entire process decreases which is reasonable.

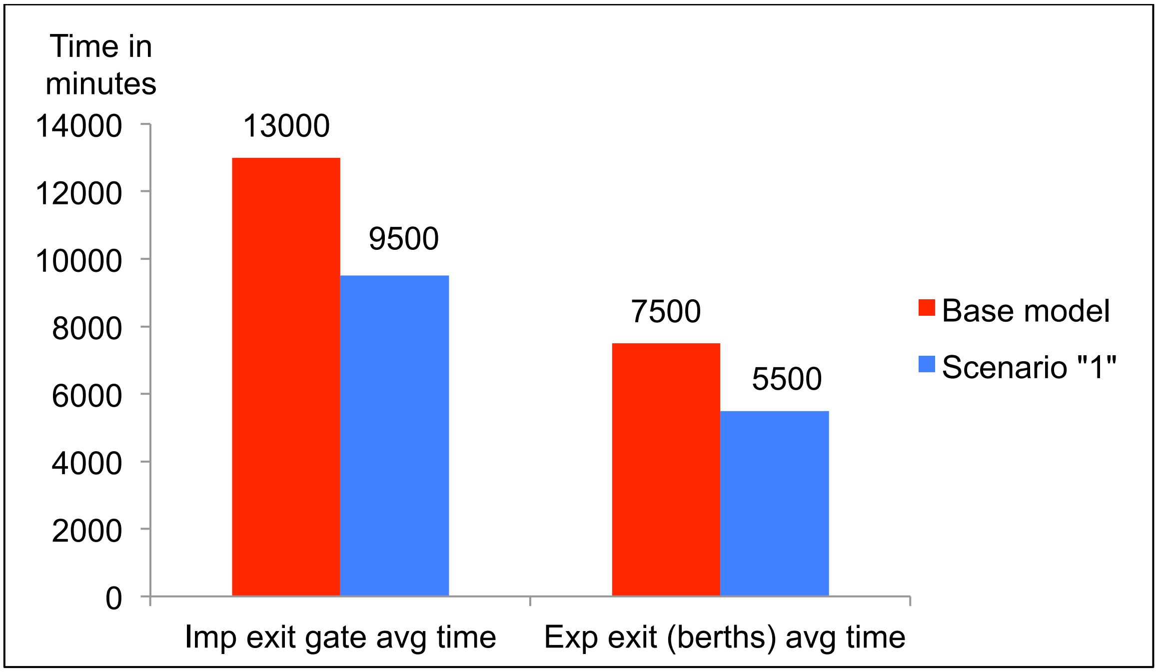


Figure 7.1: Results of average time in system for imports and exports for a trial of 12 runs

7.3.2 Results Relative to the Throughput

As regards the total throughput of the entire process (either imports or exports), the following tables compare the total number of imports and exports handled for 12 runs under the base model and scenario “1”. It is shown that there is a slight increase in imports whereas for exports, almost very close numbers of containers can be handled given the reduced time in system under scenario “1” which implies that more containers can be handled for the same time of the base model but under the settings of scenario “1”. This seems logical since the current system is stable, so that reducing dwell time should not significantly increase the throughput of imports or exports. Results relative to throughput are displayed in tables 7.2 for the base model and 7.3 for scenario “1”. The first row of the table shows the number of vessels that entered the system during each run of the trial. Note that almost the same numbers of vessels are displayed under the base model and under scenario “1”. The second row of the table represents the total number of imported containers handled through each run of the trial. The results of this row show slight variations between the base model and scenario “1”. The following row indicates the total number of exported containers that entered the system in each run, the results here are constant in the two tables. This is followed by three consecutive rows to show the total numbers of exported containers that actually left the system through the three berths of the terminal. The results of the three berths reveal minor changes form the base model to scenario “1”.

Performance Measure	1	2	3	4	5	6	7	8	9	10	11	12
Imp Entry Point No. Entered (vessels)	55	56	57	55	55	58	56	59	59	57	61	59
Imp Exit gate No. Completed (containers)	11484	13255	12834	14602	12744	13367	11775	12396	12541	12406	11607	12283
Exp entry gate No. Entered (containers)	10270	10290	10169	10174	10215	10201	10222	10275	10210	10123	10209	10189
B2 Exp No. completed (containers)	4073	4176	4091	4112	4119	4011	4118	4041	4085	3982	4089	3999
B3 Exp No. completed (containers)	2127	2001	2033	2043	2054	2018	2034	2002	1996	2006	2022	2033
B1 Exp No. completed (containers)	4108	4030	4066	4078	4079	4141	4037	4125	4082	3978	4086	4028

Table 7.2: Total throughput of imports and exports under the base model for a trial of 12 runs

Performance Measure	1	2	3	4	5	6	7	8	9	10	11	12
Imp Entry Point No. Entered	55	56	57	55	55	58	56	59	59	57	61	59
Imp Exit gate No. Completed	11771	13587	13504	15085	13152	13291	12321	12538	12752	12471	11796	12711
Exp entry gate No. Entered	10270	10290	10169	10174	10215	10201	10222	10275	10210	10123	10209	10189
B2 Exp No. completed	4069	4178	4125	4112	4089	4056	4109	4046	4123	4023	4116	4040
B3 Exp No. completed	2150	2011	2048	2051	2053	2002	2032	2030	2020	2038	2014	2065
B1 Exp No. completed	4136	4024	4113	4100	4118	4168	4064	4157	4117	4013	4098	4069

Table 7.3: Total throughput of imports and exports under scenario “1” for a trial of 12 runs

7.3.3 Results Relative to Resources

Results relative to the available resources can be divided into two groups; results relative to the storage yards (import general yards, export yards, and shared yards), and results relative to the equipment that are also classified into cranes (either quay cranes or yard cranes RTGs), lifters (imports, exports, and empty) and tractors (imports and exports).

7.3.3.1 Yards' Results

As regards general import yards, the following figures show the graphical representation of results of the five general import yards under the base model and under scenario "1". The figures give a general overview of the pattern of general import yards during the run of the simulation model. They show that yards can be relaxed by reducing dwell time, especially the most congested yards (general import yard 5, general import yard 4, and general import yard 3). This is indicated by the number of work items in relation to time during the whole run. The time on the horizontal axis represents the run time whereas the work on the vertical axis represents the number of handled containers. The difference between the graphs of the base model and those of scenario "1" appears in the number of work items (vertical axis), which means that the number of containers being handled at the same time is reduced due to reducing the dwell time because containers do not stay in the yards for too long under scenario "1" which helps relaxing congestion in import yards. This congestion results when the maximum yard capacity is reached as the case in general import yards 3, 4, and 5 as shown in the figures 7.2 to 7.6.

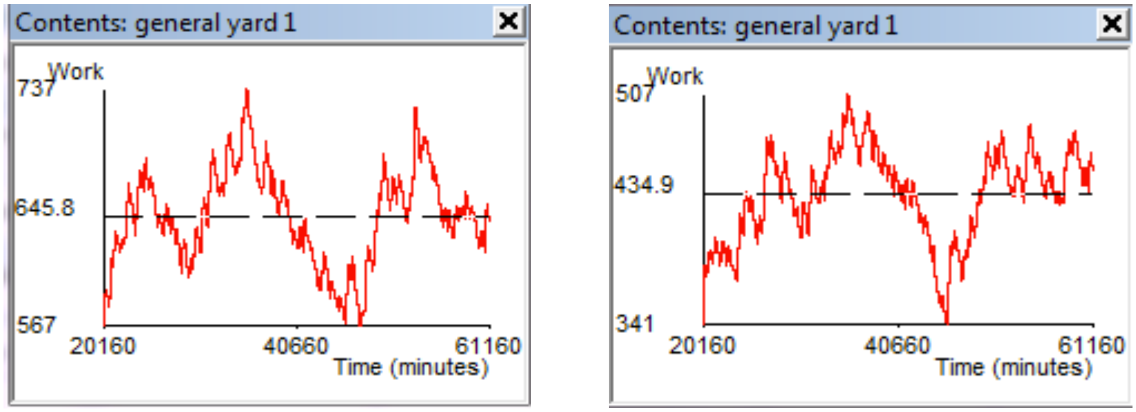


Figure 7.2: Graph results of general import yard 1 under the base model and scenario “1”

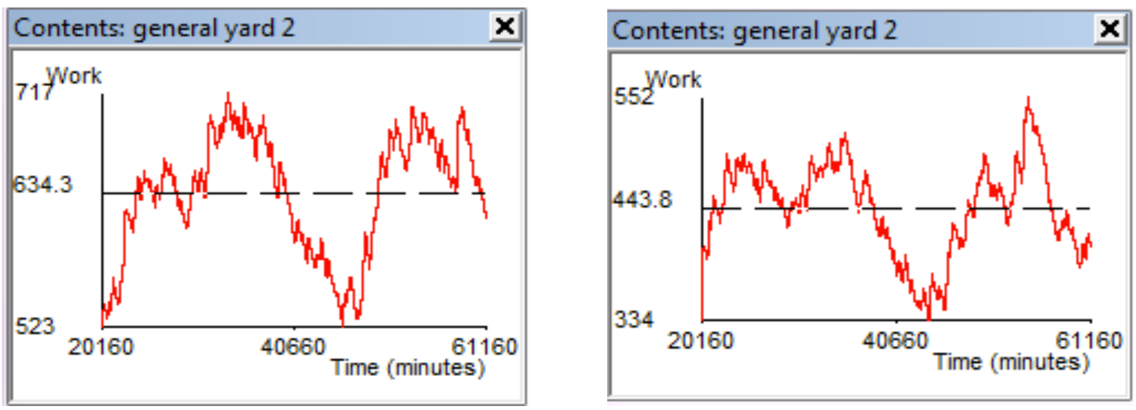


Figure 7.3: Graph results of general import yard 2 under the base model and scenario “1”

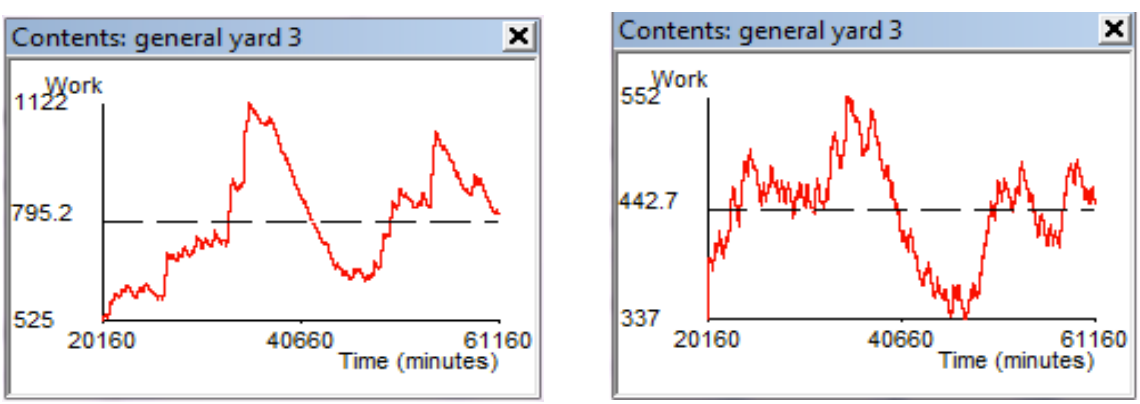


Figure 7.4: Graph results of general import yard 3 under the base model and scenario “1”

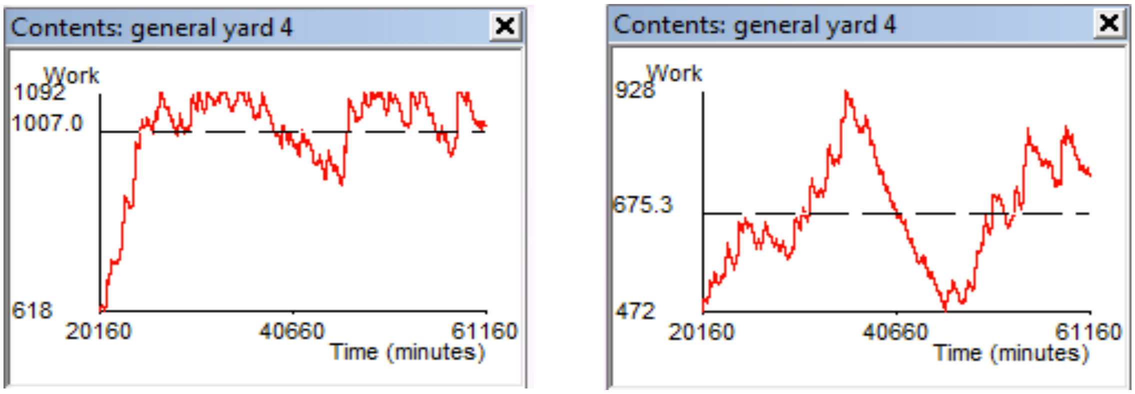


Figure 7.5: Graph results of general import yard 4 under the base model and scenario “1”

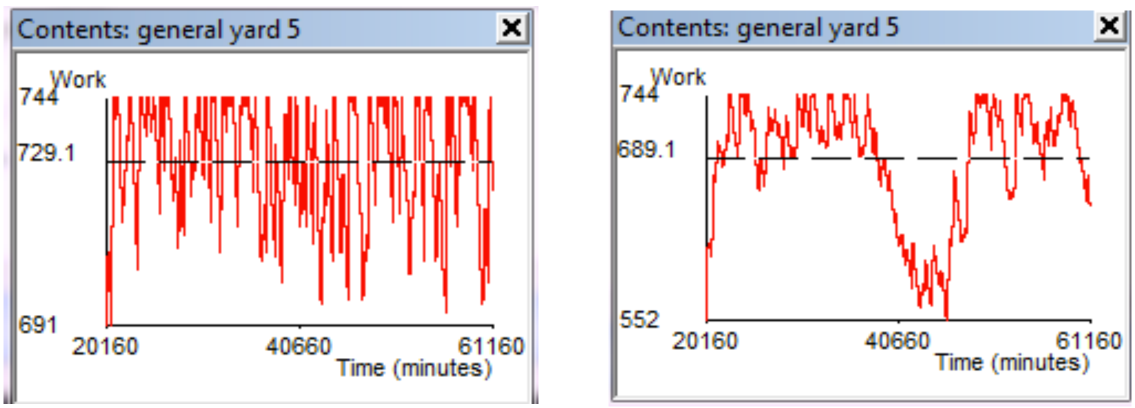


Figure 7.6: Graph results of general import yard 5 under the base model and scenario “1”

For instance, under the base model (the left side graph), the most congested yard in this run is general import yard 5 where the maximum capacity (744 containers) is reached during most of the run time. The same yard under scenario “1” is relatively less congested (the right side graph), although the maximum capacity is reached as well but only in some situations. This can be also revealed from the average use which decreases by about 6% from 730 containers under the base model to 690 containers under scenario “1”. This is followed by general import yard 4 which also reached its maximum capacity (1092 containers) during most of the run time, but this number is reduced by 15% to reach 928 containers under scenario “1” as shown in figure 7.5. Also general import yards 3 (figure 7.4), under the base model, is considered congested in some situations where the maximum capacity (1122 containers) is reached whereas under scenario “1” the maximum use falls to 552 containers representing a reduction of 51%. Concerning the last two import yards (1 and 2), although their maximum capacity is not reached, but they show a decrease in both the maximum use and average use as shown in figures 7.2 and 7.3.

Since all yards are utilized most of the time, the average utilization of each general import yard is shown in figure 7.7. The figure shows that reducing dwell time by 30% would generally result in reducing the average utilization percentage of general import yards by 7-30%. These average percentages are calculated based on the individual utilization percentages for each general import yard during the conducted trial of 12 runs of the simulation model.

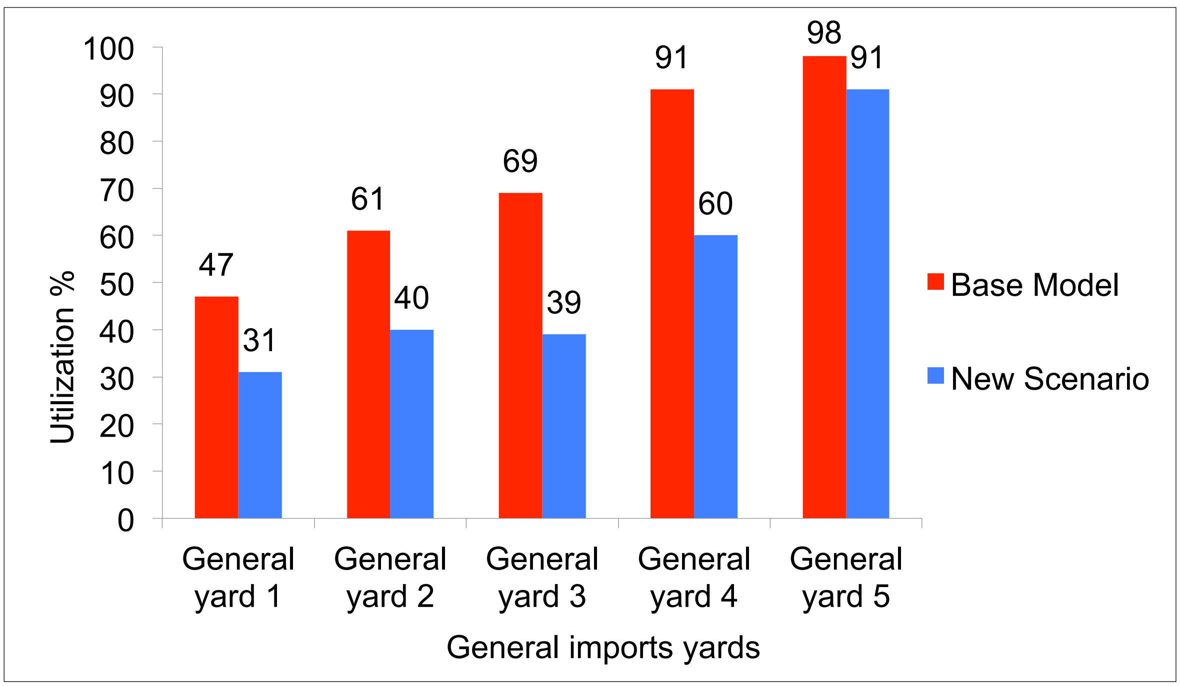


Figure 7.7: Average utilization percentages of general import yards for a trial of 12 runs

Further details of general import yards' utilization percentages as well as the numbers of handled imported containers are illustrated in tables 7.4 and 7.5, where the exact numbers of containers handled by each import yard and the relative maximum use of each yard during a trial of 12 runs of the simulation model, are represented. The tables indicate that in both cases, if a similar number of imported containers is handled under the base model and scenario "1" as by general yards 1, 2, and 3 or even if a higher number of containers is handled under scenario "1" as by general yards 4 and 5, the utilization percentage of yards decreases. For instance, general import yard 1 handled 1790 containers in the first run of the trial under the base model and the maximum use of this yard during the first run was 699 containers. Under scenario "1", the same yard handled 1757 containers with a reduced utilization percentage by 15% from 43% under the base model to 28% under scenario "1". The maximum use of the yard also decreased under scenario "1" to reach 498 containers. On the other hand, general import yard 5 handled an increased number of containers in its first run by more than 650 containers in scenario "1" than the base model. Although the maximum use of the yard was up to its maximum capacity (744 containers) in both cases, the utilization percentage falls by about 10% from 96% under the base model to 85% under scenario "1".

Performance Measure	1	2	3	4	5	6	7	8	9	10	11	12
General yard 1 (Total number of handled containers)	1790	1915	2104	2477	1904	2092	1853	1913	1943	1877	1782	1908
Utilization %	43	46	51	60	45	50	46	46	45	44	43	47
Maximum use (containers)	699	741	1097	1060	759	918	938	734	717	716	722	737
General yard 2	1829	2120	2127	2614	1967	2246	1934	1936	1876	1873	1792	1860
Utilization %	54	65	66	81	59	65	62	57	55	56	55	58
Maximum use	702	972	1092	1092	740	1092	1092	789	764	751	707	717
General yard 3	1877	2665	2392	2858	2291	2526	1989	2314	2322	2242	1857	2299
Utilization %	54	80	73	87	69	72	61	68	70	63	56	71
Maximum use	759	1122	1122	1122	1029	1122	1122	1122	1028	941	863	1122
General yard 4	2759	3099	2836	3103	3072	2966	2712	2904	3043	3066	2843	2858
Utilization %	83	95	88	96	95	90	86	90	94	93	87	92
Maximum use	1092	1092	1092	1092	1092	1092	1092	1092	1092	1092	1092	1092
General yard 5	2197	2239	2172	2186	2227	2234	2113	2232	2152	2199	2204	2196
Utilization %	96	98	98	99	98	98	97	98	98	97	97	98
Maximum use	744	744	744	744	744	744	744	744	744	744	744	744

Table 7.4: Results of general import yards under the base model for a trial of 12 runs

Performance Measure	1	2	3	4	5	6	7	8	9	10	11	12
General yard 1	1757	1988	1987	2216	1918	1907	1847	1817	1906	1842	1777	1866
Utilization %	28	33	32	36	30	31	31	30	30	30	29	32
Maximum use	498	556	611	595	561	585	594	507	575	504	569	520
General yard 2	1843	1981	2003	2164	1916	1923	1835	1895	1892	1873	1782	1916
Utilization %	37	41	41	45	39	39	39	39	38	38	38	41
Maximum use	533	561	598	617	565	589	625	525	557	553	499	540
General yard 3	1863	2026	2171	2337	1915	1996	1920	1882	1908	1857	1738	1923
Utilization %	36	40	43	47	38	39	40	38	39	36	35	40
Maximum use	525	572	843	799	542	675	735	548	576	493	525	531
General yard 4	2383	3237	3094	3812	3002	3211	2655	2784	2846	2710	2441	2861
Utilization %	47	68	65	80	61	63	58	58	57	54	50	62
Maximum use	675	1050	1092	1092	930	1092	1092	994	905	872	874	954
General yard 5	2864	3115	2994	3122	3066	2964	2845	3032	3013	3012	2915	2974
Utilization %	85	94	92	97	90	88	89	91	93	91	88	93
Maximum use	744	744	744	744	744	744	744	744	744	744	744	744

Table 7.5: Results of general import yards under scenario “1” for a trial of 12 runs

As regards the export yards, scenario “1” reveals a potentially significant result in the utilization of export yard 2. Figure 7.8 shows that under the base model, export yard 1 is fully utilized and its maximum use (744 containers) is usually reached and the average use is 740 containers which implies 99% utilization. Conversely under scenario “1”, it can be relaxed to an average use of about 680 containers and maximum use of 730 containers i.e. reducing the average use by about 8% (see figure 7.9). This means that reducing dwell time can reduce the utilization of the yards and increase its capacity at the same time as an equivalent number of exported containers can be handled under both the base model and scenario “1” given the reduced dwell time suggested in scenario “1”, i.e. in the base model export yard 1 handled an average of 4500 containers and export yard 2 handled an average of 1200 containers (an average total of 5700 containers), whereas under scenario “1” export yard 1 handled an average 5700 containers and export yard 2 did not handle any exports (an average total of 5700 containers). Since the numbers of exported handled containers are very close in all the runs, only one average is calculated. This is shown in figure 7.10.

In terms of the average utilization percentages of export yards, the base model shows an average of 34% utilization of export yard 2 which can be decreased to 0% under scenario “1”. This means that this area can be used elsewhere to optimize the overall performance of the entire process, especially in cases of peaks. Utilization percentages of yards are displayed in figure 7.11.

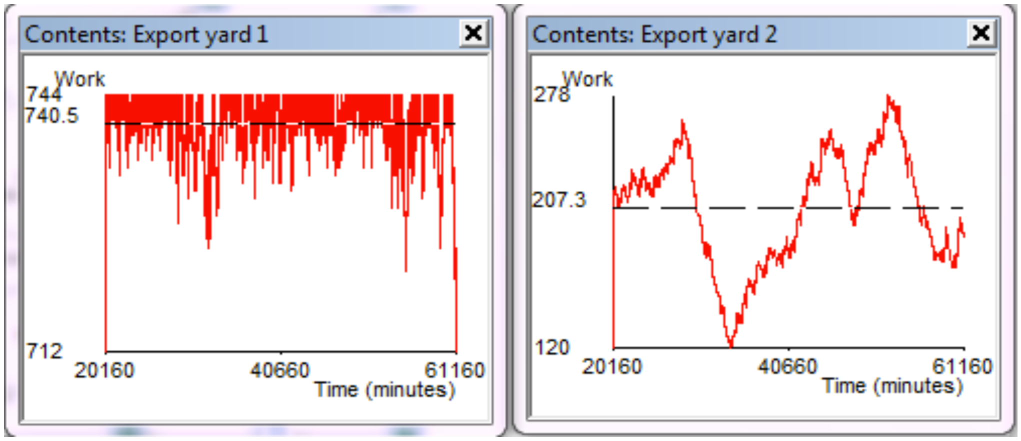


Figure 7.8: Graph results of export yards under the base model

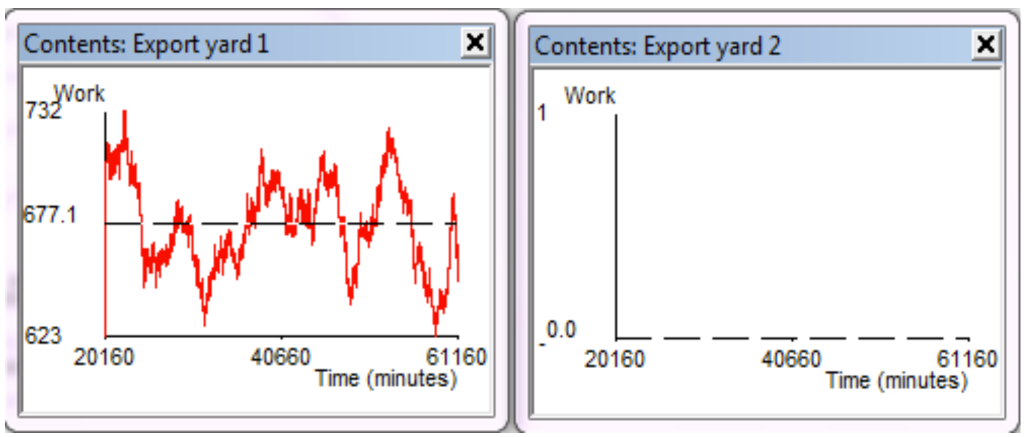


Figure 7.9: Graph results of export yards under scenario “1”

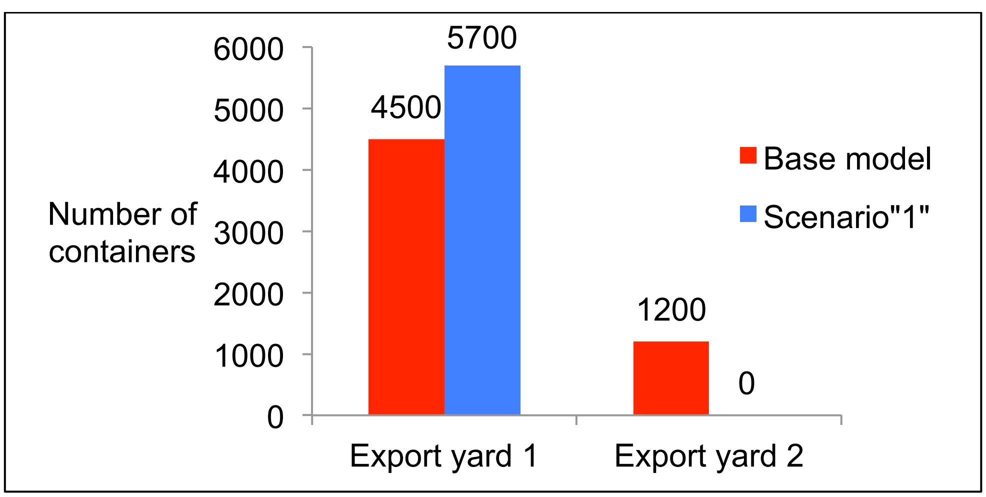


Figure 7.10: Average number of exported containers handled by export yards for a trial of 12 runs

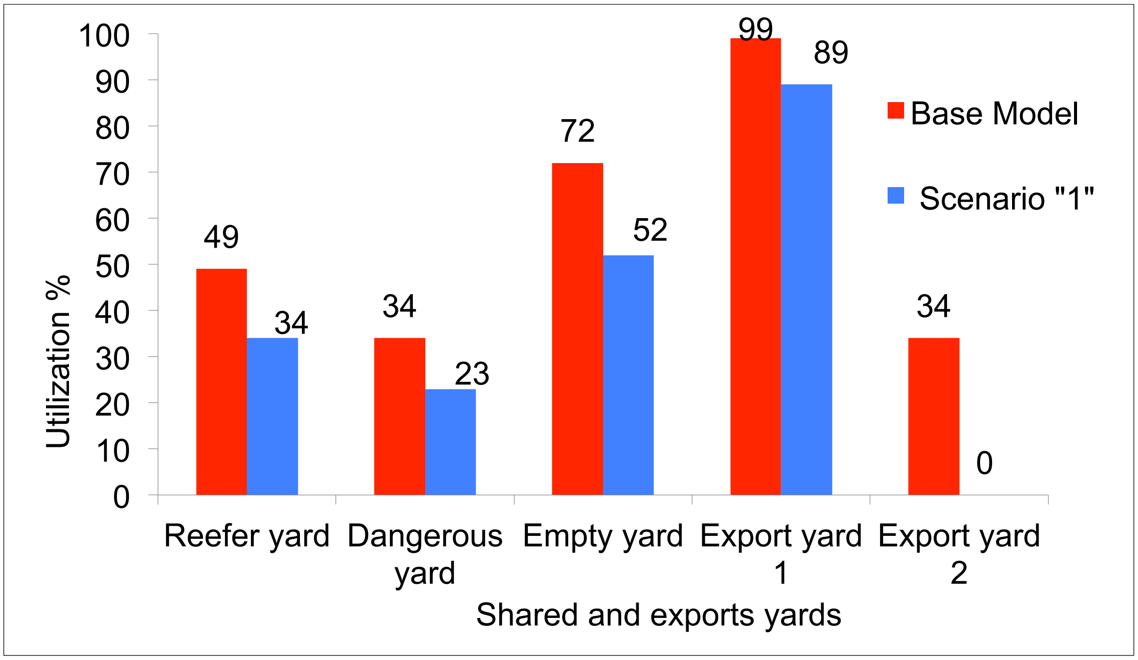


Figure 7.11: Average utilization percentage of shared yards and export yards for a trial of 12 runs

As regards the shared yards (reefer, dangerous and empty), figure 7.11 shows a decrease in the utilization percentages of the shared yards of about 10-20% on average. For instance, the reefer yard utilization decreased from 40% to 30% on average, dangerous yard utilization reduced from 30% to 20% on average and empty yard utilization decreased from 70% to 50% on average. In addition, the maximum use of shared yards revealed that by reducing the dwell time by 30% in scenario "1", the maximum use of shared yards is relaxed by about 22-26%. The results indicated that the maximum use of reefer yard (average of 12 runs) is 184 containers under the base model, a figure that is reduced to 141 containers under scenario "1" which is equivalent to a decrease of 23%. Also dangerous yard recorded a decrease in the maximum use by 22% on average from 147 containers under the base model to 114 containers under scenario "1". Whereas in empty yard, the maximum use decreased from 1136 containers to 843 containers on average, representing 26% reduction. Detailed maximum use and number of handled containers by shared yards in 12 runs are presented in tables 7.6 and 7.7.

Performance Measure	1	2	3	4	5	6	7	8	9	10	11	12
Reefer yard number completed	551	560	655	626	610	553	556	574	528	526	533	551
Reefer yard maximum use	173	173	221	198	211	182	172	182	165	174	171	173
Dangerous yard number completed	446	430	476	461	498	430	420	464	468	429	436	446
Dangerous yard maximum use	145	164	156	144	165	150	143	144	143	137	144	145
Empty yard number completed	4718	4759	4825	4752	4620	4630	4668	4604	4645	4658	4664	4718
Empty yard maximum use	1168	1109	1155	1133	1144	1162	1101	1130	1130	1144	1158	1168

Table 7.6: Results of shared yards under the base model for a trial of 12 runs

Performance Measure	1	2	3	4	5	6	7	8	9	10	11	12
Reefer yard number completed	556	547	582	674	630	597	562	571	567	526	522	540
Reefer yard maximum use	143	131	135	163	151	161	144	132	137	127	140	128
Dangerous yard number completed	441	455	441	486	472	500	444	433	471	466	444	448
Dangerous yard maximum use	104	109	120	119	108	130	120	115	111	109	112	109
Empty yard number completed	4648	4795	4846	4914	4835	4660	4709	4734	4657	4731	4742	4750
Empty yard maximum use	807	870	820	882	833	841	869	820	828	832	851	861

Table 7.7: Results of shared yards under scenario “1” for a trial of 12 runs

7.3.3.2 Equipment Results

Three kinds of equipment are involved: cranes (quay cranes and yard cranes), lifters (heavy lifters and empty lifters), and tractors. Each type of equipment is analysed separately.

As regards quay cranes, no noticeable change can be observed as similar or very close numbers of containers are handled either for imports or for exports with also similar utilization percentages under the base model and scenario “1”. The average utilization percentages for all quay cranes range between 20-30% under the base model and scenario “1”. This reflects that there are no bottlenecks expected at the quayside operations. Since the 12 runs had similar results, figures 7.12 and 7.13 display only the average share of each quay crane of imports and exports in relation to the total throughput previously discussed in section 7.3.2. To illustrate more, under the base model (figure 7.12) the total imports are slightly more than 12000 containers from which quay cranes 1 and 2 handled about 2200 containers each, quay cranes 3 and 4 handled about 2100 containers each, and quay crane 5 handled about 4100 containers. The same illustration applies for exports and figure 7.13 as well.

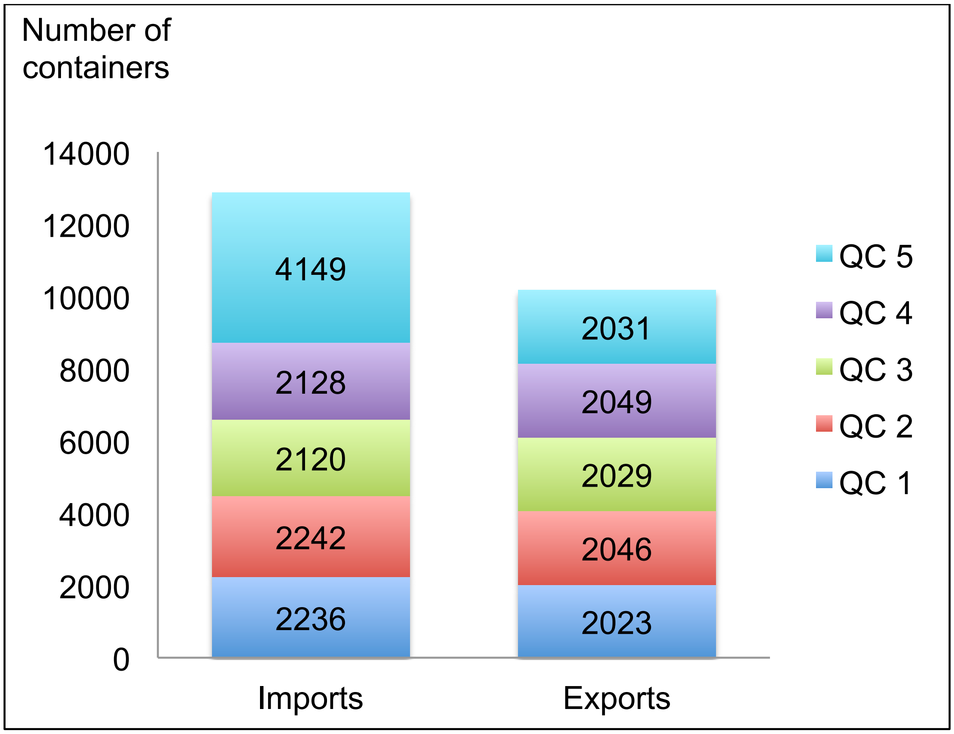


Figure 7.12: Average number handled by quay cranes under the base model for a trial of 12 runs

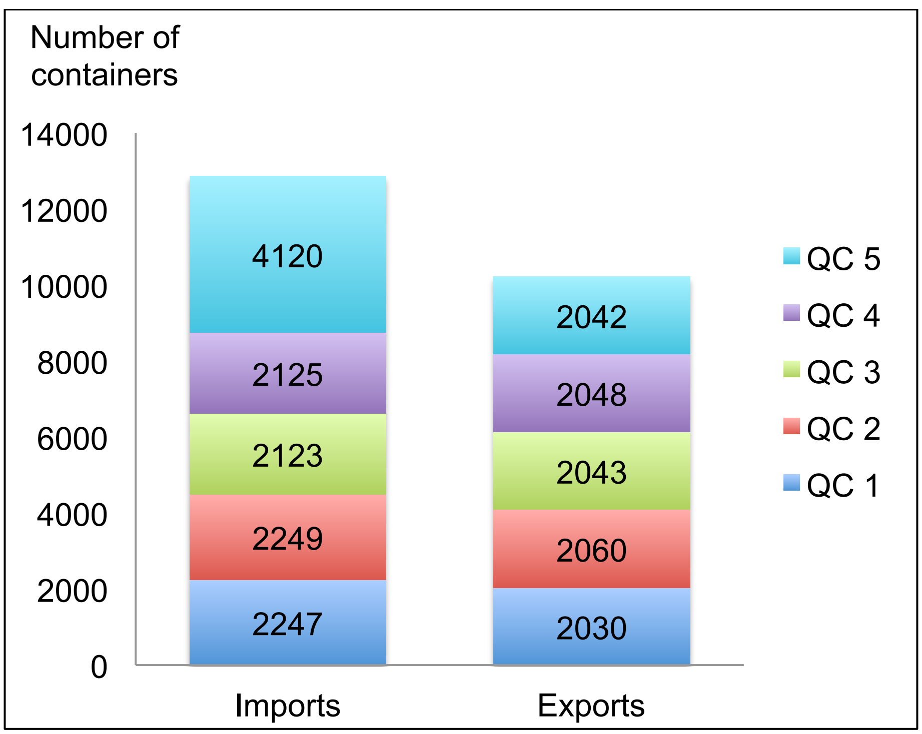


Figure 7.13: Average number handled by quay cranes under scenario “1” for a trial of 12 runs

Moving to YC RTGs, their results also do not show a great variation neither in the number of handled imported containers nor in their utilization percentages. This means that given the shorter dwell time period, similar number of containers can be handled. This is shown in figures 7.14 and 7.15, where the average numbers of containers handled in (containers going into the storage yards) and out (containers moving out of the storage yards) by each yard crane under the base model and scenario "1" are displayed.

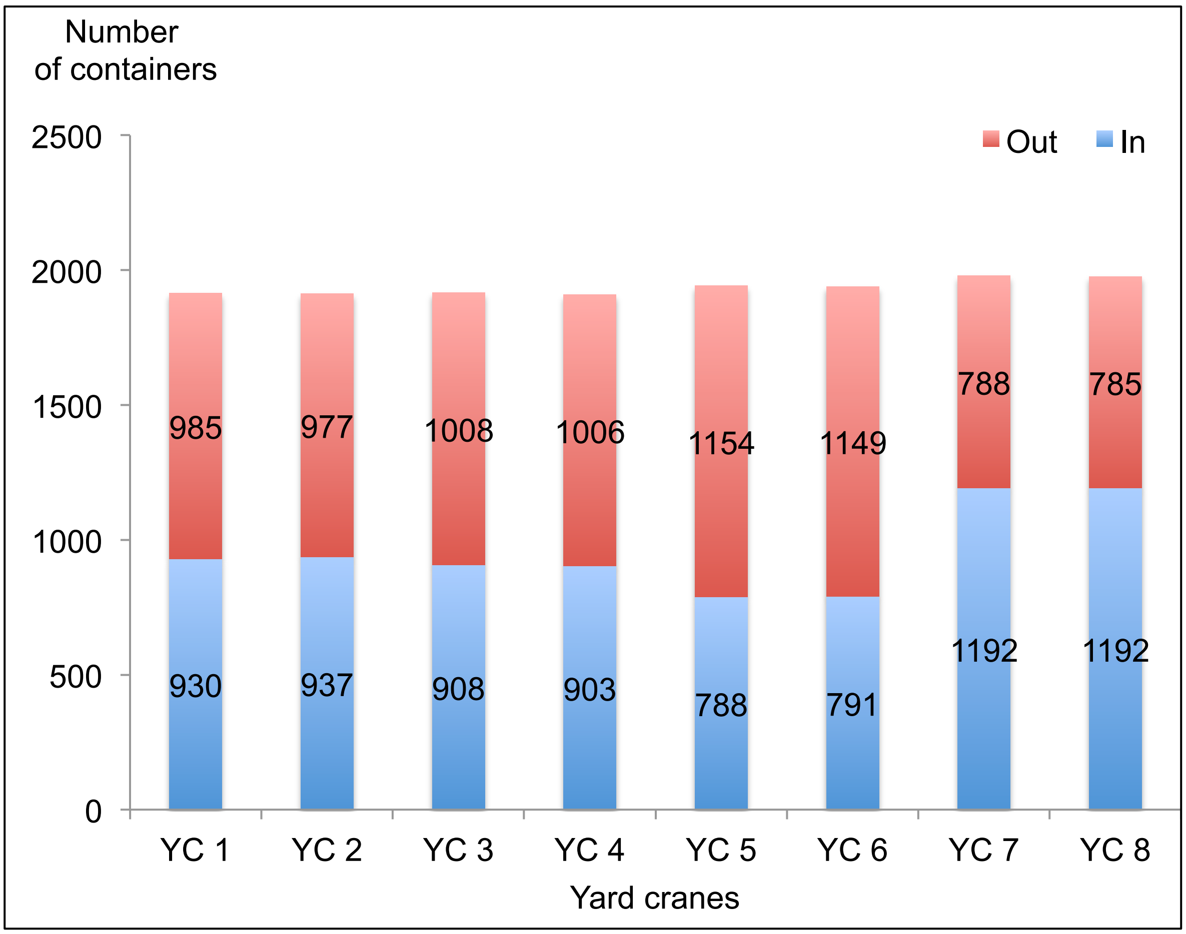


Figure 7.14: Average number of containers handled by yard cranes under the base model for a trial of 12 runs

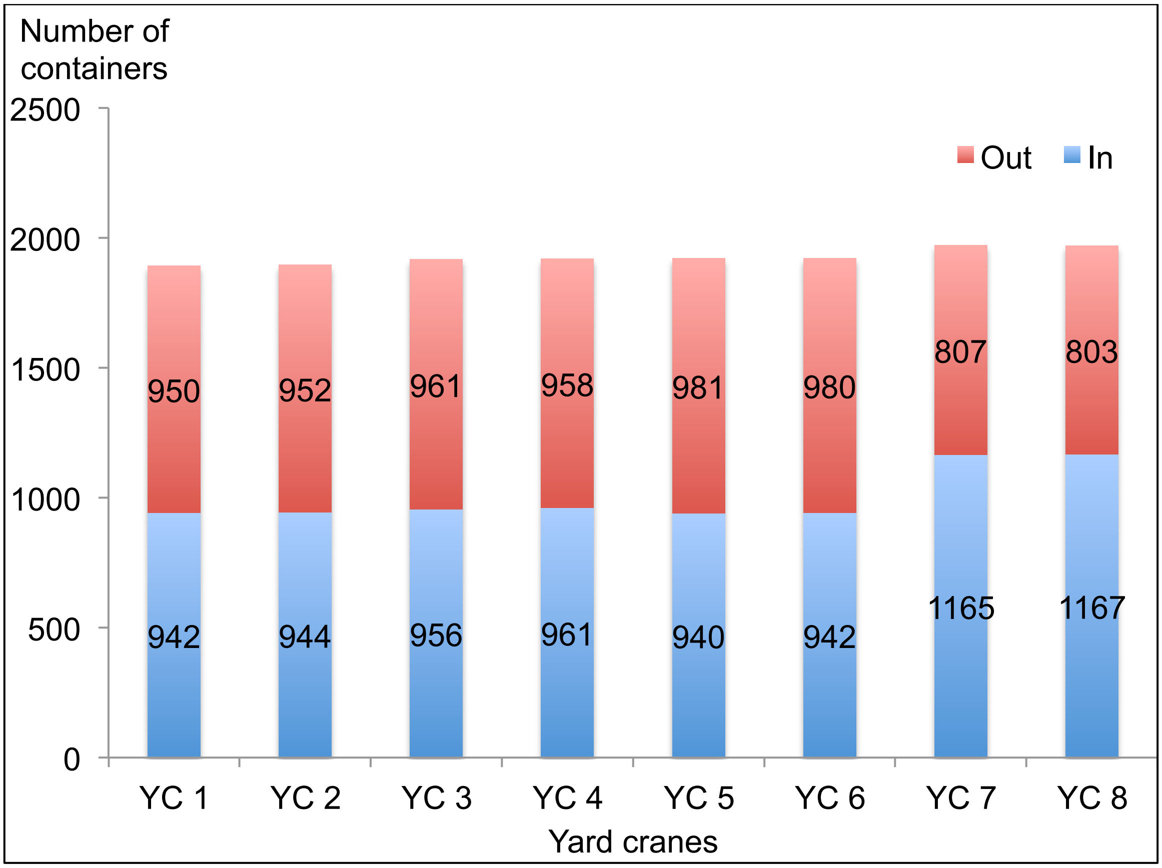


Figure 7.15: Average number of containers handled by yard cranes under scenario "1" for a trial of 12 runs

Utilization percentages of yard cranes under the base model match the statistics of the case company in terms of the YC RTGs' average working hours as previously mentioned in the validation chapter. The results showed that the average utilization percentages range from 50% to 65% (under both the base model and scenario "1"), where the company's statistics showed that the average use of YC RTGs is about 50-60%. This reflects a better utilization of the YC RTGs as they were not over used although the dwell time is reduced. This gives a space for handling more containers at peak times. The utilization percentages of each yard crane as an average for a trial of 12 runs under the base model and scenario "1" are presented in figure 7.16.

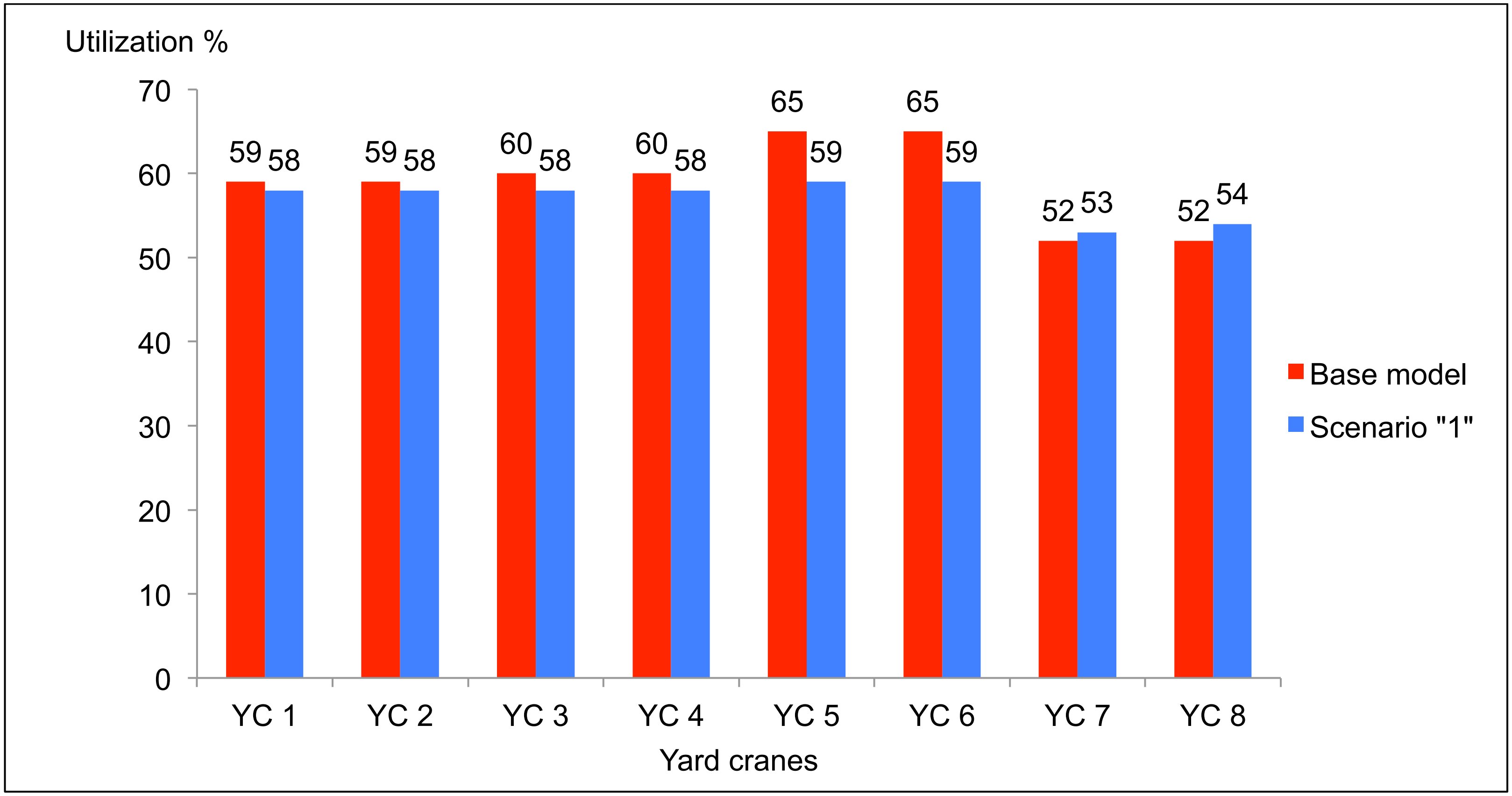


Figure 7.16: Average utilization percentages of yard cranes for a trial of 12 runs

The second type of equipment is the tractors. Either export tractors or import tractors did not face a critical change under scenario “1” as their utilization percentages under both scenarios are low in terms of the average use although the maximum use indicated that the total available number of tractors can be reached at some times. For instance, under the base model, the maximum number of import tractors is 12 tractors which is rarely reached as shown in figure 7.17 where the average use is on average 2 tractors with an average utilization of 14%. On the other hand, export tractors represent a lower utilization percentage of 10%. The maximum use hardly reaches 9 tractors while the average use is 1-2 tractors. Tractors results under scenario “1” are to a great extent similar to those under the base model (see figure 7.18). This means that tractors, especially export tractors are idle sometimes during the runs representing no bottlenecks at this stage.

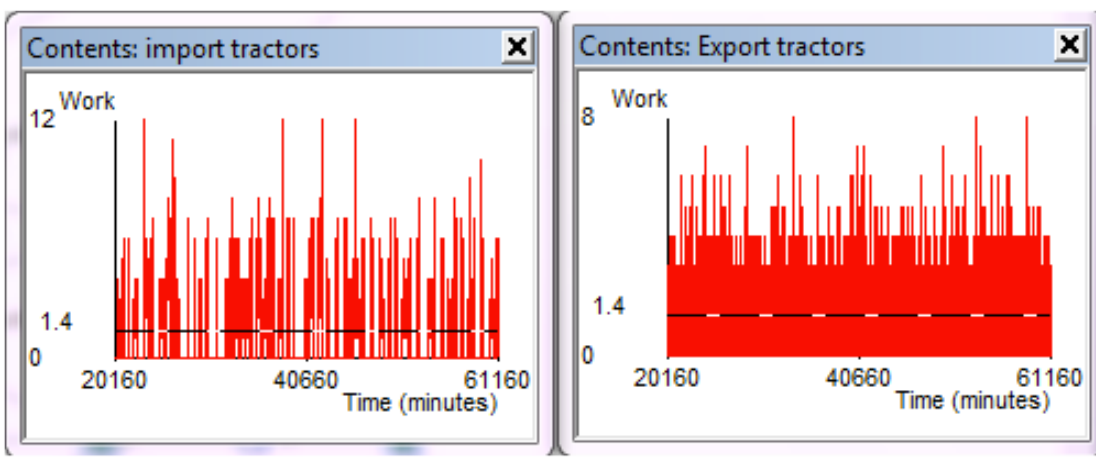


Figure 7.17: Graph results of tractors under the base model

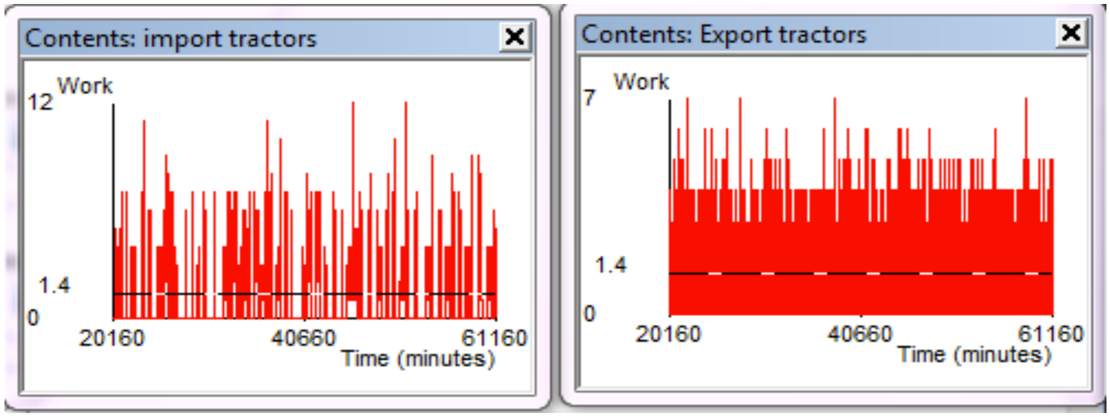


Figure 7.18: Graph results of tractors under scenario ”1”

The last type of equipment is lifters. Lifters are divided into three groups: export lifters, import lifters and empty lifters. The results showed that these resources are idle for most of the time as shown by their maximum use and average use. The maximum use indicated that lifters are fully utilized at some times, but this does not mean that they are fully utilized all the time as the utilization percentages reflect the actual use of lifters over the run time. Also the average use implies that only about half or less of the total lifters are being used throughout the total time. The results of scenario “1” revealed that the most noticeable change is in the import lifters where a better utilization of these lifters is reflected instead of being idle for some time as the average use of this type of resources is far from the maximum use. Import lifters utilization percentage increased by up to 10% in some runs from the base model to scenario “1”. The maximum use under both scenarios is 6 lifters which means that at some times all the import lifters are utilized (note that the total available import lifters are 6), but this is not the frequent case because the average use is only 2-3 import lifters under the base model and 3-4 import lifters under scenario “1”. The following table summarizes the average results of lifters for a trial of 12 runs under the base model and scenario “1”.

Performance Measure	Base model	Scenario “1”
Exp lifters Res. Utilization %	53	53
Maximum use (lifters)	7	7
Average Use (lifters)	4	4
Imp lifters Res. Utilization %	43	48
Maximum use	6	6
Average Use	2	3
Empty lifters res. Utilization %	48	48
Maximum use	6	6
Average Use	3	3

Table 7.8: Average results of lifters for a trial of 12 runs

7.4 Summary

In this chapter, running the base simulation model was considered and a scenario for improvement was suggested. This scenario addressed the dwell time as one of the main performance measures to the company’s performance. Besides, the company faces a problem of congestion in yards in some situations and dwell time is a key to solve this problem because it represents the main reason for this congestion in yards. In addition dwell time in the case company is considered relatively long when compared to other cases. Thus it is worth investigating the impact of reducing this dwell time on the entire logistics process. This scenario suggests reducing the dwell time by a reasonable percentage (30%) and tests the impact of this efficiency change on the overall performance of the system. A trial of 12 runs was conducted once under the base model and another time under the settings of scenario “1” to obtain statistically more accurate results. Results were filtered, summarized, organized, and presented in a way that facilitates their analysis and interpretation. A snapshot for the results of one run under Scenario “1” is displayed in figure 7.19.

Measuring the sensitivity testing for the results of scenario “1”, compared to the results of the base model (refer back to figure 6.3), they did not show a significant change in the total throughput of imports and exports, which is reasonable as reducing dwell time should not result in a considerable increase in throughput. Also equipment results including all types of equipment did not show a great variation in the utilization of such equipment. However, the utilization percentages results may be a helpful indicator to the company to measure the targeted utilization of equipment and accordingly enables making relevant decisions as regards for example whether to increase or decrease these utilization percentages, either to operate certain equipment or not, and if there is a need to add more equipment. Note that the developed base simulation model can be flexible to adjust the utilization percentages of equipment to the target level if required, this may be beneficial to the future implications to the company.

On the other hand, results mainly revealed that reducing the dwell time by 30% would shorten the average total time in system by about 27% as it occupies the longest duration in the whole chain. The results also showed that dwell time and yards capacity are inversely related, i.e. dwell time is directly related to yard capacity utilization where a potential significant reduction by an average of 10-30% in the utilization of yards is achieved when the dwell time is reduced. This can be crucial especially in cases of peaks when handling an increased numbers of containers is expected. In this case all import yards may be fully utilized, which may lead to a severe bottleneck in the process and may result in delay to vessels in queue and awaiting vessels. This situation may be also expected in the export process, if the two available export yards are fully utilized but this would be a worse situation than in the import process because there are only two export yards that can become full with an increased number of exported containers. Thus any potential solution to solve or even avoid this problem would be of vital importance to the whole performance of the logistics processes. This initiates the need to investigate the impact of the expected increase in the number of containers either for imports or exports on the whole system and test its results. This will be addressed in scenario “2”.

The next chapter will address scenario “2” which represents an external change to the process. It investigates the impact of increasing the number of containers handled, either for imports or exports, on the overall logistics processes with a view to identifying any bottlenecks that may happen in the chain and suggesting potential solutions to avoid these expected bottlenecks. This can give managerial insights for better improvement and optimization of the performance of the terminal as a whole and help in the decision making process of the company.

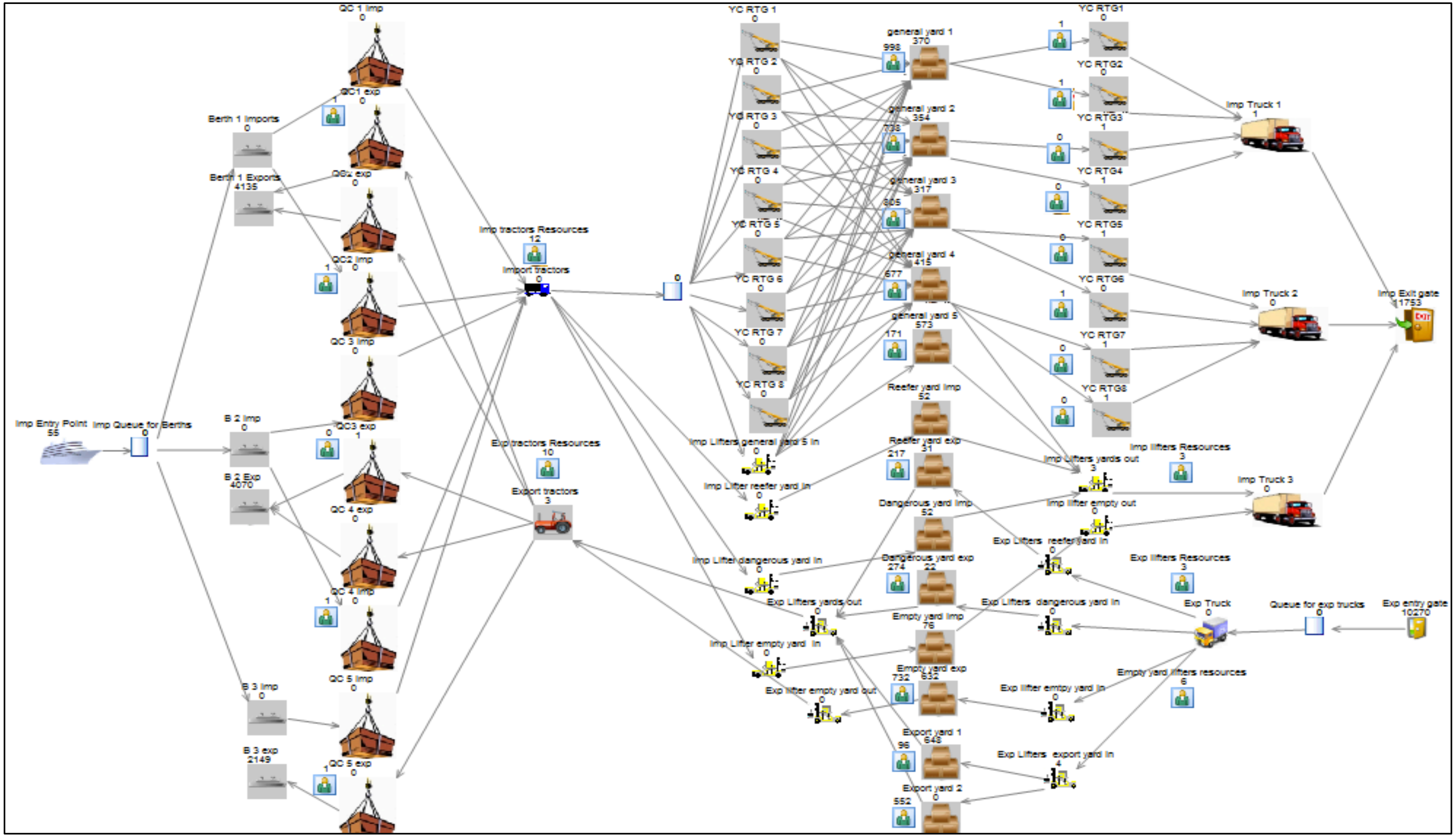


Figure 7.19: A snapshot for the results of one run under Scenario “1”

Chapter 8

What-if Scenario Analysis

In chapter 7, a scenario for improvement was suggested. It addressed an efficiency change to the model and tested the impact of this change on the overall performance of the entire system. Chapter 8 will deal with other changes to the model based on some forecasts, predictions, and current practices. Each change will be illustrated and justified, then the results of running the simulation model under this change will be displayed, analysed, and interpreted in order to show the impact of this particular change on the entire process (sensitivity testing).

8.1 Introduction and Scenario Justifications

In 1990, world container port throughput volumes were around 85 million TEUs, and they have since grown sixfold to 531.4 million TEUs over 20 years (Review of Maritime Transport, 2011). This is forecasted to reach more than 840 million TEUs by 2018 where growth rates are expected to average an annual 5.6% (Drewry Maritime Research, 2014). In 2010, container port throughput resumed its rise after a short fall in 2009 as a result of the global economic crisis. In 2011, the container throughput for developing economies grew by an estimated 8 per cent to 406.9 million TEUs. This growth is lower than the 15.8 per cent seen in the year 2010, when businesses replenished the depleted inventories because of uncertainties surrounding the global economic crisis (Review of Maritime Transport, 2011, 2012, and 2013).

Ship size and traffic are increasing worldwide. To cope with this, the Panama Canal is doubling its capacity to allow for vessels carrying 12,000 TEU containers (or up to 13000 TEU as stated by CNBC, 2015) from the current capacity of 5,000 TEU. The Nicaragua Canal is another shipping route that is under construction through Nicaragua to connect the Caribbean Sea (and therefore the Atlantic Ocean) with the Pacific Ocean. Hong Kong Nicaragua Canal Development Investment (HKND) claims that it will complete the megaproject in 2019 and it will be able to accommodate ships of up to 23,000 TEU (CNBC, 2015). Transoceanic canals play a vital role in globalization, and the Suez Canal is critical to the economic stability of Egypt (The New York Times, 2014), especially with the new Suez Canal project, previously discussed in chapter three, and its potential benefits mainly increasing the numbers and sizes of sailing vessels. This will certainly results in a growth in container throughput as well.

As long as Egypt is concerned, it was noted that among the top 20 developing countries and countries with economies in transition in 2011, Egypt was of the top 15 with a percentage change of 15 per cent from 6 709 053 TEUs in 2010 to 7 737 183 TEUs in 2011. According to the World Bank, the forecasted growth in container throughput in Egypt by 2016 is shown in figure 8.1. Also in The Report: Egypt (2010), since the fastest growth in demand is anticipated in container traffic so it is expected that container traffic would rise to 15.9 million TEUs by 2025.

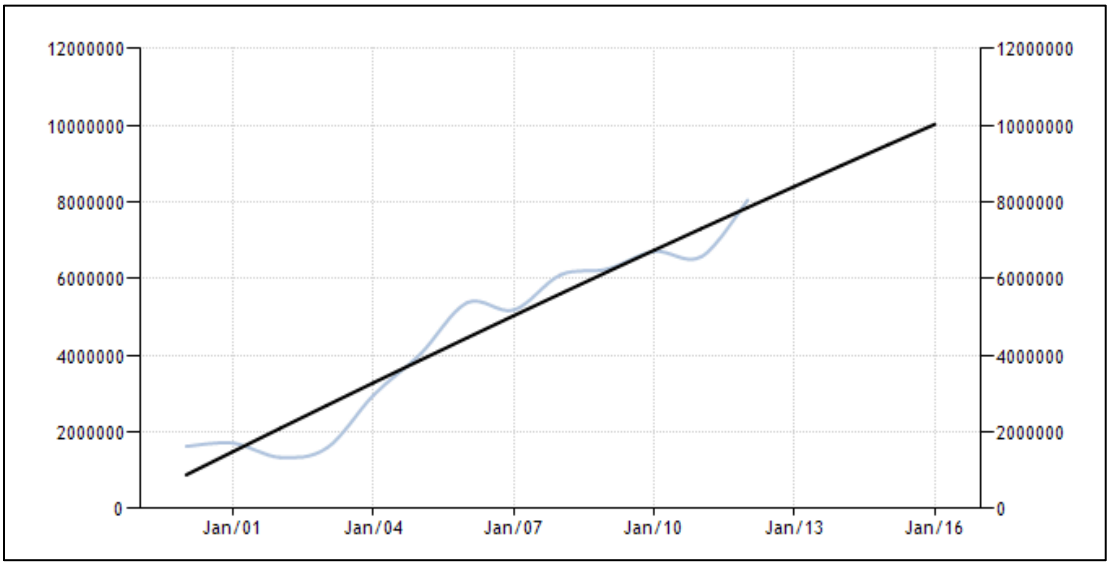


Figure 8.1: Forecasted growth in container throughput in Egypt (Source: World Bank, 2012)

On the company's level, there is a continuous increase in the imports and exports throughput since 2004. This can be shown in figure 8.2, which reveals an average annual increase in throughput by 15 per cent from 2004 to 2008. After 2008, there was a noticeable decline in the rate of increase in throughput compared to the rate of increase before 2008. This is due to the world economic crisis, followed by the revolutions that occurred in Egypt and the unstable political and economical situations that faced the country for about three consecutive years. The same situation applies to the number of vessels where figure 8.3 shows the total number of vessels visited the terminal form 2007 to 2011. In general, the number of vessels is increasing per year and this is expected to increase more specially after the new Suez Canal project is completed and also because the current political and economical situations in Egypt are getting more stable, which encourages handling more vessels and more numbers of containers.

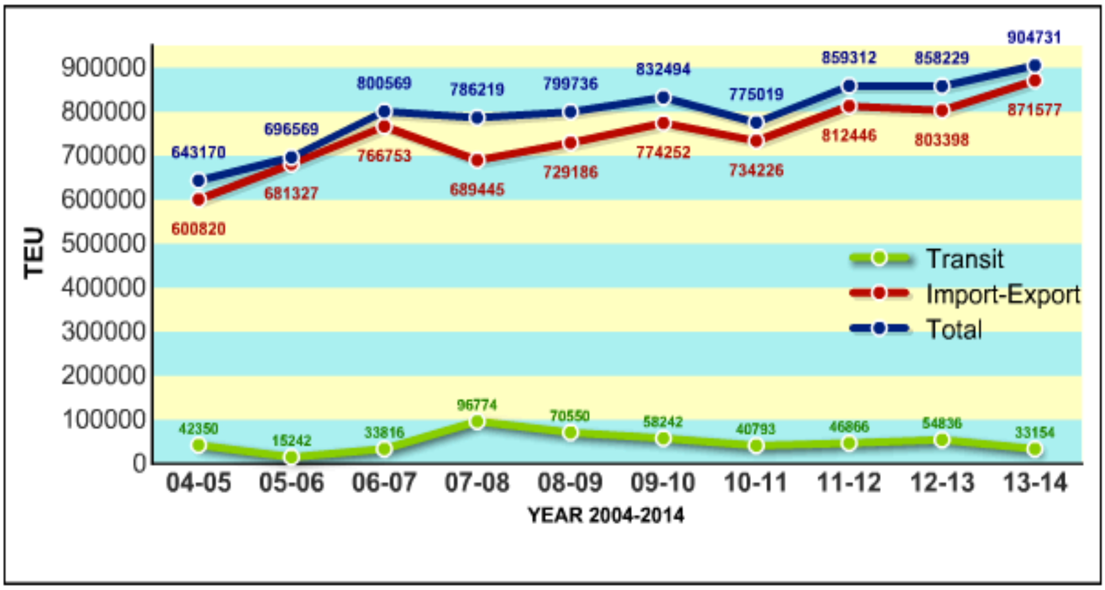


Figure 8.2: Container throughput from 2004 to 2014 in the case company

(Source: The case company's website, 2015)

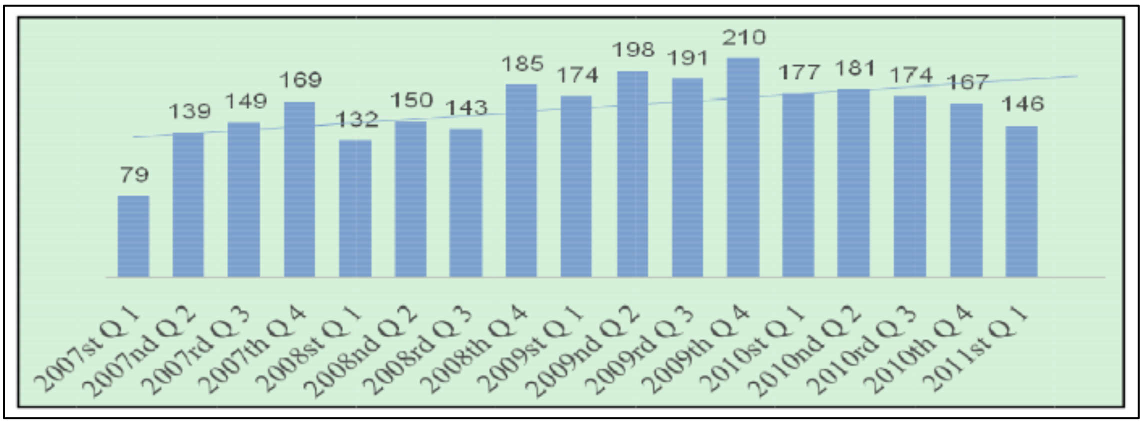


Figure 8.3: Total number of vessels handled by the company from 2007 to 2011

(Source: ElKalla and ElShamy, 2012)

This supports the literature review previously mentioned in chapters two and three, which shows that uncertainty exists in customer demands and processing activities that are related to container logistics processes and that there is a lack of research which reports comprehensive scenario analysis of the impacts of various uncertainties in the logistics processes, on terminal performance. This issue is considered the main objective of this chapter.

Consequently, this chapter investigates the issue of uncertainty that exists in container terminals through testing the impact of an external change to the current system, i.e. a scenario of increasing the number of handled containers in both flows. Another scenario that helps relax the whole system in case of expected bottlenecks is also addressed in the chapter. Finally, a real scenario is examined to report its results and interpret its impact on the process. This would support future managerial decisions in this regard.

8.2 Scenario "2": 20% increase in Number of Containers Handled

In the light of the above illustration and since increasing numbers of containers and vessels are expected, a scenario that addresses this increase will be suggested, its results will be tested and a potential solution will be proposed. In the following sections, the scenario is discussed, and then its results are displayed in three sub-sections; results relative to storage yards; results relative to throughput; and results relative to equipment.

This scenario "2" addresses an external change to the current system, represented in increasing the numbers of handled containers per vessel. Since the records of the company showed a 15% average increase before 2008 provided a stable economy, and since all efforts are currently motivating handling more containers, thus scenario "2" suggests a slightly higher increase at 20%. This is considered as a reasonably potential increase percentage given the current situations in Egypt and the forecasted growth in container traffic volumes.

Therefore, the change in the model parameters will be in the batching value of berths (for imports). The number of containers is categorized into six groups as illustrated in the first column of table 8.1. Under the base model, the percentage of each group is calculated based on the actual number of vessels entered the terminal within each category as in the second column of the same table. For instance, under the base model, the company handles up to 110 containers from about 30% of the total number of vessels that enter the terminal. By increasing the number of containers per vessel by 20% as suggested by scenario “2”, the new percentages of each category will change as the number of vessels will change within each category (but keeping the total number of vessels fixed under both the base model and scenario “2”). The new percentages under scenario “2” are presented in the third column of table 8.1.

Numbers of containers handled	% under the base model	% under scenario “2”
0-110	30%	20%
110-220	35%	34%
220-330	10%	14%
330-440	15%	13%
440-550	7%	13%
550-660	3%	3%
660-770		3%

Table 8.1: Percentages of each category of containers handled under the base model and scenario “2”

On the other hand, as regards the exports, the number of containers handled is determined by the inter arrival times (minutes). Under the base model, it is set as average 4 minutes which means that a new container arrives every 4 minutes on average. Increasing the total number of handled exported containers by 20% requires changing this average to be average 3.3 minutes under scenario ”2”.

8.2.1 Results of scenario “2”: 20% increase in Number of Containers Handled

The following section presents the results of running the simulation model under the settings of scenario “2” to test the impact of increasing the number of containers handled on the entire system. Each following sub-section displays the results of a selected performance measure after increasing the number of containers by 20% (scenario “2”) and compares the results of the same performance measure under the base model. These results are driven from running the simulation model for one run and for a trial of 12 runs to obtain more accurate and reliable results. Figure 8.4 presents a snapshot for the results of running the simulation model for one run under scenario “2”.

8.2.1.1 Results Relative to Storage Yards

The most significant result of scenario “2” is revealed in the congestion of the storage yards where most of the yards are fully utilized during most of the runs of the conducted trial. This would have a severe impact and results in several bottlenecks through the entire system, which will be discussed afterwards. In terms of imports, the five general import yards reach their maximum capacity in almost all the runs. It is worth noting also that the average use of general import yards is nearer to the maximum capacity than to the minimum use. This means that the yards are nearly full for most of the time. The same applies for export yards especially export yards 1 where the average use is very close to the maximum capacity in all the runs. This results in achieving very high utilization percentages. As shown in table 8.2, since almost all storage yards (mainly import yards) are fully utilized in all the runs of the trial, this may influence the utilization of other resources such as tractors, lifters, and cranes. Note that the maximum capacities for import yards 1 to 5 are: 1368, 1092, 1122, 1092, and 744 respectively. Over-congestion in yards may also adversely affect the throughput of the entire system. As long as yards are fully congested, then yard cranes and lifters will be also fully utilized. Consequently, tractors and quay cranes will be also fully occupied which means that the system may be blocked and is unable to handle any more containers (this appears in the queue for exports and imp queue for berths). This may lead to a reduction in the throughput for either imports or exports or both as well as an over utilization of equipment and resources.

The influence of this congestion in storage yards on individual resources will be illustrated in the following sections.

A major result of the congestion in storage yards appears in the “Imp queue for berths” and “Queue for exp trucks” which are occupied during almost all the runs. This is considered relatively high when compared to the base model results. As regards imports, under the base model, the minimum queue size is zero and the maximum queue size is one. This means that during the 12 runs, there was a maximum of one vessel in this queue. Whereas under scenario “2” the average queue size ranges up to 30 which means that in some runs, an average of 30 vessels are in the queue for import berths due to the increased numbers of handled imported containers. On the other hand, the “Queue for exp” also shows a sharp increase in number of containers when compared to that of the base model. The results of scenario “2” shows an average queue size of about 4000 exported containers although the maximum queue size under the base model hardly reaches 10 containers in only one run throughout the whole trial. This reveals a severe impact where a bottleneck is expected to occur in case the number of containers handled increased by 20%. The detailed results of “Imp queue for berths” and “Queue for exp” under the base model and scenario “2” are displayed in tables 8.3 and 8.4.

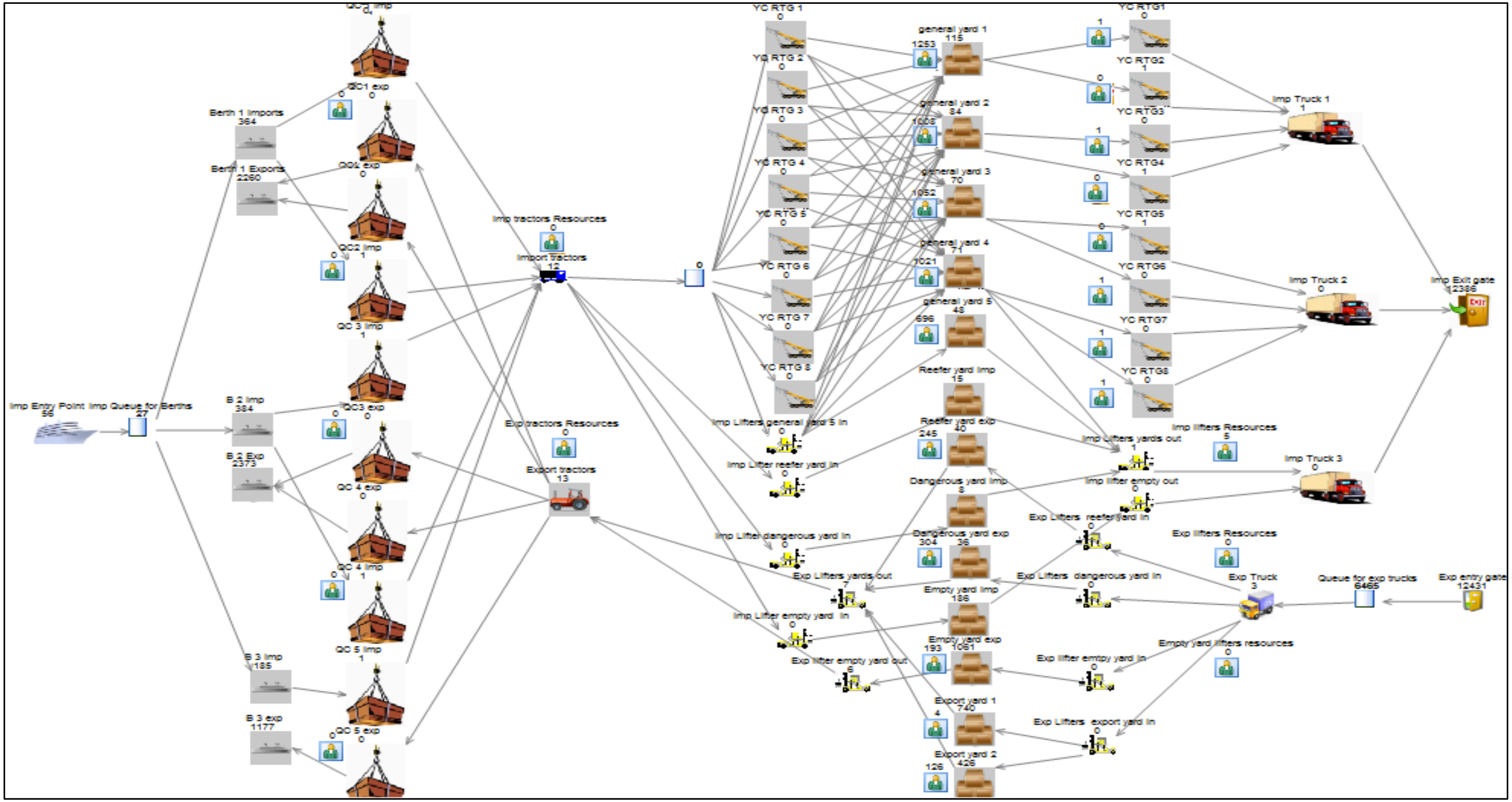


Figure 8.4: A snapshot of the results of one run of the simulation model under scenario “2”

Performance measure	1	2	3	4	5	6	7	8	9	10	11	12
General yard 1 avg use	700	534	1090	1346	265	296	864	485	1368	323	1011	1285
General yard 1 max use	1368	1368	1368	1368	1222	1242	1368	1368	1368	1368	1368	1368
General yard 2 avg use	628	433	1049	1088	203	220	840	411	1092	244	1018	1070
General yard 2 max use	1092	1092	1092	1092	940	967	1092	1092	1092	1092	1092	1092
General yard 3 avg use	673	445	1092	1122	205	217	937	438	1122	245	1083	1113
General yard 3 max use	1122	1122	1122	1122	968	993	1122	1122	1122	1122	1122	1122
General yard 4 avg use	657	417	1082	1092	199	217	950	412	1092	227	1074	1089
General yard 4 max use	1092	1092	1092	1092	912	961	1092	1092	1092	1092	1092	1092
General yard 5 avg use	468	303	739	744	128	143	661	281	744	172	736	742
General yard 5 max use	744	744	744	744	660	672	744	744	744	744	744	744
Export yard 1 avg use	742	740	743	738	740	740	741	738	743	737	742	742
Export yard 1 max use	744	744	744	744	740	740	744	744	743	738	744	744
Export yard 2 avg use	408	376	409	377	399	395	393	399	380	340	364	366
Export yard 2 max use	434	424	432	416	399	395	440	424	380	340	439	395

Table 8.2: Average and maximum use of storage yards under scenario “2”

Performance measure	1	2	3	4	5	6	7	8	9	10	11	12
"Imp queue for berths" (under the base model)												
Minimum queue size	0	0	0	0	0	0	0	0	0	0	0	0
Maximum queue size	1	1	1	1	1	1	1	1	1	1	1	1
"Imp queue for berths" (under scenario "2")												
Average queue size	9	18	6	23	28	30	2	19	30	27	0	15

Table 8.3: Results of "Imp queue for berths" for a trial of 12 runs under the base model and scenario "2"

Performance measure	1	2	3	4	5	6	7	8	9	10	11	12
"Queue for exp" (under the base model)												
Minimum queue size	0	0	0	0	0	0	0	0	0	0	0	0
Maximum queue size	7	7	8	9	7	9	8	10	8	7	9	7
"Queue for exp" (under scenario "2")												
Average queue size	2213	4194	1330	5444	6972	6664	528	4441	6921	6357	127	3386

Table 8.4: Results of "Queue for exp" for a trial of 12 runs under the base model and scenario "2"

8.2.1.2 Results Relative to Throughput

Being unable to handle more containers (which is reflected by the increasing queue sizes for both imports and exports) justifies the expected reduction in throughput during some runs of the trial. This reduction is expected in both flows (imports & exports). Throughput results of imports and exports under scenario “2” for a trial of 12 runs are displayed in table 8.5. The table shows that in some runs the system is completely blocked to the extent that the results are zero containers. This happens when all the import yards are fully occupied and all “yards cranes in” are also in use. And since yard cranes cannot work in and out at the same time, then “yard cranes out” remain idle and consequently no containers can go out resulting in zero imports. In other runs, there is a sharp decline in the numbers of containers completed whereas in just a few runs, the system is normal and can handle a reasonable number of containers.

8.2.1.3 Results Relative to Equipment

In general, results relative to equipment show a high increase in the utilization percentages of most types of equipment including cranes (quay cranes or yards cranes), tractors, and lifters. This is due to handling an increased number of containers throughout the different runs of the conducted trial.

As regards quay cranes, the utilization percentages jump greatly from an average of 20% under the base model to an average of 80% under scenario “2”. Under the base model, as mentioned in chapter 7, all quay cranes are being utilized at a utilization percentage that ranges between 20% to 30% maximum. While under scenario “2”, the utilization of quay cranes starts from 40% and may reach 100% in some runs. This reveals that increasing the handled containers by 20% may lead to a minimum of 20% increase in the utilization of quay cranes. The utilization percentages of quay cranes in a trial of 12 runs are shown in table 8.6.

Performance measure	1	2	3	4	5	6	7	8	9	10	11	12
Imp Exit gate Number Completed	11547	8631	8203	729	4936	5111	14432	7876	0	5688	13803	3824
Berth 1 Exports Number Completed	1978	845	2591	287	0	0	3478	723	0	1	4246	1221
Berth 2 Exports Number Completed	1954	934	2595	277	0	0	3522	712	0	2	4249	1255
Berth 3 Exports Number Completed	1001	419	1290	137	0	0	1744	363	0	1	2073	654

Table 8.5: Throughput results under scenario “2”

Performance measure	1	2	3	4	5	6	7	8	9	10	11	12
Quay crane 1 utilization %	71	86	61	97	100	100	43	86	100	100	36	78
Quay crane 2 utilization %	71	86	61	97	100	100	44	86	100	100	36	78
Quay crane 3 utilization %	69	87	58	94	100	100	49	88	100	100	34	81
Quay crane 4 utilization %	69	87	58	94	100	100	49	89	100	100	34	82
Quay crane 5 utilization %	73	91	69	98	100	100	53	89	100	100	46	84

Table 8.6: Utilization percentages of quay cranes of a trial of 12 runs under scenario “2”

Another type of equipment is the tractors. Results of scenario “2” show an increase in the utilization percentages as well as the average use when compared to the results of the base model. Under the base model, the average use for import tractors is on average 2 tractors with an average utilization of 14%. Under the scenario “2”, the average use is on average 9 tractors with an average utilization of 79%. That is increasing the number of handled imported containers by 20% increases the average use of import tractors by 65%. For instance, as table 8.7 indicates, the average use of import tractors starts from 4 tractors and reaches 12 tractors in about 4 runs out of the 12 runs of the trial conducted. Note that basically the maximum number of import tractors is 12 tractors, which is at the same time the average use in about one third of the trial runs. In terms of export tractors, the results also show an average of 60% increase in utilization percentage from an average of 10% under the base model to an average of about 78% under scenario “2”. An increased number of tractors also appears in average use which rise from an average of 1-2 tractors under the base model to an average of 10 tractors under scenario “2”. Like the import tractors, the average use of export tractors as well reaches its maximum (13 export tractors) in 4 runs throughout the whole trial. This is shown in table 8.7. For both types of tractors, the maximum number of tractors is reached as a maximum use in all the runs.

Moving to the last type of equipment, which is lifters. As previously mentioned, the average utilization percentage of export lifters under the base model is 53%, a figure that increases to an average of 90% under scenario “2”. 100% utilization is achieved in few runs of the trial. In addition, the average use rises from 4 lifters under the base model to 6 lifters under scenario “2”. Table 8.8 show the results of lifters under scenario “2”.

Performance measure	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Imp tractors Resources Utilization %	67	86	57	96	100	100	42	88	100	100	31	80
Average Use	8	10	7	12	12	12	5	11	12	12	4	10
Exp tractors Resources Utilization %	65	85	54	95	100	100	38	86	100	100	25	78
Average Use	8	11	7	12	13	13	5	11	13	13	3	10

Table 8.7: Results of import and export tractors for a trial of 12 runs under scenario "2"

Performance measure	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Imp lifters Resources Utilization %	34	24	75	97	10	10	44	21	100	12	60	88
Average Use	2	1	4	6	1	1	3	1	6	1	4	5
Exp lifters Resources Utilization %	86	94	81	98	100	100	75	95	100	100	70	91
Average Use	6	7	6	7	7	7	5	7	7	7	5	6
Empty lifters Resources Utilization %	83	92	78	98	100	100	70	93	100	100	66	89
Average Use	5	6	5	6	6	6	4	6	6	6	4	5

Table 8.8: Results of lifters for a trial of 12 runs under scenario "2"

The average use reaches the maximum use in about 33% of the runs and the maximum of 7 export lifters is reached in all the runs. As regards the empty lifters, the results reveal an increase of about 40% in the utilization percentage from an average of 48% under the base model to an average of 89% under scenario “2”. The average use also rises from an average of 3 lifters to an average of 5 lifters from the base model to scenario “2”.

In the light of all the above results, sensitivity testing is revealed in that increasing the number of containers handled by 20% as suggested by scenario “2” would have a significant impact on the entire system and cause several bottlenecks along the imports and exports’ flows. This mainly resulted in an over congestion in storage yards (imports and exports) as nearly all yards are fully utilized. The consequences of this congestion are reflected in the huge number of vessels in the “imp queue for berths” and the huge number of containers in the “queue for export trucks”. Another result is reducing the overall throughput for both flows due to the inability of the system to handle more containers at some points. The increased utilization of equipment is a third result that is revealed by this scenario, i.e. increasing 20% in numbers of handled containers resulted in increasing the utilization of quay cranes by 20% as a minimum, tractors by 60-65% on average, and lifters by about 40%.

And since this scenario is expected according to the growth rates and container traffic forecasts, therefore it is highly required to recommend a potential solution to relax these bottlenecks. Thus a potential solution is suggested in the following section.

8.3 Scenario “3”: Suggesting Scenario “1” as a Potential Solution in Case of Scenario “2”

As discussed earlier, scenario “1” addressed an efficiency change represented in reducing dwell time by 30% to improve the performance of the whole system. Moreover, scenario “2” addressed an expected external change of increasing the number of handled containers by 20%. Scenario “3” will test the impact of reducing dwell time by 30% as a suggested solution when increasing the number of handled containers by 20%. In other words, scenario “3” is a combination of scenarios “1” and “2”.

Re-running the simulation model for 1 run and for a trial of 12 runs under scenario “3”, the results are generally stable and consistent and the overall system is relaxed. Figure 8.5 presents a screenshot for the results of running the simulation model for one run under scenario “3”.

Each of the following sub-sections will test the influence of reducing dwell time (provided an increased number of containers handled) on a particular performance measure and display its results.

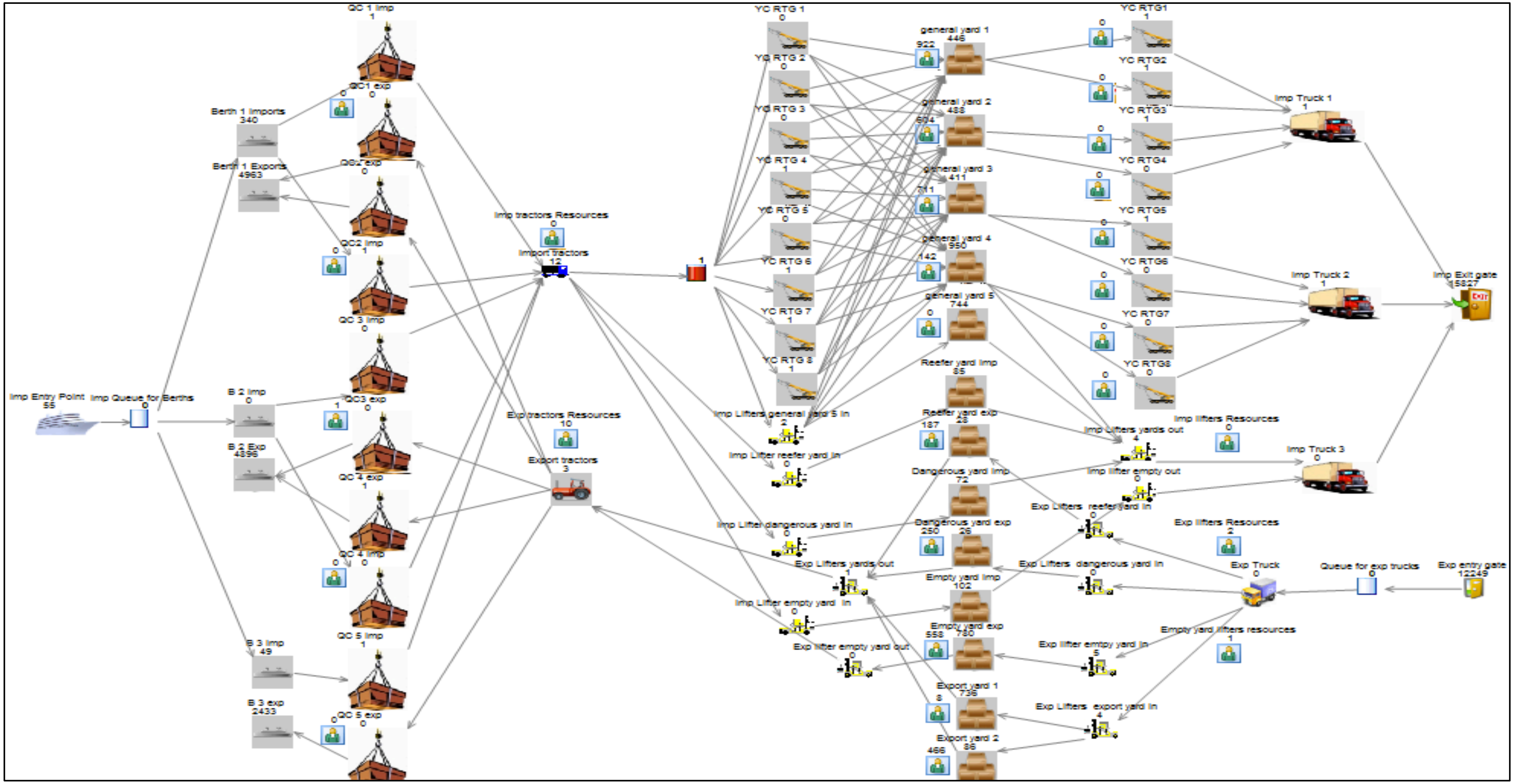


Figure 8.5: A screenshot of the results of one run of the simulation model under scenario “3”

8.3.1 Results Relative to Total Throughput and Average Time in System

Since the results reveal no great variations between the 12 runs of the trial, an average of all the runs will be considered in the displayed results. In terms of throughput, reducing the dwell time by 30% enables the system to handle the 20% increase in number of handled containers and consequently increases the throughput of the whole process. The average throughput of imports is about 17500 containers per run. This seems reasonable as scenario “1” shows an average imports throughput of about 13000 containers, then scenario “3” results in a slight increase in throughput given the 20% increase in number of containers handled (20% increase rises the throughput from 13000 containers under scenario “1” to about 16000 containers under scenario “3”). Exports throughput results show the same change where the average exports throughput for berths 1 and 2 rise by 20% (scenario “2”) from about 4000 containers under scenario “1” to about 4800 containers under scenario “3” and from an average of about 2000 containers to an average of 2400 containers for berth 3. This is shown in figure 8.6. Note that the results of scenario “3” reveal a stable system like the base model, although the number of handled containers is increased and dwell time is reduced.

Figure 8.7 displays the results of the average time in system for imports and exports under the base model and the three scenarios. The results of scenario “3” indicate that average time in system for imports is 9600 minutes which is similar to the results of scenario “1” taking into consideration the 20% increase in the number of containers handled. The average time in system for exports is about 5500 minutes due to reducing the dwell time as in scenario “1”.

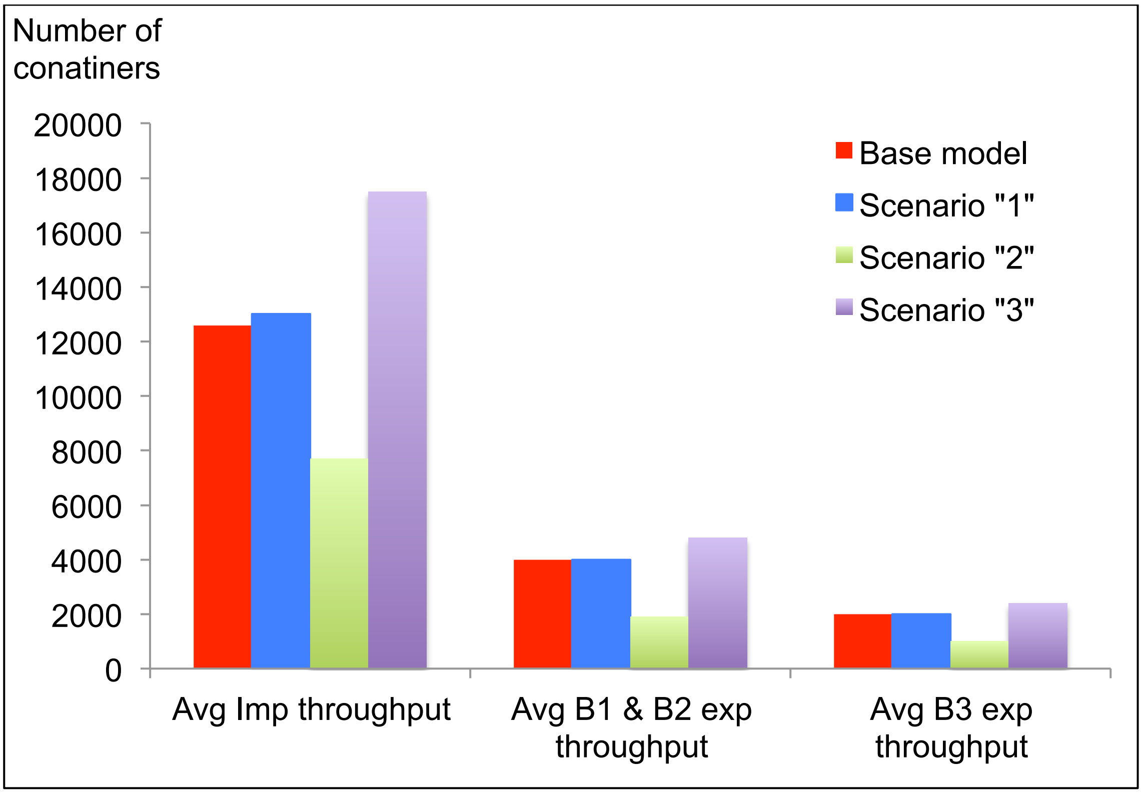


Figure 8.6: Average import and export throughput for a trial of 12 runs

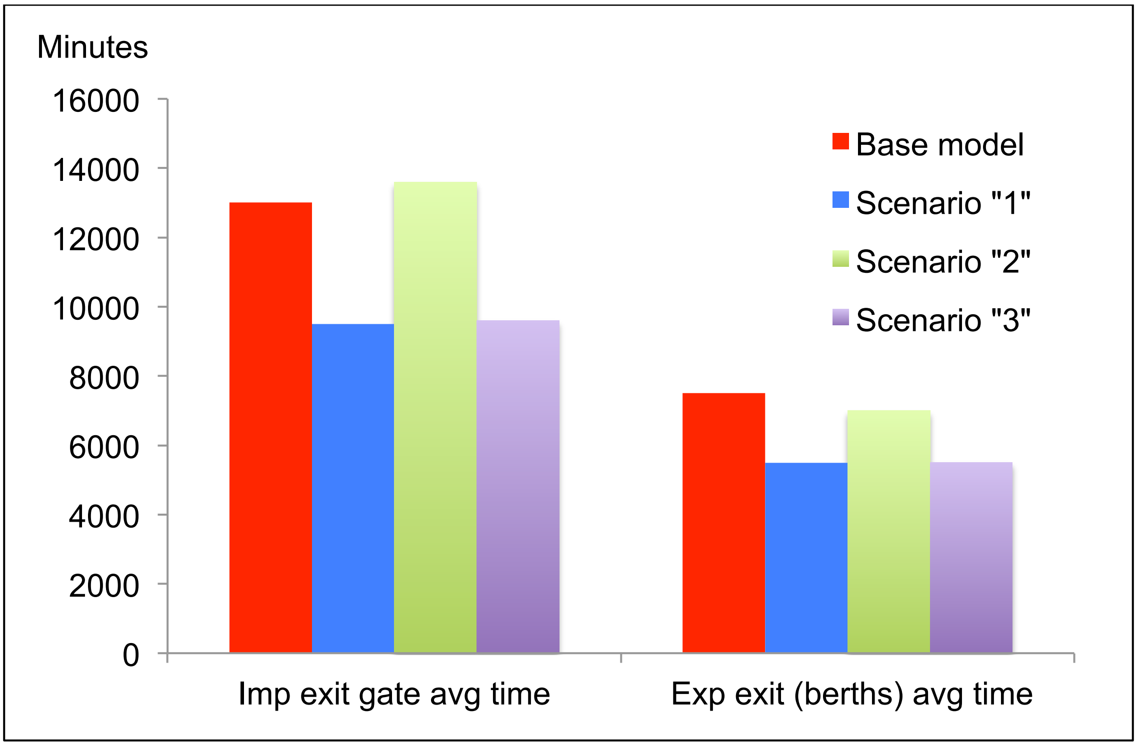


Figure 8.7: Results of average time in system for imports and exports for a trial of 12 runs

8.3.2 Results Relative to Storage Yards

A major result of scenario “3” appears in relaxing the utilization of storage yards. Despite the increased number of containers being handled, reducing the dwell time relaxes the congestion of storage yards (which is the main problem resulting from scenario “2”). It is generally noticed from the results of storage yards under scenario “3” that the average use is much less than the average use under scenario “2” in general yards 1 and 2. For instance, the average use of import general 1 reduced from an average of 800 containers under scenario “2” to an average of 575 containers under scenario “3”. In general yards 3, 4, and 5 the average use is increased from scenario “2” to scenario “3” due to the increased number of handled containers. However, this increase is normally handled representing no bottlenecks under scenario “3”.

Export yard 1 does not reveal a noticeable change in the average use under scenario “3” where the average use is on average 740 containers under both scenarios “2” and “3”. This is very close to the maximum use, which is 744 containers in all the runs under both scenarios. The main difference is in the number of exported containers handled (number completed), which greatly increased from about 1900 containers under scenario “2” to an average of 6100 containers under scenario “3”. Export yard 2 faced a sharp decline in the utilization percentage by about 55% from scenario “2” to scenario “3”. The average number of exported containers handled is reduced from 950 containers with an average use of about 380 containers under scenario “2” to 615 containers with an average use of about 73 containers under scenario “3”. The following figures show the average numbers of containers handled by each storage yard under the base model and the three suggested scenarios.

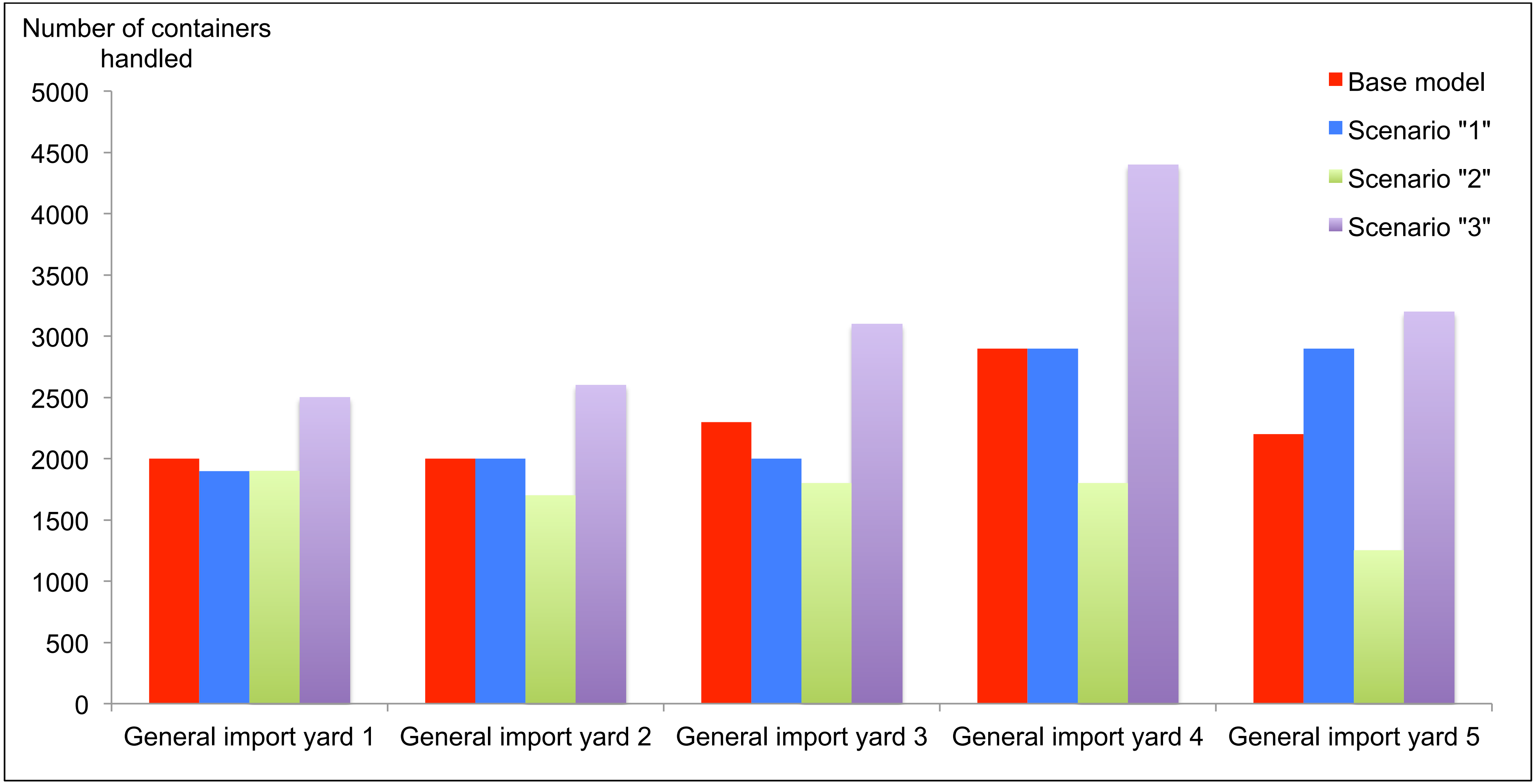


Figure 8.8: Average number of imported containers handled by import yards for a trial of 12 runs

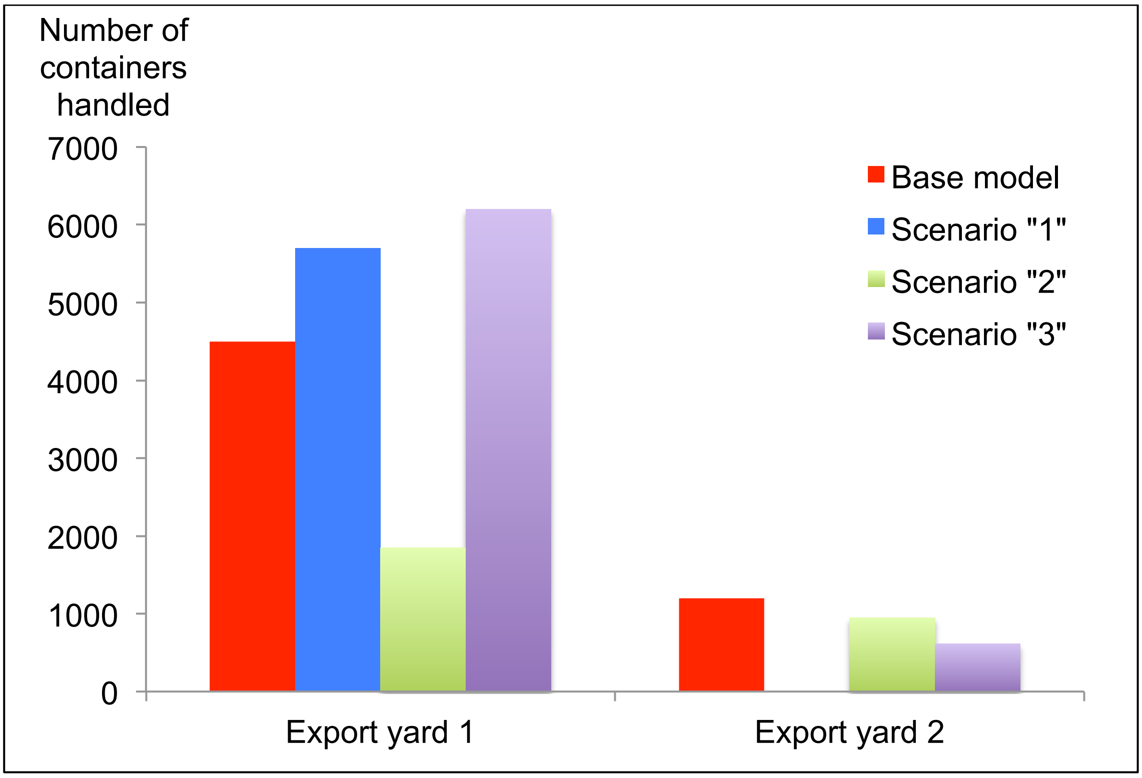


Figure 8.9: Average number of exported containers handled by export yards for a trial of 12 runs

8.3.3 Results Relative to Equipment

The results of quay cranes show a strong decrease in the utilization percentage in scenario “3” when compared to scenario “2”. The average decrease is about 40-50% from scenario “2” to scenario “3”. In general, the average utilization percentage of quay cranes is about 80% under scenario “2” and about 30% under scenario “3”. In terms of numbers of containers handled, the average numbers of imported and exported handled containers by each quay crane under the base model and the three scenarios are given in figures 8.10 and 8.11. It is clear that due to the increased numbers of containers under scenario “2” by 20% that resulted in several bottlenecks throughout the system as discussed earlier in the results’ analysis of the scenario, the least numbers of containers are handled compared to the base model and the other scenarios.

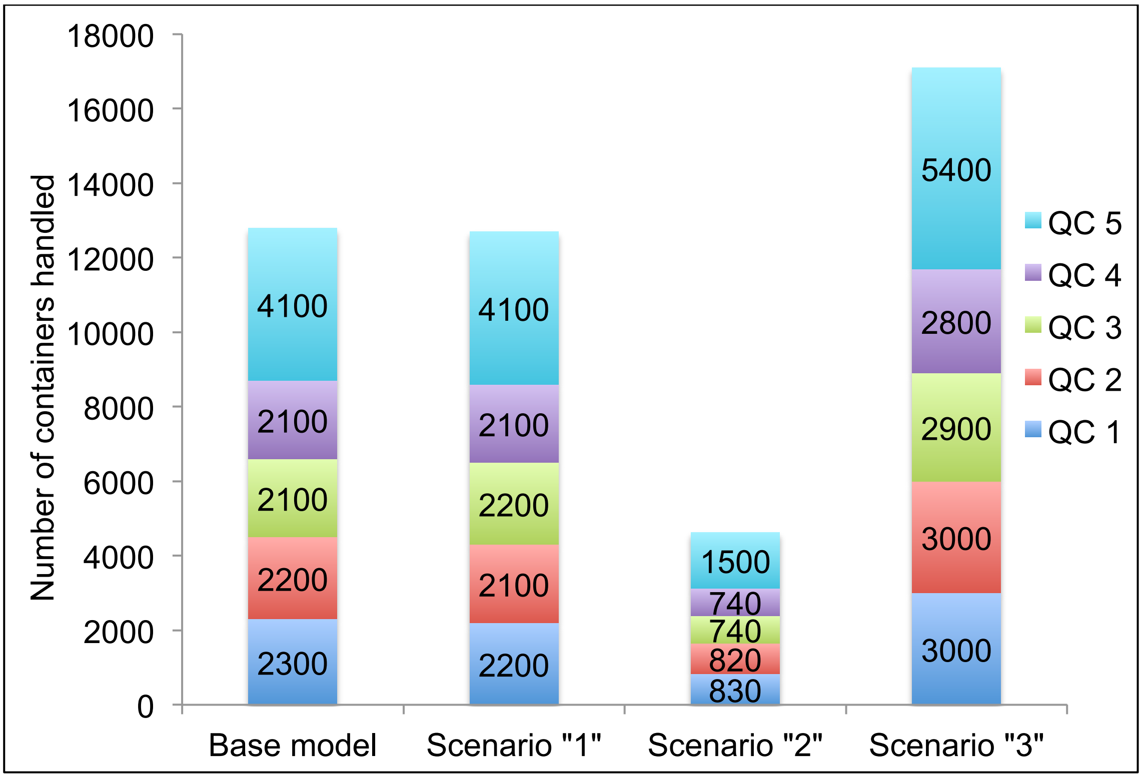


Figure 8.10: Average numbers of imported containers handled by quay cranes for a trial of 12 runs

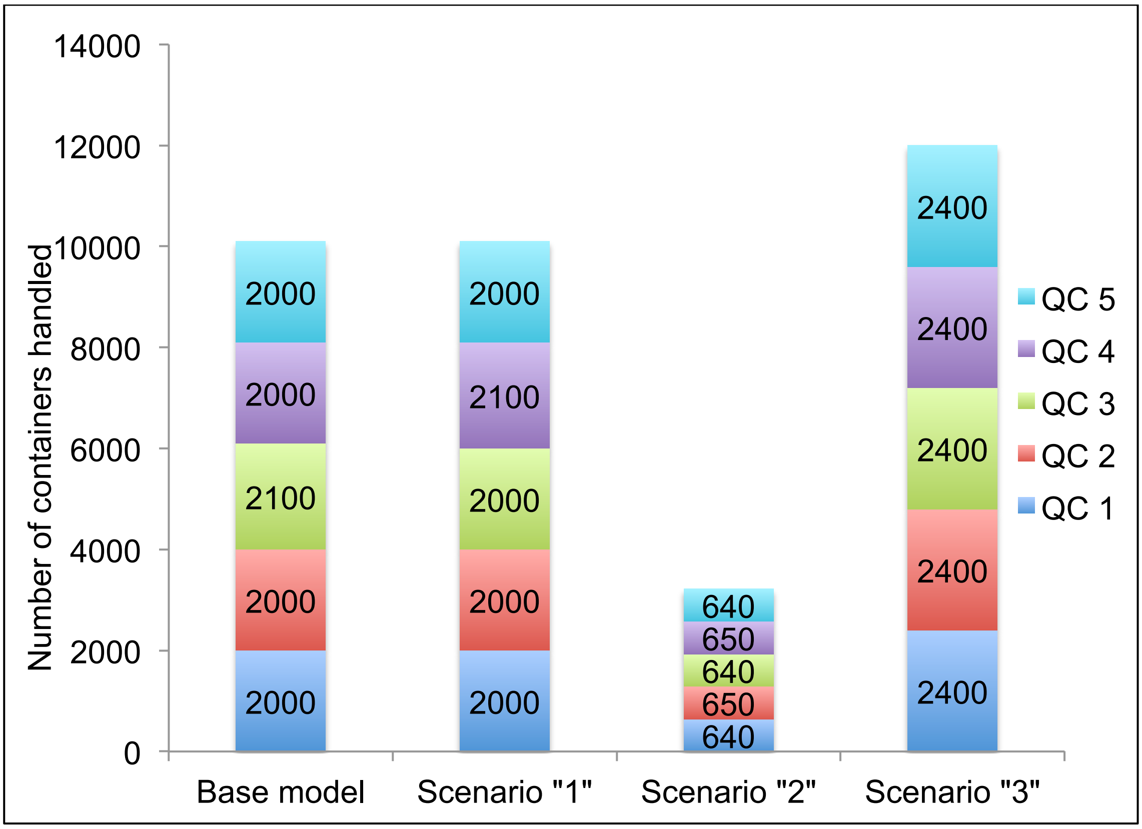


Figure 8.11: Average numbers of exported containers handled by quay cranes for a trial of 12 runs

As regards import tractors, utilization percentages show a noticeable decrease from scenario “2” with an average of 79% to scenario “3” with an average of about 25%. It is also noted that the average use is reduced from about 9 import tractors under scenario “2” to about 3 import tractors under scenario “3”. The number completed (i.e. number of imported containers handled) by import tractors sharply rises from an average of 4600 containers under scenario “2” (due to the bottleneck discussed in scenario “2”) to an average of about 17200 containers under scenario “3” after relaxing the bottleneck and accordingly smoothing the flow of imported containers. The same situation is repeated in the export tractors, where a reduction is achieved in both the utilization percentage and the average use while an increase is realized in the number completed. For instance, the utilization percentage falls from 77% on average with an average use of 10 export tractors under scenario “2” to a utilization percentage of 15% on average with an average use of only 2 export tractors under scenario “3”. The average number of exported containers handled increased from 3200 containers to 12000 containers from scenario “2” to scenario “3”. Figures 8.12, 8.13, and 8.14 show the average results of tractors for a trial of 12 runs.

Moving to the lifters resources, the variations in the results of import lifters under scenario “2” as reflected by table 8.8 are more stable when compared to the results of scenario “3”. Under scenario “3” the average utilization percentage of import lifters is about 66% with an average use of 4 lifters. On the other hand, export lifters’ utilization percentages under scenario “2” are very high with an average of about 91% and an average use of about 6 export lifters out of a maximum of 7 available export lifters.

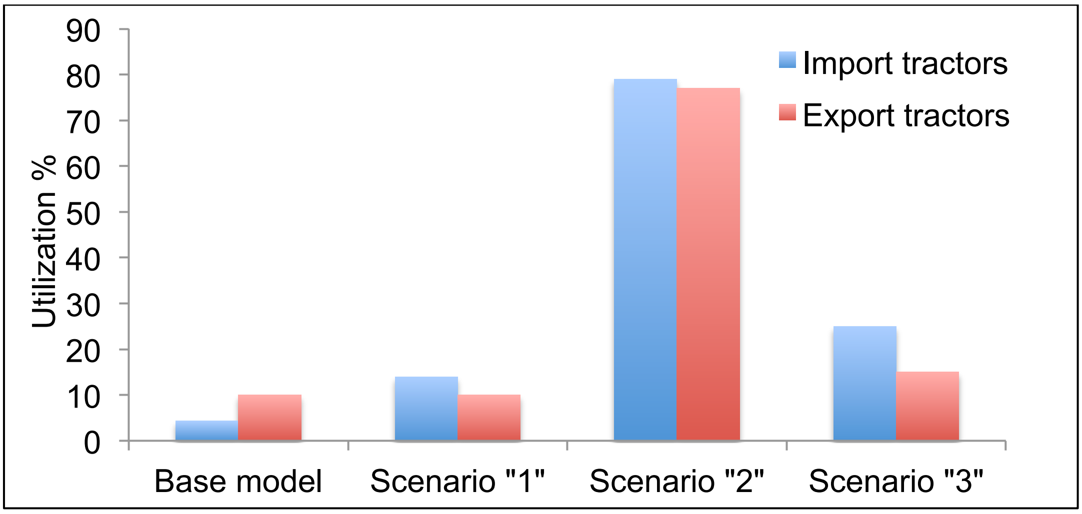


Figure 8.12: Average utilization percentages of tractors for a trial of 12 runs

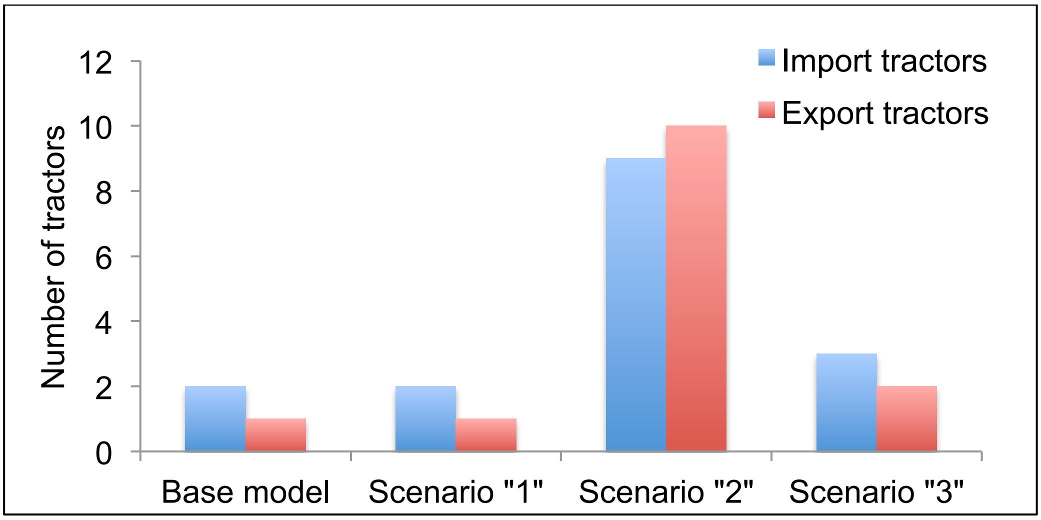


Figure 8.13: Average use of tractors for a trial of 12 runs

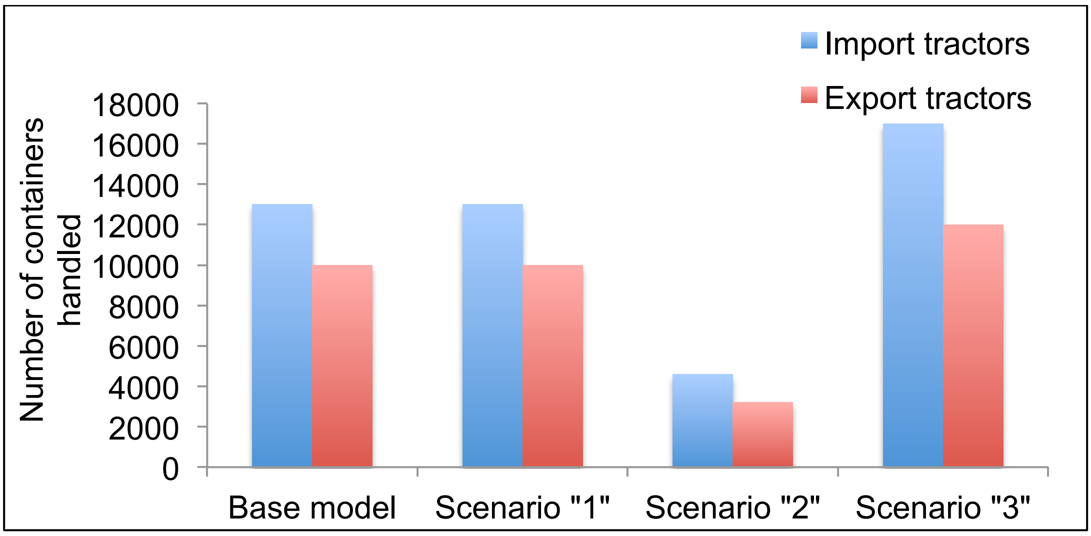


Figure 8.14: Average containers handled by tractors for a trial of 12 runs

The utilization percentage of export lifters is reduced (after decreasing the dwell time in scenario “3”) to an average of 65% and an average use of about 5 export lifters. The utilization percentage of empty lifters are decreased as well from an average of 89% to an average of 60% from scenario “2” to scenario “3”. Graphical results relative to lifters resources are shown in the following figures.

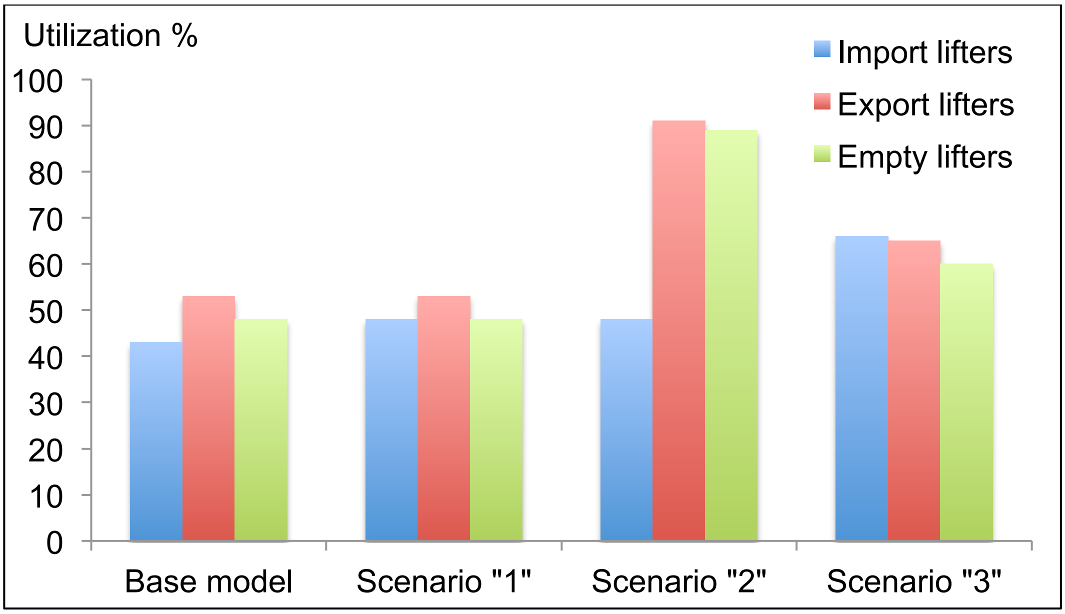


Figure 8.15: Average utilization percentages of lifters for a trial of 12 runs

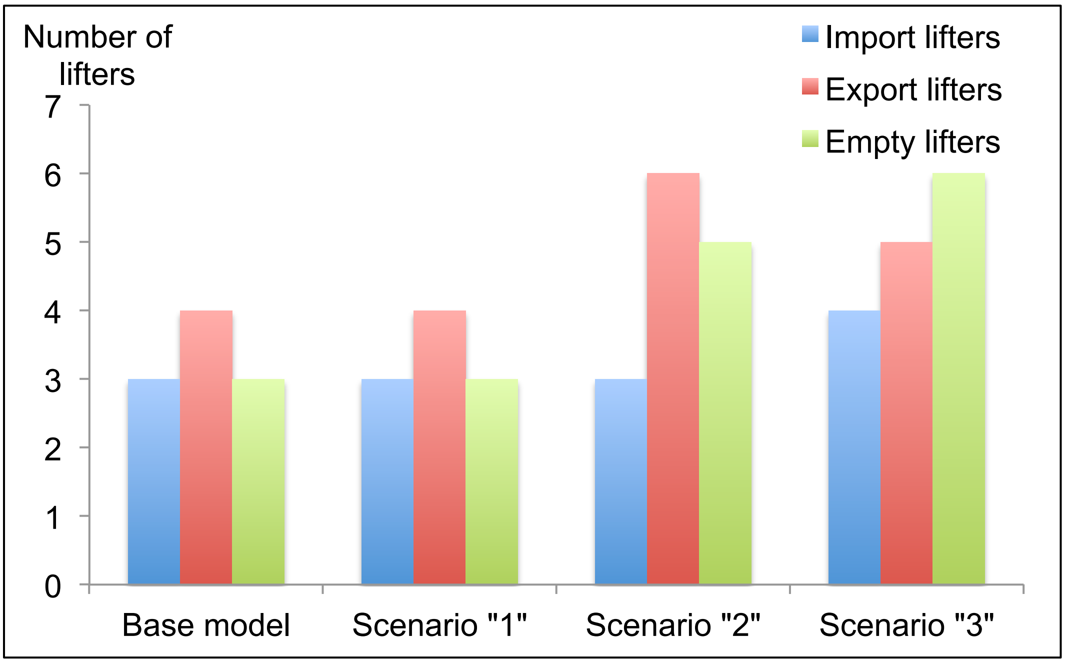


Figure 8.16: Average use of lifters for a trial of 12 runs

8.3.4 Results Relative to Queues

A significant result of scenario “3” is revealed in the “Imp queue for berths” and “Queue for export trucks” as they both reflected severe bottlenecks in the results of scenario “2” when number of handled containers is increased by 20%. Under scenario “3”, by reducing dwell time by 30%, both queues are greatly relaxed. The following table shows the maximum queue size and the items entered during the whole trial of 12 runs. When comparing these results to the results indicated by tables 8.3 and 8.4, it is obvious that scenario “3” would have a significant impact on relaxing the bottlenecks resulted from scenario “2”. In “Imp queues for berths”, the maximum size in queue is 1 in all the runs except just one run only. This means that a maximum of only one vessel is in queue for berths in 11 runs of the trial, which greatly differs from scenario “2” as the average queue size is 17 vessels. Similarly, the maximum “Queue for export trucks” size is around 14 containers in 11 runs of the trial. The maximum size in only one run is about 3000 containers. This is very different from the same results under scenario “2” where the average queue size for exports is 4000 containers on average. The maximum queue size for exports and imports for the whole trial under scenario “3” is shown in table 8.9.

Performance measure	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Imp queue for berths	1	1	12	1	1	1	1	1	1	1	1	1
Queue for exp trucks	14	12	3106	12	14	17	12	15	12	10	13	13

Table 8.9: Results of imports and exports’ queues for a trial of 12 runs under scenario “3”

As a conclusion, the sensitivity revealed from the results of scenario “3” is that reducing dwell time by 30% enables the system to handle the 20% increase in numbers of handled containers and consequently increases the throughput of the whole process. The yards are less congested than in scenario “2” representing no bottlenecks at this stage. This directly reduced the queues’ sizes either for imports or exports to a great extent. Results of equipment indicated a general decrease in the utilization percentages (compared to scenario “2”) by about 40-50% for quay cranes, 55-60% for tractors, and 30% for lifters. This reflected a more stable and reasonable system.

8.4 Scenario “4”: Increasing Numbers of Selected Equipment

This scenario addresses a management change to the current system. It tests the impact of increasing the numbers of some selected equipment on the performance of the model. Note that this scenario is a current practice that is recently put into action as a way of development to the current situation. The company decided to increase the number of yard cranes by two more cranes, the number of tractors by ten tractors (divided between exports and imports), and the number of lifters by four lifters (two heavy lifters and two empty lifters). This decision is an attempt to reduce the utilization of yard cranes and lifters. As regards tractors, a number of tractors were out of service (may be for maintenance purpose) and they are back in service. This gives a space for maintaining other types of equipment which are in service all the time. It is also a preventive action in order not to face any breakdowns of equipment especially when an increased number of containers is expected to be handled in the coming years. The updated numbers of equipment are considered in the settings of the model under scenario “4” to test the impact of this change on the results of running the simulation model (mainly the results of the selected equipment mentioned above). This change has slightly changed the structure of the model (from figure 8.4), to include two more yard cranes “in and out” numbered as “yard crane 9 in and out” and “yard crane 10 in and out”. Linkages to/from those cranes are considered, and their parameters are set as the other cranes in terms of timing, routing in, routing out…etc. As regards tractors, a total of 35 tractors are divided between imports and exports where 17 tractors are allocated for imports and 18 tractors are allocated to exports. The number of lifters also increased by one more import lifter to be 7 import lifters, one export lifter to be 8 export lifters, and two empty lifters to be a total of 8 empty lifters. Figure 8.17 shows a screenshot for the results of running the simulation model for one run under scenario “4”.

Since this change is just in the numbers of selected equipment, thus most of the results do not show a noticeable change from the base model. For instance, throughput results (either for exports or imports), average time in system, utilization of import yards or export yards, and quay cranes’ results do not reveal a remarkable variation between the base model and scenario “4”. The following section will display the results of scenario “4” for a trial of 12 runs, focusing on the results of yard cranes, lifters, and tractors. Some figures will compare the results of the base model to the results of scenario “4”.

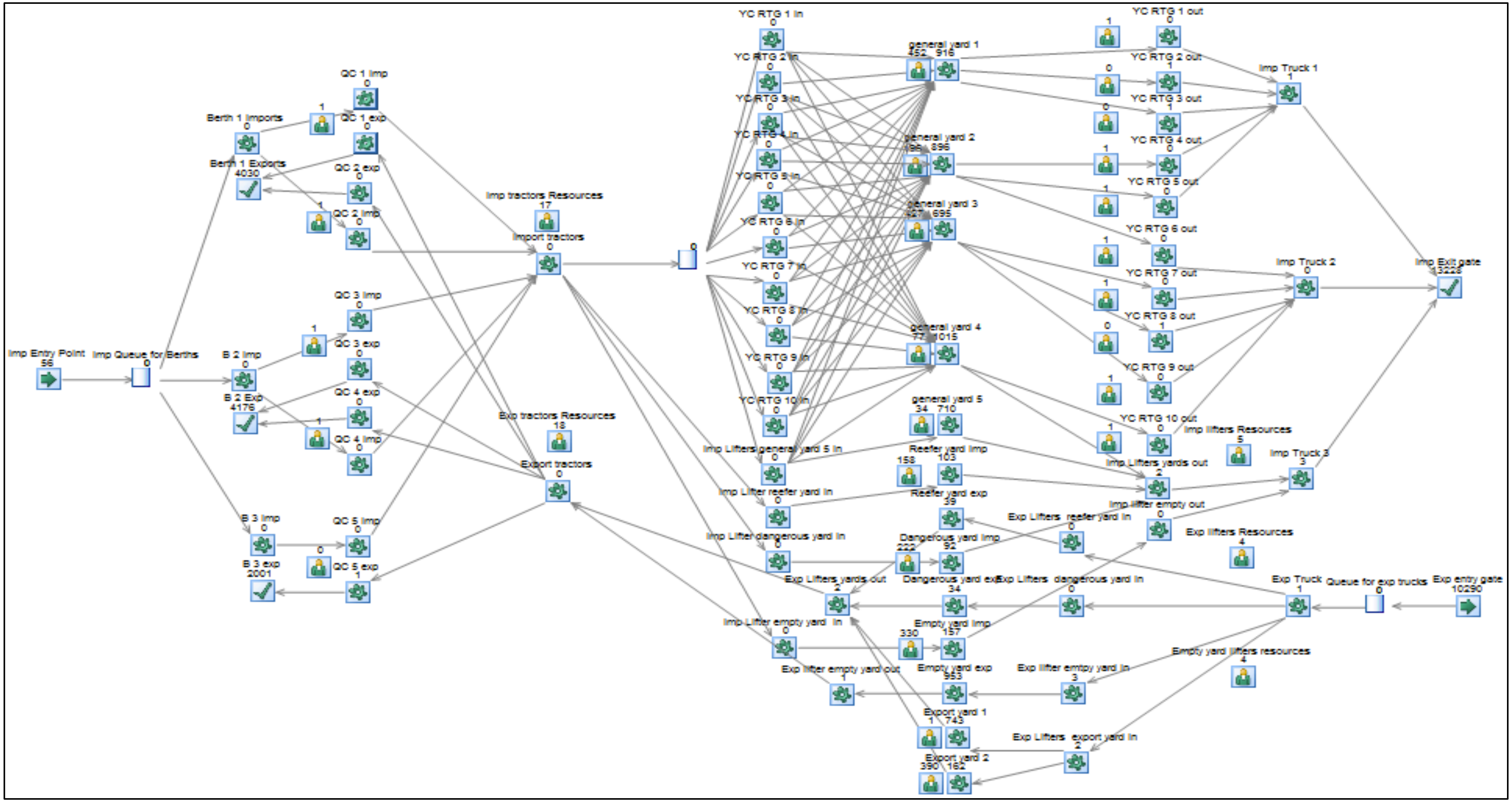


Figure 8.17: A screenshot of the results of one run of the simulation model under scenario “4”

8.4.1 Results Relative to Yard Cranes

The most significant result of scenario “4” is revealed in the utilization percentages of yard cranes and the number completed (i.e. the number of containers handled). Adding two more yard cranes reduced the utilization percentages of the old cranes and the number of containers handled. Since the results of all the runs are similar, the following figures show the average utilization percentages and the average numbers of containers handled by the eight yard cranes under the base model and the ten yard cranes under scenario “4”. When comparing the average numbers of containers handled under scenario “4”, which are shown in figure 8.18 with those numbers under the base model (refer back to figure 7.14), it is clear that the average numbers of handled containers either “in” or “out” are reduced from 955 “in” containers and 980 “out” containers on average under the base model to about 890 “in” containers and 780 “out” containers under scenario “4”.

In figure 8.19, the average utilization of each yard crane is displayed. The results reveal that adding two more yard cranes reduces the average utilization percentage of yard cranes by about 10% from 59% on average under the base model to about 49% under scenario “4”.

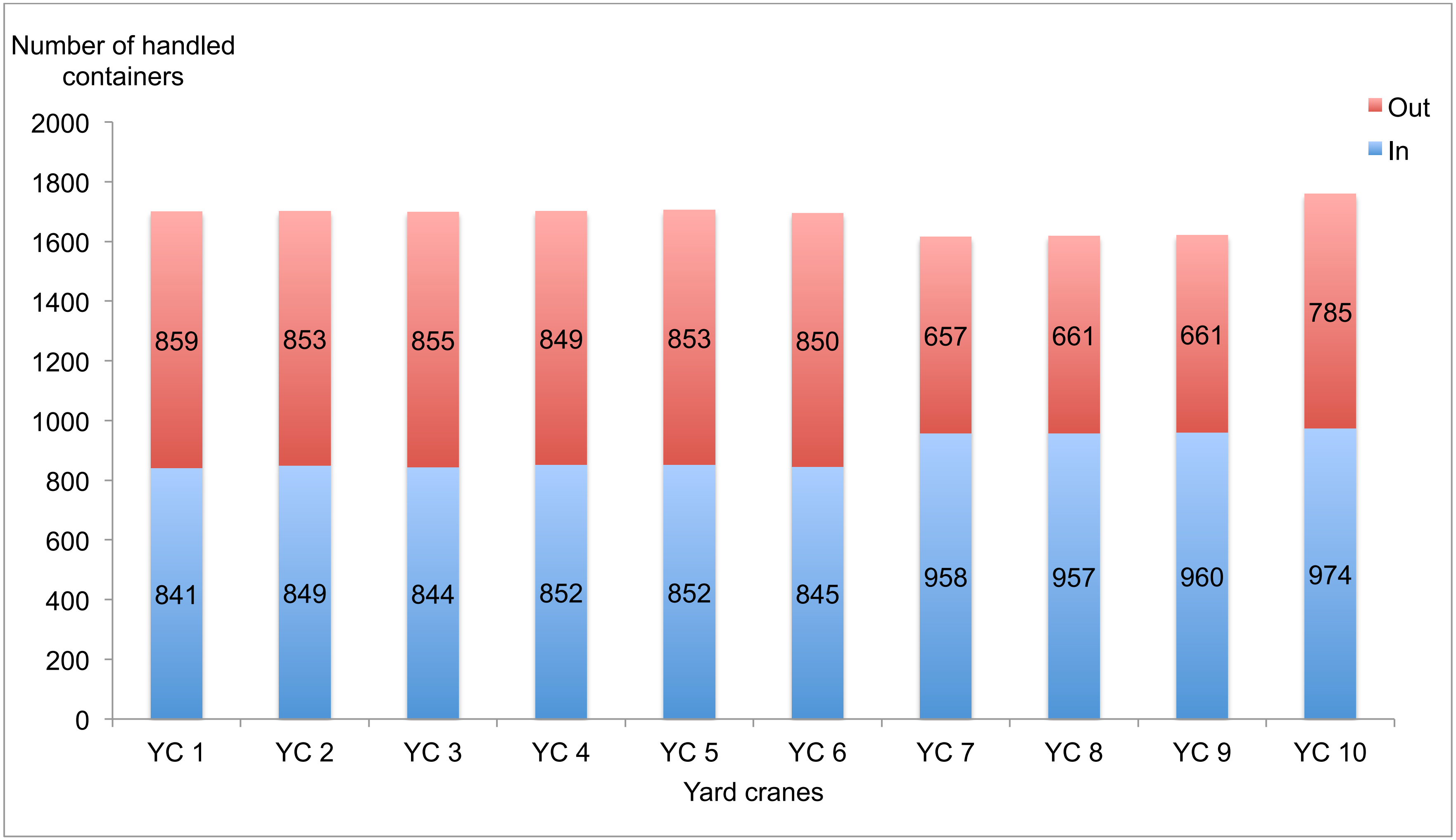


Figure 8.18: Average number completed by yard cranes for a trial of 12 runs under scenario “4”

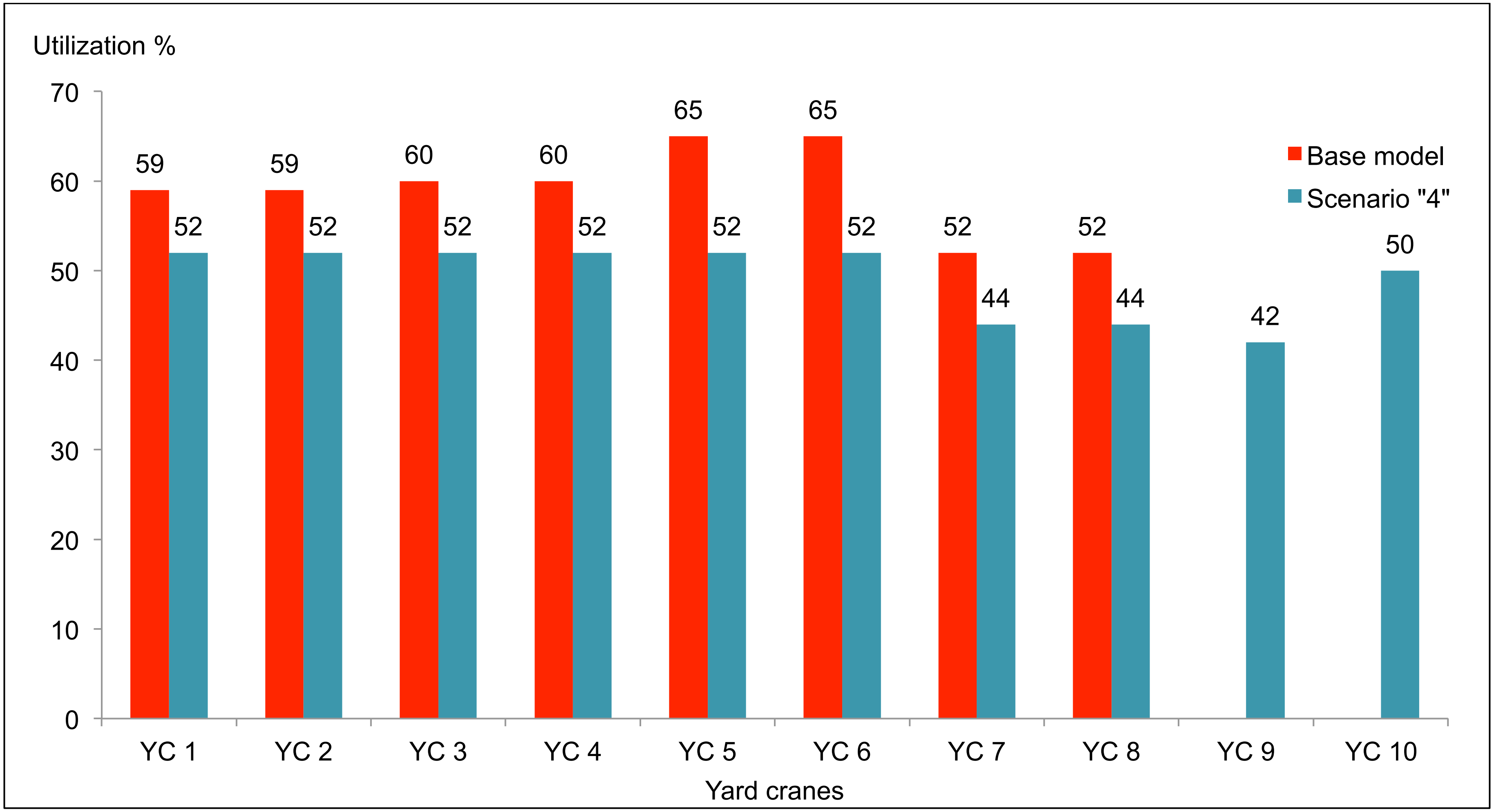


Figure 8.19: Average utilization percentages of yard cranes for a trial of 12 runs

8.4.2 Results Relative to Tractors

Under scenario “4”, it is assumed that 17 tractors are allocated to imports (this number is 12 under the base model) and 18 tractors are allocated to exports (which is 13 under the base model). The results show a decrease in the average utilization percentage of import tractors by about 5-10% from 14% on average under the base model to 9% on average under scenario “4”. The average utilization percentage of export tractors also decreased by about 2-5% from the base model to scenario “4”. This is shown in figure 8.20. In general, import and export tractors do not reach their maximum capacity in nearly all the runs. This indicates that increasing the number of tractors does not have a significant influence in this stage of the model.

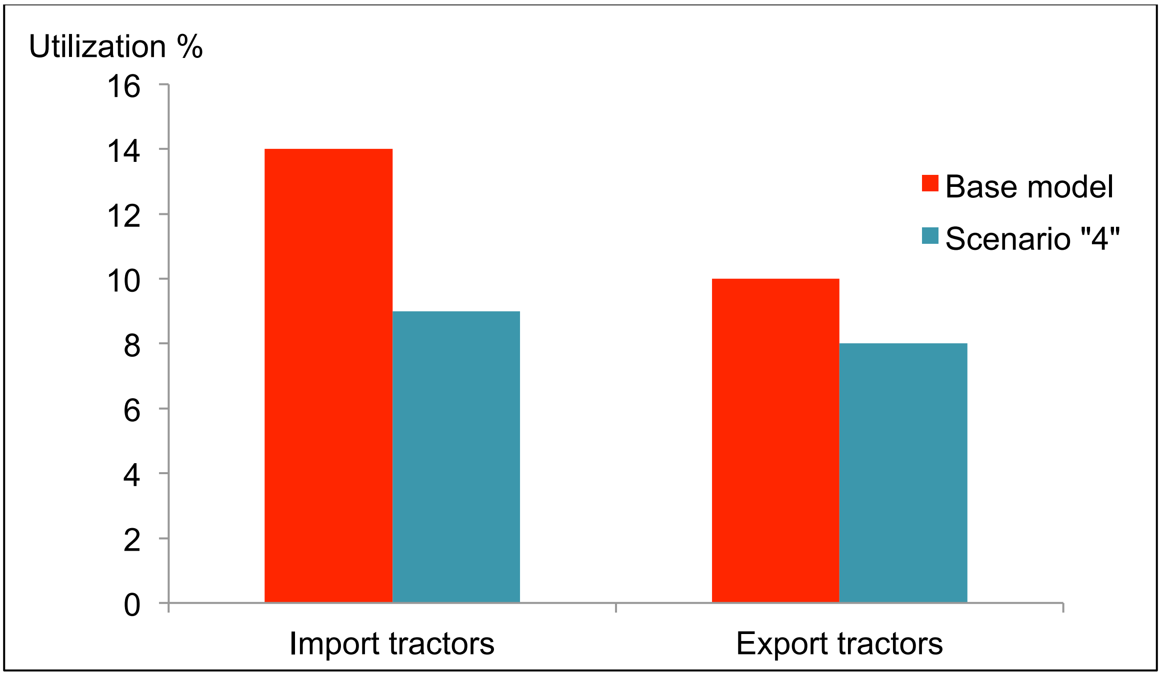


Figure 8.20: Average utilization percentages of tractors for a trial of 12 runs

8.4.3 Results Relative to Lifters

Increasing the number of import lifters by one lifter results in decreasing the average utilization percentage of import lifters by about 10% from an average of 43% under the base model to about 33% under scenario “4”. Also adding one more export lifters reduces the average utilization percentage of export lifters from 53% on average under the base model to 47% on average under scenario “4”. Empty lifters are increased by 2 lifters, which results in a reduction of more than 10% from 48% on average under the base model to an average of 37% under scenario “4”. Note that in all types of lifters, the maximum number of available lifters is reached in most of the runs. This gives a managerial insight that it would be useful to reduce the utilization percentages of lifters in case of peaks. Figure 8.21 compare the average utilization percentages of all types of lifters under the base model and scenario “4”.

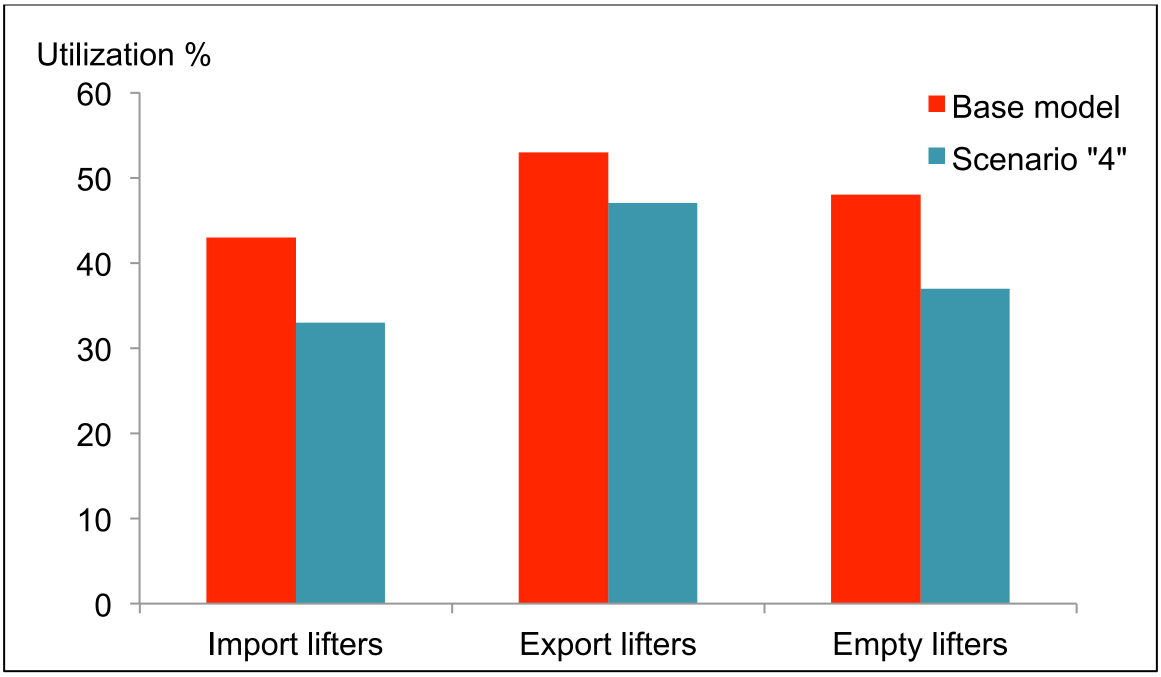


Figure 8.21: Average utilization percentages of lifters for a trial of 12 runs

To conclude scenario “4” and measure its sensitivity, as a result of increasing the number of some equipment in the system (two yard cranes, ten tractors, two heavy lifters, and two empty lifters), the results showed a decrease in the average utilization percentages by about 10% in yard cranes and lifters (all types) and up to about 5% in tractors, reflecting a more relaxed system.

8.5 Summary

This chapter analysed three additional scenarios. Firstly, it started with scenario “2”, which represented an external change to the logistics processes. It investigated the impact of increasing the number of containers handled by 20% (based on the forecasts and expected growth in container traffic), either for imports or exports, on the overall logistics processes with a view to identifying any bottlenecks that may happen in the chain. The scenario parameters are modified to represent the change and the simulation model was re-run. The results of the scenario revealed a few expected bottlenecks at some stages of the model along the imports and exports flows.

Secondly, scenario “3” was suggested as a potential solution to relax the bottlenecks discovered by scenario “2”. It tested the impact of reducing dwell time by 30% (as suggested by scenario “1” in chapter 7) on the status of scenario “2” (increasing numbers of handled containers by 20%). The settings of the simulation were adjusted to re-run the model and obtain the new results. Scenario “3” showed to be a significant solution to overcome the expected problems stimulated by scenario “2”, reflecting a more reliable and stable system.

Thirdly, scenario “4” was tested to address the impact of a management change to the current system, it examined increasing the numbers of selected equipment as a recent practice decided by the company. The scenario included adding two more yard cranes, two more heavy lifters, two more empty lifters, and ten tractors back to service. Since the main target of this decision is to relax the utilization of equipment, the results of this scenario focused on the utilization percentages of the equipment that have been increased. This can be a helpful decision to relax the equipment utilization especially when an increased number of containers is expected to be handled as discussed in scenario “2”.

The next chapter will be the discussion chapter. It will summarize and conclude the whole thesis, link the main research objectives to its findings, identify the limitations of the existing work, and discuss its contributions to theory, industrial practice and policy.

Chapter 9

Discussion

9.1 Introduction

The previous two chapters (7 and 8) presented a comprehensive analysis for the base simulation model and the four suggested scenarios. The suggested scenarios addressed different kinds of changes to the base model, i.e. efficiency change, external change, and management change. The impact of each one on the results of re-running the simulation model was tested, analysed, and interpreted. In this chapter, a critical discussion of how this work has changed the understanding of the relevant issues is presented. It starts with an introduction then it briefly reviews the literature and identifies the main research gaps. The next section discusses how research questions and objectives have been met through highlighting the research framework and methodology adopted. The remaining sections discuss the contribution of this study to knowledge/theory, industrial practice, and policy. The chapter concludes by pointing out the research limitations.

Container terminal logistics systems play an increasingly important role in modern international logistics (Li and Li, 2010) as global container traffic has grown from 28.7M to 152.0M movements between 1990 and 2008. This corresponds to an average annual compound growth of 9.5% and is projected at 10% until 2020. In the same period, container throughput went from 88M to 530M an increase of 500% (Salido et al, 2012). To cope with this rapid increase in the number of containers is a key challenge that faces container terminals. They have to innovate ways to optimize their logistics processes (Rashidi and Tsang, 2005, 2013). Other issues facing container terminals today include capacity constraints, lack of adequate decision making tools, congestion, and environmental concerns (Sharif and Huynh, 2013).

It is increasingly important for terminals to be able to provide high-quality services for their users, particularly shipping lines as they focus on the provision of door-to-door logistics services (Panayides and Song, 2009). In order for a container terminal to be able to compete effectively, it has to provide a first class container logistics system through optimizing task assignment, resources allocation and scheduling management (Li and Li, 2010). However, managing the entire system is a very complex process that requires numerous decisions and stimulates the need to develop simulation tool systems for decision support. This is a crucial contribution whereby the simulation process encompasses parameters for measuring terminal productivity and identifies the required working processes. Efficient simulation tools assist managers to make appropriate operational decisions (Beškovnik and Twrdy, 2010).

9.2 Issues Investigated

In this study, the literature review was organized as follows. Firstly, an overview of container terminal planning was provided, which includes terminal strategic and tactical planning, and operational planning. Secondly, the literature related to modeling logistics process at container terminals was reviewed.

Depending on the planning horizon of container terminals, planning levels can be categorized into strategic, tactical, and operational planning problems. At the strategic level, the location and layout design of new terminals, including the type and quantity of equipment to be used and the degree of automation are the main decision variables. Tactical decisions involve the space utilization within the terminal, i.e. assigning specific stacks to different types of containers such as reefer, empty, and special containers and the layout of traffic courses for the horizontal transport system. At the operational level, plans for container terminal resources are generated to organize the service of vessels, trucks and trains (Meisel, 2009). Strategic and tactical planning levels of a container terminal are referred to as terminal design, while operational problems are referred to as terminal logistics (Lehmann et al, 2006).

During the first stage of the planning process for a container terminal when planners have to tackle terminal design problems, they should analyse these problems in terms of economic as well as technical feasibility and performance. The various design problems include: multimodal interfaces, terminal layout, equipment selection, berthing capacity, and IT systems and control software (Gunther and Kim, 2006, Zeng et al, 2011, Alessandri et al, 2009, Chu and Huang, 2005 and Schmidt et al, 2005).

The level of operational planning consists of the main planning steps required to perform the various logistics processes in a container terminal. When planning and scheduling the use of available resources for a short term planning horizon, usually several days or weeks, specific operational issues should be considered (Steenken et al, 2004 and Gunther and Kim, 2006). Meisel (2009) classified the operational planning problems at a container terminal into three categories: the seaside operations, the yard operations, and the landside operations.

The second section of literature reviewed the planning problems at a container terminal from the modelling perspective. This literature is more relevant since the main purpose of this study is to model the logistics process through the different stages of operations planning. This section was classified into three sub-sections: terminal internal operations planning either at the seaside operations planning or the yard operations planning, landside operations planning, and integrated operations planning.

A trend in the literature viewed the container terminal as a global system, and instead of a single optimization problem, the entire flow of containers is considered and optimized and all the container terminal operations are studied together (Yang and Shen, 2013, Li and Li, 2010, Legato et al, 2009, Stahlbock and Voß, 2008, Legato and Trunfio, 2007, Günther and Kim, 2006, Kim, 2005, Murty et al, 2005, Hartmann, 2004, Veenstra et al, 2004 and Steenken et al, 2004).

This thorough extensive literature review helped identify the research gaps and related research questions. It is obvious that research on container terminal planning is abundant, with a specific group of literature focusing on using modelling and simulation techniques and tools to study container terminal operations and how they are interrelated. Within this group, some researchers focused on a particular planning level while others attempted to address a combination of two or several planning levels.

Three research gaps can be observed. Firstly, although integrated operations planning in container terminals has attracted a lot of attention in the last decade (Stahlbock and Voß, 2008, Günther and Kim, 2006 and Steenken et al, 2004), there is a lack of research to address the terminal logistics processes from both pipe flow and dynamic operation perspectives. Secondly, as uncertainty exists in customer demands and processing activities such as consolidation, movement, handling, discharge, maintenance and repair (Song et al, 2007), it represents an inherent characteristic in container terminal logistics processes. Many existing studies adopted a deterministic approach, or focused on specific types of uncertainties in a specific activity (Arango et al, 2011, Legato et al, 2010 and He et al, 2010). However, there is a lack of research which reports comprehensive scenario analysis of the impacts of various uncertainties in the logistics processes, on terminal performance. Thirdly, although some studies included case studies for some container terminals worldwide, little research has been undertaken into Egyptian container terminals. However, there is a growing need for research in the areas of simulation and modelling of integrated container terminal operations with specific applications in Egyptian container terminals with a view to raising the performance level of such terminals.

9.3 Overview of Research Methodology and Framework

This research follows a case study approach for two main reasons. Firstly, case study methods provide a convenient strategy with which to investigate how and why type research questions (Dinwoodie and Xu, 2008), and this matches the research questions of this study that were summarized in chapter two. Secondly, this approach suits the nature of this study and fits our aim and objectives (that are listed in chapter one). Note that modelling and simulating the logistics processes of a container terminal requires a detailed level of data including both statistical and operational data. The case study approach is appropriate in the sense that we can concentrate on a single container terminal to collect sufficient operational data that enables us to build the model.

The methodology used in this research included both qualitative and quantitative methods. The research followed a descriptive methodology by which data was dealt with according to sequential processes. Data was collected in terms of primary data collected by the researcher as well as secondary data in the company’s records. This study was conducted in the following sequential steps to achieve the research objectives:

Step 1: Reviewing literature related to container terminal operations and logistics control issues, then surveying Egyptian container terminals to decide on a specific case study. This step achieved the first objective of the research.

Step 2: Upon selecting the case company, data required was collected using the method of "interviewing" by which several interviews were conducted with different personnel within the case company starting from the chairman of the company to the operations department employees, management department employees, and the research and development department employees. A few unstructured interviews as well as a number of semi-structured interviews were conducted. During these interviews, various groups of questions were addressed to the interviewees to obtain the required data for the research. This step helped achieving research objective two.

Step 3: The findings of these interviews were organized and presented in two main sets. First, a description of the entire logistics processes that take place in the company for both import and export flows. Second, a set of quantitative data representing the resources of the company as well as operational data relative to the entire operations of the logistics processes. This met the scope of the third research objective.

Step 4: Data was initially presented in a pipe flow model to show the interrelations between the various resources of the company. The pipe flow model would contribute to identifying bottleneck resources/activities at a higher planning level. This step achieved research objective four and partially satisfied the first research gap observed.

Step 5: The proposed pipe flow model was then used as a guide to further build and develop an operational level simulation model, using Simul8 software, that covers the entire logistics processes of import and export container flows and shows, to a great extent, the actual inbound and outbound flows of containers from the entry point to the exit point. This dynamic operation model would enable evaluation of the interacting effect between various activities at a lower planning level. This step is complementary to the previous step to completely satisfy the first research gap and meet the fifth research objective and part of the sixth objective.

Step 6: Several versions of the model were developed in order to establish the most reasonable and representative one. First, a separate model for imports logistics process and a separate model for exports logistics process were built. Second, based on these two models, an integrated logistics model for both import and export processes was built considering the shared resources between both flows (i.e. yards and equipment). Third, the integrated model was then refined by taking into account the operational data collected as its input parameters. Fourth, several runs and trials were conducted to test the programming code. Finally, the simulation model was verified and validated to ensure that the model is correct, reasonable and representative. Validating the model is part of the sixth research objective and simultaneously, it satisfies the third research gap.

Step 7: After building and validating the base simulation operational model, scenarios were suggested for improving the terminal's performance. Every scenario addressed a certain change to the model parameters based on some forecasts, predictions, and current practices. Each change was illustrated and justified, then the results of running the simulation model with this change were displayed, analysed, and interpreted in order to show the impact of this particular change on the entire process. This analysis revealed expected bottlenecks at some stages of the process under certain circumstances in some scenarios, provided potential solutions for expected problems in other scenarios, and presented managerial insights for improvement or for better performance to the concerned decision makers in other scenarios. This step was undertaken to achieve the last research objective and satisfy the second research gap.

The following table summarizes and links the steps undertaken throughout this research to the desired research objectives, gaps, and questions.

Step(s) undertaken	Research objective(s) achieved	Research gap(s) satisfied	Research question(s) answered
Step 1: Literature review	Objective 1: Analyse the characteristics of container terminal layout and operations and related logistics control issues.		
Step 2: Case study survey	Objective 2: Identify the various logistics processes performed within container terminals, noting any processes specific to Egyptian container terminals.	Gap 3: Little research has been undertaken into Egyptian container terminals.	
Step 3: Case study description	Objective 3: Synthesise the key issues that affect logistics processes in a case study of one Egyptian container terminal.	Gap 3: A growing need for research in the areas of simulation and modelling of integrated container terminal operations with specific applications in Egyptian container terminals.	Question 1: How are the main logistics processes in the container terminal carried out?
Step 4: Pipe flow model	Objective 4: Develop a pipe flow model of the physical and information flows through a container terminal to identify the key bottlenecks in the case company.	Gap 1: A lack of research to address the terminal logistics processes from pipe flow perspective.	Question 2: Where are the bottlenecks in the container terminal logistics processes?

Step 5: Base Simulation model	Objective 5: Propose and evaluate appropriate techniques or tools to model dynamic flows in container terminals. Objective 6: Build the simulation model.	Gap 1: A lack of research to address the terminal logistics processes from a dynamic perspective. Gap 3: A growing need for research in the areas of simulation and modelling of integrated container terminal operations with specific applications in Egyptian container terminals.	Question 4: How is the container terminal's performance measured for individual resources and as a whole system?
Step 6: Model verification and validation	Objective 6: Evaluate and validate the simulation model.		
Step 7: Scenario analysis	Objective 6: Undertake sensitivity testing and scenario analysis, and feedback the findings and results.	Gap 2: A lack of research which reports comprehensive scenario analysis of the impacts of various uncertainties in the logistics processes, on terminal performance.	Question 3: How can the container terminal's managers overcome the main problems or bottlenecks? Question 5: How can performance measures be improved?

Table 9.1: Linking research steps to its objectives, gaps, and questions

9.4 Research Contribution

In the light of the above framework, this research provides some contributions to knowledge, industrial practice, and policy. These contributions will be discussed in the following sections.

9.4.1 Contribution to Knowledge

This study proposes a pipe flow model for container terminal logistics process to show the interrelations between the various resources. This pipe flow model contributes to identifying the bottlenecks in the entire logistics process through analyzing the aggregated flow capacity at different stages along the pipe. Therefore, our model would help terminal planners and operators to make decisions related to the strategic/tactical and operational planning problems discussed in the literature review (Meisel, 2009 and Lehmann et al, 2006).

In addition, this is a novel study, which simulates the operational level of the entire import and export logistics processes within container terminals using Simul8 software. To the best of our knowledge, no such model has been reported in the literature.

This study also attempts to evaluate a typical container terminal logistics system including both import and export containers in the presence of multiple uncertainties in terminal operations (e.g. quay crane operations, tractor operations, yard crane operations).

The research seeks to make an original contribution by adopting the use of Simul8 software not only to develop a dynamic flow simulation model but also by its application to a specific Egyptian container terminal, where such kinds of studies are very rare as reflected by the literature review. For instance, the literature review revealed that research relative to Egyptian container terminals has been undertaken either as surveys or modelling and simulation regarding port activities. In this context, this study makes a contribution by fulfilling this gap through its dynamic flow representation of logistics processes in a specific Egyptian container terminal using Simul8 software.

9.4.2 Contribution to Industrial Practice

The study provides a contribution to industrial practice in that the developed simulation model can be used as a tool by which container terminal planners, operators, and managers can make strategic/tactical and operational decisions regarding the terminal operations either in the long term or the short term. The base simulation model enables testing of different scenarios, for example, scenarios with potential solutions for the perceived problems, forecasting scenarios, and scenarios for improvement. Scenario testing enables terminal managers to make managerial decisions for the improvement of performance in areas which concern them. It can also be used by terminal planners, managers, and operators as a guidance tool to yield managerial insights or as a forecast tool to test the future investment scenario before making the real implementation.

On the case company's level, the study included four suggested scenarios to reveal the impact of different changes on the overall performance. The contribution of this study to the industrial practice can be concluded from its main findings, which can be summarized as follows:

- Scenario "1": This scenario suggested reducing the dwell time by a reasonable percentage (30%) and tested the impact of this efficiency change on the overall performance of the system. The results did not show a significant change neither in the total throughput of imports and exports nor in the utilization of equipment. This supports the literature and seems logical since the current system is stable, so that reducing dwell time should not significantly increase the throughput of imports or exports. On the other hand, results mainly revealed that reducing the dwell time by 30% would shorten the average total time in system by about 27% as it occupies the longest duration in the whole chain. The literature mentioned that dwell time and yard capacity are inversely related, this is also supported by the results of this scenario as it is found that dwell time is directly related to yard capacity utilization where a potential significant reduction by an average of 10-30% in the utilization of yards is revealed when the dwell time is reduced. This can be crucial especially in cases of peaks when handling an increased numbers of containers is expected.

- Scenario “2”: This scenario represented an external change to the logistics processes. It investigated the impact of increasing the number of containers handled by 20% (based on the forecasts and expected growth in container traffic), either for imports or exports, on the overall logistics processes. The results of the scenario revealed a few expected bottlenecks at some stages of the model. This mainly resulted in an over congestion in storage yards (imports and exports) as nearly all yards are fully utilized. Another result is reducing the overall throughput for both flows due to the inability of the system to handle more containers at some points. The increased utilization of equipment is a third result that is revealed by this scenario, i.e. increasing 20% in numbers of handled containers resulted in increasing the utilization of quay cranes by 20% as a minimum, tractors by 60-65% on average, and lifters by about 40%. This scenario contributes as a forecasting scenario with an expected problem that is likely to happen, and highlights its main consequences.

- Scenario “3”: This scenario tested the impact of reducing dwell time by 30% while increasing numbers of handled containers by 20%. The results reveal that reducing the dwell time by 30% enables the system to handle the 20% increase in numbers of handled containers and consequently increases the throughput of the whole process. The yards are less congested than in scenario “2” representing no bottlenecks at this stage. This directly reduced the queue sizes either for imports or exports to a great extent. Results of equipment indicated a general decrease in the utilization percentages (compared to scenario “2”) by about 40-50% for quay cranes, 55-60% for tractors, and 30% for lifters. This reflected a more stable and reasonable system. The contribution of this scenario is to provide a potential solution for the expected problem investigated in scenario “2” and proposes how to overcome its adverse effects.
- Scenario “4”: This scenario addressed the impact of a management change to the current system, it examined increasing the numbers of selected equipment as a recent practice decided by the company. The results show a decrease in the average utilization percentages by about 10% in yard cranes and lifters (all types) and up to about 5% in tractors. This can be a helpful decision to relax the equipment utilization especially when an increased number of containers is expected to be handled, or when some of the equipment needs to be maintained or in case of equipment breakdown.

9.4.3 Contribution to Policy

It is worth mentioning that the new Suez Canal project as a governmental policy adds value to the practical aspect of this study. The New Suez Canal is an under-construction artificial sea-level waterway project in Egypt, parallel to the pre-existing Suez Canal to allow ships to sail in both directions at the same time. The New Suez Canal is expected to expand trade along the fastest shipping route between Europe and Asia, which does not require navigating around Africa. This will decrease waiting hours for most ships. This non-stop navigation will naturally expand the number of vessels passing through the canal. Some 18,000 ships sail through the canal every year, a figure that could double after the new project increases the number of giant cargo vessels passing through. This could have a huge impact on Egyptian container terminals. A simulation tool like the one developed in this study could help to evaluate the impact of increasing numbers of vessels and containers on the performance of container terminal operations or the impact of any other change in governmental or company's policy on the overall system.

9.5 Limitations of the Study

Although the study contributes to the existing knowledge, industry practice and policy, its scope encompasses a few limitations that can be listed as follows:

- First, due to the nature of the collected data during the first stage of the study which was mainly operational data, the input parameters of the developed simulation model did not consider the cost factor as it focused only on the operational aspect of the process rather than the cost issue. Thus, this study does not consider any cost calculations and accordingly, no cost results can be obtained. This can give insights for upgrading the study through engaging the simulation based optimization approach in a way to find the minimum cost or the optimal values for any other variable previously introduced in the simulation model.

- Second, since the developed simulation model mainly simulates the dynamic flows of imported and exported containers from the point of entry to the exit point, thus all the performance measures and results that can be displayed are relevant to containers and their associated performance measures. Therefore, it is difficult to obtain results related to some specific issues such as vessel turnaround time or queuing time per vessel because the model mainly targets the container flows and not individual vessels.
- Third, one of the simulation model assumptions is that resources are available, i.e. workers and equipment are available when required. It does not handle disruptions to resources, although the percentage of resource availability can be easily introduced in the Simul8 model.
- Fourth, this is a case study based research that dealt with a specific Egyptian container terminal. Therefore, the parameters of developed simulation model were tailored based on the collected data of the case study. Generalizing the simulated model was not examined in the study, however, the implementation of the simulation model to other cases could be possible.
- Finally, this study required collecting primary data. However, some required figures were unavailable and accordingly they were estimated based on the given data.

9.6 Summary

This chapter discussed the contribution of the whole thesis. It started with a discussion of the issues identified for study in the literature review undertaken, then it summarized the research framework and methodology adopted throughout the research linking its main objectives to its findings. The chapter also discussed its contributions to theory, industrial practice, and policy. Finally, it identified the limitations of the existing work.

The next chapter will draft a set of recommendations that include recommendations for future academic work and future industrial developments and policy.

Chapter 10

Conclusions and Recommendations

The previous chapter mainly discussed the contribution of the whole thesis in terms of its contributions to theory, industrial practice, and policy. The research objectives, questions, and gaps were linked to its main findings. The limitations of the work were also identified at the end of the chapter. In this chapter, the main conclusions are outlined followed by a set of recommendations for future research either academically or industrially.

10.1 Conclusions

The main aim of this research is to model the logistics processes in container terminals, i.e. the container flows (both imports and exports) from entry to exit. The purpose of such a model is to enable different scenarios to be tested with a view to improving the overall performance. An Egyptian case study was conducted, whereby empirical and statistical data was collected to build, develop, verify, and validate an operational level simulation model using Simul8 software. A few scenarios were suggested and tested and their impact on the results was interpreted. Finally, the simulated model, its validation, and some of the suggested scenarios were reviewed by the case company with a view to obtaining relevant evaluation, assessment, feedback comments, and if any recommendations. Accordingly, the following section will summarize the main conclusions of the research, and then some recommendations for future academic work and future industrial developments and policy will be highlighted.

In chapter 9 some conclusions were discussed with the findings of the study. However, the general important conclusions, which were identified in the course of conducting this research, can be summarized as follows:

- This study revealed that simulation, as a modeling tool, is considered suitable for developing a simulation model at the operational level that simulates the logistics processes that are carried out in container terminals, especially Egyptian terminals. In addition, the study has shown that Simul8 software is convenient to be used when pipe flow modeling is the issue.
- In terms of the results of the suggested scenarios, it was concluded from scenarios “1” and “3” that dwell time is a key performance measure to improve the overall performance of the entire logistics process within container terminals, particularly when an increased number of containers to be handled is expected or even targeted.
- Another conclusion that can be extracted from scenario “2” is that the recent forecasts and trends regarding container throughput are rising considerably, both worldwide and locally. This implies that the company should clearly understand and be able to identify the areas along the whole flow of containers where bottlenecks may occur when such forecasts are met.
- Scenario “4” reflects a current practice made by the company. It measures the impact of increasing the quantity of some equipment on the whole process, especially the results which are relevant to the utilization of such equipment. This scenario is highly important not only because it represents a current practice, but also it gives considerable indications for expected future forecasts as suggested by scenario “2”.

- Finally, the study proposed a base simulation model for the logistics processes of containers in Egyptian container terminals. It was verified and validated against the collected data from the case company. This base model was shown to be representative, responsive, and reliable.

10.2 Evaluation by the Case Company

To conclude the research a further step was undertaken to finalize the study. This step was to present and discuss the model, its validation, and the suggested scenarios to the case company itself to obtain their evaluation and assessment as well as to construct a set of recommendations either for future research or for industrial developments based on their valuable feedback and constructive comments. In this context, a visit was conducted to the premises of the company and the idea of the study was presented to them. This visit was crucial to add to the credibility of this work. In general, they praised very much the efforts exerted throughout this study especially to build and develop the simulation model, which was generally satisfying to them. They confirmed the data collected since year 2010 to verify and validate the base simulation model, and then the suggested scenarios were discussed. They agreed that the suggested scenarios can be achievable especially scenarios “2” & “4”. They confirmed that scenario “4” is currently being practiced and that the relevant data are available on the company’s website. They also endorsed that one of their objectives is to increase the number of containers being handled (i.e. increasing throughput), which was addressed by scenario “2”. After a long discussion, some comments from the practitioner perspective were given from which a few recommendations will be outlined in the following sections. By the end of the visit, an internal official report from the company was written to confirm this visit and summarize the main outcomes of it. Since the company does not issue any translated reports, the report was issued in Arabic. The report was written on an officially headed paper with the name of the company, it was signed by the chief board of directors and stamped with the logo of the company. A copy of this report is attached to the appendix of the study.

The next sub-sections will draw a set of recommendations based on the findings and conclusions of the study, as well as the comments received from the case company.

10.2.1 Recommendations for Future Research

As previously mentioned in chapter 9 of the study, there are some imitations to this work. These limitations create some implications for future research in this area that can be outlined as follows:

- Since the study only focuses on the operational issues and it does not consider the cost factor, future research can incorporate the cost element in the parameters of the simulation model (this should be possible as Simul8 has the financial module to include the costs), and may even use other software (e.g. ARENA) to develop similar models. The study can be also enhanced by employing the simulation based optimization as a more advanced approach, which is the process of finding the best values of some decision variables for a system where the performance is evaluated based on the output of a simulation model of this system.
- The main focus of this study and the simulation model is the flow of containers, so that further research can adjust the model to consider the vessel rather than the container to enable obtaining a wider range of performance results as regards vessel turnaround time for example, which is a key objective to container terminals.

- The simulation model developed does not handle disruptions to resources, although the percentage of resource availability can be easily introduced in the Simul8 model. Thus, prospective researchers are invited to adapt the model to represent different cases taking into consideration the issue of unavailable resources, including for example the case of a strike, equipment breakdown or damage.
- In addition, there is a potential that pipe-flow logistics simulations can be applied to model other different logistical areas such as modelling automated guided vehicles in terminals, repositioning of containers and related developments.

10.2.2 Recommendations for Future Industrial Developments

Some of the following recommendations are derived from the visit conducted to the case company and the practical feedback and comments obtained; other recommendations can be beneficial to the industry in general:

- Due to the time constraint, generalizing the simulated model was not examined in the study. In this sense, it is highly recommended that this model can be implemented to other Egyptian cases with slight changes to the model according to the case and its collected data. The case company operates another terminal in ElDekhiela port and it was suggested that the developed simulation model of this study can be implemented and further scenarios can be tested. The scope of application of the simulated model can also be extended to other Egyptian container terminals in accordance with the collected data and investigation undertaken and revealed in chapter three.
- One of the recommendations of the case company is that the model can be helpful to examine the impact of increasing the number of entering

vessels to the terminal rather than the number of containers as addressed by scenario “2”. This can be easily examined using the same parameters of scenario “2” with a very slight change.

- It is also recommended that the model can be adjusted to give some performance suggestions relative to the optimal number of cranes to be allocated to a vessel with a certain number of containers with a view to achieving the highest operating rate of the vessel.
- Another suggestion is related to yard cranes where a variable can be added to each crane to control whether or not to operate this crane according to the operating conditions.

10.3 Summary

This chapter outlined the general conclusions of the study followed by a set of recommendations for future research and future industrial developments based on the outcomes of the visit that was conducted to the case company to discuss the idea of the research.

Appendix I

An Internal Report from the Case Company

شا	ن	7017

وزارة الاستثمار
الشركة القابضة للنقل البحري والبرى
شركة الإسكندرية لتداول الحاويات والبضائع
ALEXANDRIA CONTAINER & CARGO HANDLING CO
شركه تابعه مساهمه مصريه(ش0ت0م0م)

رقم القيد :
التاريخ : 2/ 2 / 2015
المرفقات : ------

الى من يهمه الأمر

تقدمت السيدة / هبة المسمارى مساعد محاضر بأكاديمية العربية للنقل البحرى بشأن نموذج رسالة الدكتوراه المتقدمة بها مع أخذ محطة الاسكندرية لتداول الحاويات والبضائع كحالة دراسية يتم تجربة النموذج عليها .

- تم استعراض النموذج والتعرف على فكرة تنفيذه وكيفية تطبيقه على البيانات الحاصلة عليها السيدة / هبة المسمارى من محطة الأسكندرية عام 2010 حيث أن الغرض الرئيسى من النموذج هو عرض تدفق تحركات الحاوية (وارد / صادر) فى محطة الحاويات من بداية دخولها للمحطة حتى إتمام صرفها من المحطة .
- تم إستعراض السيناريوهات المقترحة لهذا النموذج .
- تم إقتراح بعض التوصيات لتعظيم الأستفادة من هذا النموذج وعلى سبيل المثال الاتى :-

(أ) - وضع تصور للطريقة المثلى لتشغيل سفينة ما بعدد حاويات معينة على أن يقوم النوذج بإحتساب العدد المثالى من أوناش الرصيف المقترحة للعمل لتحقيق أعلى معدل تشغيل لهذه السفينة .

(ب) - نظراً لأن النموذج المطبق يعتمد على ربط عملية تدفق البيانات من كل معدة إلى أخرى بعدد كبير من الروابط التدفقية فإننا نقترح فكرة إضافة متغير لكل ونش يسمح بإعتباره OFFأو ON حسب ظروف التشغيل مما يسهل عملية التحكم فى مدخلات النظام .

مع الأخذ فى الأعتبار المجهود المبذول فى هذه الرسالة أملين دوام النجاح والتوفيق .

لواء بحرى أ.ح /
" علاء الدين مأمون ندا "
رئيس مجلس الادارة والعضو المنتدب

القطاع :- الحركة والتشغيل	الادارة :-العامة للحاسب الالى	التوقيع :------------

محطة الإسكندرية : فاكس : 4862124 – 4816635 تليفون : 4800634 – 4800633– 4804111–4875085 العنوان : رصيف 49 / 54 داخل الدائرة الجمركية ميناء الإسكندرية
محطة الدخيلة : فاكس : 4460013 تليفون 4451115 – 4460122 – 4460145 – 4460111العنوان : رصيف 96 – ميناء الدخيلة

إصدار رقم : **3** تعديل رقم :

Appendix II

A translation of the Internal Report

To Whom It May Concern

This is to certify that Mrs. **Hebatallah ElMesmary**, an assistant lecturer at the Arab Academy for Science, Technology and Maritime Transport, has considered "Alexandria Container & Cargo Handling Terminal" as a case study for the proposed model in her PhD thesis.

- The model was presented, its idea was introduced and how it can be applied on the data collected by Mrs. Hebatallah ElMesmary from Alexandria terminal since year 2010, as the main purpose of this model is to show the flow of containers (imports/exports) in the container terminal from entry to exit.
- The suggested scenarios for this model were discussed.
- A few recommendations were outlined to maximize the benefit of this model, for example:
    - Suggesting a scenario for an optimal operation of a vessel with a certain number of containers so that the model can be able to suggest the optimal number of yard cranes to be allocated to the vessel in order to achieve the maximum operation rate for the vessel.
    - Since the applied model considers the flow of data between equipment with several interwoven connections and linkages, it is recommended to add a variable to each crane to control its operation either ON or OFF according to the operating conditions.

Taking into consideration the effort exerted in this thesis with our wishes for success and good luck.

Appendix III

Interview Sample Questions

- **About the company:**

1. What is/are the objective(s) of the company?
2. Who are the main competitors for the company?
3. How long has the company been competing with such competitors?
4. What makes your company unique from others?
5. Who are your customers?
6. What privileges do you provide to your customers?

- **About the business:**

7. What is the main business of the company?
8. Are you satisfied with the performance level of the company?
9. What are the main performance indicators for the company?
10. How do you measure the company's performance?
11. What issues do you think may affect this performance?

- **About the problem:**

12. What kind of problems do you have?
13. What is the major problem that the company faces?
14. What are the reasons/causes of this problem?
15. What are the results/consequences of this problem?
16. How do you think this problem can be solved?
17. If this problem is solved, how this will affect the overall performance? What will be the further related benefits?

Details of the conducted interviews:

	Interviewee's position	Duration	Date
Unstructured interviews			
1	Chairman of the company	45 minutes	Late 2009
2	An expert in the operations department	2 hours	Late 2009
3	The head of the research and development department	2 hours	Late 2009
4	An employee in the operations department	1 hour	Late 2009
Semi- structured interviews			
1	The head of the research and development department	Multiple interviews were conducted to collected different sets of data	Early 2010 2011 2012 2015
2	An employee in the operations department	45 minutes	2010
3	The computer general manager	2 hours	2015
4	An employee in the R&D department	30 minutes	2011
5	An employee in the computer department	30 minutes	2010

Appendix IV

Results of a 12 Runs Trail of the Base Model

Simulation Object	Performance Measure	Run 1	2	3	4	5	6
7	8	9	10	11	12	-95%	Average	+95%
Imp Exit gate	Average Time in System	12989.99071	13223.93118	12757.05407
13134.34273	13145.15086	13631.72871	12803.21879	13318.93095
13340.5628	13410.23457	13304.44686	12969.19545	13006.19302
13169.06564	13331.93826
YC RTG6	Waiting %	50.99035	30.92665	39.33766	26.76468
40.67984	34.35685	49.10095	39.0151	39.08491
40.98861	50.00742	40.2873	35.44882	40.12836
44.8079
Working %	46.03031	65.41993	57.914	69.51324	55.90689
61.55645	47.47077	56.16775	56.73455	55.07731
45.24594	55.13487	51.33806	56.01433	60.69061
Blocked %	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0
Stopped %	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0
Number Completed Jobs	941	1339	1196	1414	1144	1269	997
1156	1147	1118	921	1140	1054.18037	1148.5	1242.81963
Minimum use	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0
Average use	0.46207	0.6561	0.57939	0.6961	0.55915
0.61476	0.47512	0.5611	0.56732	0.55146	0.45341
0.55146	0.5139	0.56062	0.60734
Maximum use	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1
Current Contents	0	0	1	1	1	0	0	0
0	0	1	0	0.0205	0.33333	0.64617
Change Over %	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0
Off Shift %	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0
Resource Starved %	2.97934	3.65343	2.74834	3.72208
3.41327	4.0867	3.42828	4.81715	4.18054	3.93408
4.74664	4.57783	3.43602	3.85731	4.27859
YC RTG5	Waiting %	51.03924	31.45156	38.33258	27.20879
40.0884	35.21935	48.11585	39.89398	40.22186
42.0344	49.72499	40.49172	35.83452	40.31856
44.8026
Working %	45.73683	65.0268	58.25322	69.46735
56.14714	61.54573	47.37681	56.65557	57.12258
54.82167	45.55467	56.19603	51.50417	56.1587
60.81323
Blocked %	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0
Stopped %	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0
Number Completed Jobs	940	1326	1196	1441	1146	1258	991
1158	1176	1125	934	1161	1059.17162	1154.33333	1249.49504
Minimum use	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0
Average use	0.45756	0.64805	0.58268	0.69488
0.56037	0.61476	0.47134	0.5639	0.57171	0.54732
0.45671	0.56207	0.5145	0.56095	0.60739

Maximum use 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1
Current Contents 0 0 1 1 1 0 1 1
0 0 1 0 0.16819 0.5 0.83181
Change Over % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Off Shift % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Resource Starved % 3.22393 3.52163 3.4142 3.32386
3.76445 3.23493 4.50734 3.45046 2.65555
3.14393 4.72034 3.31225 3.15771 3.52274
3.88777
YC RTG4 Waiting % 51.87315 44.19456 43.4258 32.28482
47.67655 41.46547 48.14141 49.28814 48.95474
50.77742 53.29333 50.70485 43.15669 46.84002
50.52335
Working % 44.15724 51.45663 51.90636 63.80524
48.16721 55.02315 46.91147 46.83308 46.35623
45.73417 42.90625 44.99009 45.31565 49.02059
52.72554
Blocked % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Stopped % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Number Completed Jobs 905 1062 1068 1314 990 1119 960
968 943 942 886 920 930.15039 1006.41667 1082.68294
Minimum use 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Average use 0.43841 0.51573 0.51866 0.63561
0.4822 0.54963 0.46829 0.46646 0.4628 0.45683
0.42915 0.4511 0.4527 0.48957 0.52644
Maximum use 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1
Current Contents 0 0 0 1 0 1 1 0
0 0 0 0 0 0.25 0.53736
Change Over % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Off Shift % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Resource Starved % 3.96962 4.34881 4.66784 3.90994
4.15624 3.51138 4.94712 3.87878 4.68903
3.48841 3.80042 4.30506 3.84336 4.13939
4.43542
YC RTG3 Waiting % 51.7548 44.29287 43.69931 30.9147
47.44367 41.29558 48.36769 48.22181 49.29789
49.91894 52.43626 50.10572 42.71817 46.4791
50.24004
Working % 44.80988 51.29531 51.70339 63.16066
47.47275 55.43904 47.18262 47.32579 45.67044
45.10502 44.16132 45.54083 45.52878 49.07225
52.61573
Blocked % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Stopped % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Number Completed Jobs 924 1059 1063 1294 977 1126 972
969 933 931 908 940 936.74174 1008 1079.25826
Minimum use 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Average use 0.44927 0.51232 0.51622 0.63122
0.47451 0.55293 0.47049 0.475 0.45512 0.45134
0.44049 0.45463 0.45497 0.49029 0.52562

Maximum use 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1
Current Contents 0 0 0 1 1 0 1 0
0 0 1 0 0.0205 0.33333 0.64617
Change Over % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Off Shift % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Resource Starved % 3.43531 4.41182 4.5973 5.92463
5.08359 3.26538 4.44969 4.45241 5.03167
4.97604 3.40242 4.35345 3.95078 4.44864
4.9465
YC RTG 6 Waiting % 57.44103 29.46762 37.57143 21.85705
35.59178 37.49783 41.62801 44.48646 44.74896
36.12711 45.21342 44.08315 33.96461 39.64282
45.32103
Working % 9.79102 8.99237 9.42708 8.70548
9.60488 8.69125 11.3133 9.7304 9.0645 9.45354
10.70419 9.99224 9.12705 9.62252 10.118
Blocked % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Stopped % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Number Completed Jobs 807 739 774 729 795 706 931
794 744 787 865 826 751.75288 791.41667 831.08046
Minimum use 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Average use 0.09695 0.08866 0.09585 0.08841
0.09573 0.08695 0.11244 0.09683 0.09 0.09195
0.1078 0.09927 0.09095 0.0959 0.10085
Maximum use 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1
Current Contents 0 0 0 0 0 1 0 1
0 0 0 0 0 0.16667 0.41399
Change Over % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Off Shift % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Resource Starved % 32.76795 61.54 53.00149 69.43747
54.80334 53.81092 47.0587 45.78315 46.18654
54.41935 44.08239 45.92461 44.79841 50.73466
56.67091
YC RTG 5 Waiting % 57.23707 34.2667 42.94832 24.6419
40.26986 30.98936 41.07225 43.79141 39.09728
37.95118 53.59378 38.97726 34.78424 40.40303
46.02182
Working % 9.76122 8.99019 9.34876 9.11278
9.89035 8.83754 11.4597 9.69497 8.37258
9.86627 10.65923 9.51742 9.10024 9.62592
10.1516
Blocked % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Stopped % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Number Completed Jobs 801 743 769 739 814 716 927
797 691 802 877 783 746.38002 788.25 830.11998
Minimum use 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Average use 0.09634 0.08951 0.09354 0.09171
0.09829 0.08744 0.1161 0.09793 0.08427 0.09841
0.10573 0.09341 0.09065 0.09606 0.10147

Maximum use 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1
Current Contents 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0
Change Over % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Off Shift % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Resource Starved % 33.00171 56.74311 47.70292 66.24532
49.83979 60.1731 47.46804 46.51361 52.53014
52.18255 35.74699 51.50533 44.09052 49.97105
55.85158
YC RTG 4 Waiting % 52.98327 43.56598 39.45431 25.25565
41.77543 37.56266 40.9328 45.78356 43.11779
42.64903 46.13136 48.90815 38.01625 42.34333
46.67041
Working % 10.50058 11.8021 10.76487 10.64974
11.77864 9.50188 11.35991 11.07289 10.72179
10.87491 11.16666 11.98635 10.5804 11.01503
11.44966
Blocked % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Stopped % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Number Completed Jobs 867 959 891 878 971 794 919
908 874 879 916 974 870.09593 902.5 934.90407
Minimum use 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Average use 0.10488 0.11488 0.10878 0.10915
0.11756 0.0972 0.11171 0.11049 0.10927 0.10805
0.11134 0.11841 0.10654 0.11014 0.11374
Maximum use 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1
Current Contents 0 0 1 0 0 0 0 1
0 0 1 0 0 0.25 0.53736
Change Over % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Off Shift % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Resource Starved % 36.51615 44.63192 49.78081 64.09461
46.44593 52.93546 47.70729 43.14354 46.16043
46.47605 42.70199 39.1055 42.16269 46.64164
51.12059
YC RTG 3 Waiting % 46.6258 44.75371 37.47598 27.72159
52.59891 36.7915 47.34981 48.70207 45.61675
50.28223 54.19124 52.11368 40.41514 45.35194
50.28874
Working % 10.08209 11.75004 11.18328 10.98918
12.57433 9.74159 11.46359 10.79881 10.81989
10.94906 10.69553 11.54974 10.57442 11.04976
11.5251
Blocked % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Stopped % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Number Completed Jobs 831 959 915 911 1025 808 936
881 888 903 889 954 871.638 908.33333 945.02867
Minimum use 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Average use 0.10378 0.11927 0.11098 0.11256
0.12646 0.09732 0.11463 0.10634 0.1111 0.11171
0.10817 0.11561 0.10676 0.11149 0.11623

Maximum use 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1
Current Contents 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0
Change Over % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Off Shift % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Resource Starved % 43.29212 43.49625 51.34073 61.28923
34.82676 53.46691 41.1866 40.49913 43.56336
38.76871 35.11323 36.33658 38.49073 43.5983
48.70587
Imp Entry Point Number Entered 55 56 57 55 55 58 56
59 59 57 61 59 56.00478 57.25 58.49522
Number Lost 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Net Number Entered 55 56 57 55 55 58 56 59
59 57 61 59 56.00478 57.25 58.49522
QC 1 imp Waiting % 85.67122 78.84176 86.25314 85.90163
82.01345 82.64421 82.18743 78.66257 84.46877
74.70107 87.15161 88.19943 80.49309 83.05802
85.62296
Working % 8.9733 11.49229 12.41814 12.52081 12.0206
11.64328 9.34731 11.17559 10.006 11.2396 9.43646
10.83312 10.15108 10.92554 11.7
Blocked % 0.02671 0.05857 0.00555 0.11173
0.01959 0.01855 0.01954 0.01481 0 0.02225
0.0276 0.03251 0.01096 0.02978 0.04861
Stopped % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Number Completed Jobs 1827 2344 2529 2588 2475 2370 1909
2293 2049 2302 1927 2213 2074.15948 2235.5 2396.84052
Minimum use 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Average use 0.09085 0.11634 0.12488 0.12463
0.12098 0.1161 0.09415 0.11159 0.09915 0.11317
0.09329 0.1078 0.1016 0.10941 0.11722
Maximum use 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1
Current Contents 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0
Change Over % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Off Shift % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Resource Starved % 5.32878 9.60737 1.32316 1.46584
5.94635 5.69396 8.44573 10.14702 5.52524
14.03708 3.38433 0.93495 3.44165 5.98665
8.53165
QC2 exp Waiting % 89.99818 90.16137 90.0247 90.13486
89.81505 89.86495 89.9875 89.76191 90.08199
90.06129 89.85284 90.08168 89.90193 89.98553
90.06912
Working % 10.00182 9.83863 9.9753 9.86514 10.18495
10.13505 10.0125 10.23809 9.91801 9.93871
10.14716 9.91832 9.93088 10.01447 10.09807
Blocked % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Stopped % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Number Completed Jobs 2044 2018 2041 2003 2097 2079 2043
2099 2035 2013 2074 2015 2025.66114 2046.75 2067.83886

Minimum use 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Average use 0.09378 0.09683 0.09732 0.10024
0.09768 0.09902 0.09671 0.09915 0.10232
0.10098 0.09878 0.10598 0.09708 0.09907
0.10105
Maximum use 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1
Current Contents 0 0 0 0 0 0 0 0
0 0 1 0 0 0.08333 0.26675
Change Over % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Off Shift % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Resource Starved % 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0
QC 3 imp Waiting % 90.29896 87.75672 84.5464 85.34421
66.47763 85.20103 86.50963 81.27268 73.79806
89.68005 88.28884 84.27084 79.20515 83.62042
88.03569
Working % 8.77036 10.9159 8.93619 13.19441
12.51075 8.29043 12.09145 9.93193 9.47851
9.37019 10.4821 10.30425 9.36533 10.35637
11.34741
Blocked % 0.01525 0.00849 0.14151 0.03097
0.00486 0.03093 0.0385 0.00127 0.05816 0.02059
0.03383 0.0933 0.01382 0.03981 0.06579
Stopped % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Number Completed Jobs 1776 2256 1819 2706 2550 1686 2474
2044 1953 1914 2138 2126 1915.09806 2120.16667 2325.23527
Minimum use 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Average use 0.0878 0.10951 0.09085 0.13134 0.12488
0.08415 0.12293 0.09963 0.09488 0.0922 0.10598
0.10463 0.09421 0.10407 0.11392
Maximum use 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1
Current Contents 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0
Change Over % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Off Shift % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Resource Starved % 0.91543 1.31889 6.3759 1.43041
21.00675 6.47761 1.36042 8.79413 16.66527
0.92916 1.19524 5.3316 1.75775 5.9834 10.20905
QC 4 exp Waiting % 89.96135 90.12316 89.94055 89.84677
89.70364 90.18878 90.25457 89.90671 89.86235
90.18547 90.22483 90.24424 89.91756 90.03687
90.15618
Working % 10.03865 9.87684 10.05945 10.15323
10.29636 9.81122 9.74543 10.09329 10.13765
9.81453 9.77517 9.75576 9.84382 9.96313
10.08244
Blocked % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Stopped % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Number Completed Jobs 2045 2044 2072 2070 2118 2012 2026
2045 2074 2022 2005 2010 2023.9792 2045.25 2066.5208

Minimum use 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Average use 0.1 0.09463 0.09549 0.1022 0.10012
0.09451 0.0978 0.10207 0.09915 0.09768 0.0972
0.09927 0.09669 0.09834 0.1
Maximum use 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1
Current Contents 0 0 0 0 0 0 0 0
1 1 0 0 0 0.16667 0.41399
Change Over % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Off Shift % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Resource Starved % 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0

QC 5 imp Waiting % 79.92784 74.19826 74.6083 74.58077
82.30769 77.16241 75.98167 78.14248 76.96507
80.35189 80.13569 75.32725 75.7638 77.47411
79.18442
Working % 17.91628 23.03759 22.7289 22.71073
15.97735 20.62687 21.73063 19.71414 20.6521
17.82656 17.92071 22.15018 18.74864 20.24934
21.75003
Blocked % 0.02899 0.04968 0.13159 0.11963
0.01798 0.0402 0.03759 0.0031 0.02895 0.0009 0.03281
0.1025 0.02152 0.04949 0.07747
Stopped % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Number Completed Jobs 3666 4702 4672 4666 3293 4245 4434
4043 4217 3662 3683 4507 3846.17669 4149.16667 4452.15665
Minimum use 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Average use 0.18195 0.23183 0.23 0.22841 0.15927
0.20695 0.21744 0.19659 0.20756 0.17695 0.18
0.22329 0.18795 0.20335 0.21876
Maximum use 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1
Current Contents 0 0 1 0 0 0 0 1
0 0 0 0 0 0.16667 0.41399
Change Over % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Off Shift % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Resource Starved % 2.12688 2.71447 2.53121 2.58887
1.69698 2.17052 2.25011 2.14028 2.35388
1.82065 1.91079 2.42007 2.02781 2.22706
2.42631

Imp Lifters general yard 5 in Waiting % 0 0 0 0 0 0
0 0 0 0 0 0 0
Working % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Blocked % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Stopped % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Number Completed Jobs 2959 4619 4382 5599 4038 3993 3951
3893 3791 3636 3332 4045 3599.91735 4019.83333 4439.74931
Minimum use 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Average use 0.35878 0.55902 0.53122 0.6828 0.49598
0.48439 0.48159 0.47671 0.46671 0.44793
0.40671 0.49524 0.43974 0.49059 0.54144

Maximum use 6 6 6 6 6 6 6 6 6
6 6 6 6 6 6
Current Contents 0 0 1 0 0 0 0 1
0 0 2 0 0 0.33333 0.74718
Change Over % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Off Shift % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Resource Starved % 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0
Imp Lifter reefer yard in Waiting % 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0
Working % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Blocked % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Stopped % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Number Completed Jobs 289 326 322 400 385 309 315
302 304 302 271 298 294.70437 318.58333 342.4623
Minimum use 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Average use 0.03317 0.04134 0.04049 0.04744
0.04707 0.03805 0.03829 0.03659 0.03695
0.03756 0.03402 0.03537 0.03596 0.03886
0.04176
Maximum use 2 3 3 3 3 3 3 2 3
2 2 3 2.35383 2.66667 2.9795
Current Contents 0 0 0 1 0 0 0 0
0 0 0 0 0 0.08333 0.26675
Change Over % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Imp Lifter dangerous yard in Waiting % 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0
Working % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Blocked % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Stopped % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Number Completed Jobs 202 275 262 280 286 264 257
249 244 245 229 238 237.64447 252.58333 267.5222
Minimum use 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Average use 0.02476 0.03439 0.03268 0.03341
0.03463 0.03293 0.03012 0.03122 0.03024
0.03073 0.02793 0.02902 0.02918 0.03101
0.03283
Maximum use 2 2 2 2 3 2 3 3 3
2 3 2 2.08949 2.41667 2.74384
Current Contents 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0
Change Over % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Off Shift % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Resource Starved % 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0
general yard 1 Waiting % 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0
Working % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0

Blocked % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Stopped % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Number Completed Jobs 1790 1915 2104 2477 1904 2092 1853
1913 1943 1877 1782 1908 1842.82414 1963.16667 2083.5092
Minimum use 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Average use 581.8439 625.95915 696.90427 817.71341
615.05 678.52695 633.54463 634.92061 622.33756 602.03927
591.48854 645.76354 605.16389 645.50765 685.85141
Maximum use 699 741 1097 1060 759 918 938 734 717
716 722 737 728.40415 819.83333 911.26252
Current Contents 538 713 658 617 715 550 763 598
570 573 680 640 588.50989 634.58333 680.65678
general yard 2 Waiting % 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0
Working % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Blocked % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Stopped % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Number Completed Jobs 1829 2120 2127 2614 1967 2246 1934
1936 1876 1873 1792 1860 1866.27329 2014.5 2162.72671
Minimum use 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Average use 591.49793 707.24439 719.85866 886.54646
641.24537 713.89988 673.10122 625.46646 597.9011
615.60159 598.99 634.3011 614.30731 667.13785 719.96839
Maximum use 702 972 1092 1092 740 1092 1092 789 764
751 707 717 765.08661 875.83333 986.58006
general yard 3 Waiting % 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0
Working % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Blocked % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Stopped % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Number Completed Jobs 1877 2665 2392 2858 2291 2526 1989
2314 2322 2242 1857 2299 2113.01296 2302.66667 2492.32037
Minimum use 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Average use 604.43732 895.88585 820.60744 977.21634
770.84988 806.36171 686.72488 768.0761 782.1561
711.43341 627.67049 795.16537 703.77687 770.54874
837.32061
Maximum use 759 1122 1122 1122 1029 1122 1122 1122 1028
941 863 1122 961.11408 1039.5 1117.88592
Current Contents 486 1018 843 803 1022 519 1080 529
764 578 827 814 642.08103 773.58333 905.08564
general yard 4 Waiting % 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0
Working % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Blocked % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Stopped % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Number Completed Jobs 2759 3099 2836 3103 3072 2966 2712
2904 3043 3066 2843 2858 2850.7537 2938.41667 3026.07963

Minimum use 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Average use 909.08927 1035.92732 966.09829 1052.7178
1035.50061 978.41659 939.93866 987.91902 1025.57146
1012.35244 947.70976 1006.99195 963.3055 991.51943
1019.73336
Maximum use 1092 1092 1092 1092 1092 1092 1092 1092 1092
1092 1092 1092 1092 1092 1092
Current Contents 728 1049 1006 1071 1082 940 1063 1043
1004 1027 1025 1015 944.15048 1004.41667 1064.68285
general yard 5 Waiting % 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0
Working % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Blocked % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Stopped % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Number Completed Jobs 2197 2239 2172 2186 2227 2234 2113
2232 2152 2199 2204 2196 2172.35643 2195.91667 2219.4769
Minimum use 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Average use 716.41415 726.93049 726.97268 734.15037
725.43756 728.31402 722.8628 729.2822 728.91524
724.45841 724.68537 729.0828 723.70929 726.45884
729.20839
Maximum use 744 744 744 744 744 744 744 744 744
744 744 744 744 744 744
Current Contents 724 717 737 743 738 743 741 731
713 732 723 722 723.74517 730.33333 736.9215
Change Over % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Off Shift % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Resource Starved % 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0
Berth 1 imports Waiting % 88.59342 86.03791 84.88186 84.4915
85.43067 85.69837 88.41333 86.03783 87.50916
86.06166 87.90129 86.65948 85.61746 86.47637
87.33529
Working % 1.3666 1.39625 1.46117 1.49087 1.36655
1.42644 1.36761 1.59336 1.39651 1.39754
1.50497 1.62027 1.39345 1.44901 1.50457
Blocked % 10.03998 12.56584 13.65696 14.01763
13.20278 12.87519 10.21907 12.3688 11.09433
12.5408 10.59373 11.72025 11.22648 12.07461
12.92275
Stopped % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Number Completed Jobs 19 19 20 19 18 20 20
20 20 19 20 21 19.07951 19.58333 20.08716
Minimum use 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Average use 12.96451 19.57012 23.58037 26.13866
26.73024 21.07268 11.78402 19.18915 16.6272
19.0439 13.69817 14.99085 15.61083 18.78249
21.95415
Maximum use 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1
Current Contents 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0

Change Over % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
B 2 Imp Waiting % 89.03098 86.36897 88.58505 84.05858
84.73709 89.46838 85.12276 87.6964 87.93944
88.39371 86.86808 87.16045 86.00857 87.11916
88.22975
Working % 1.33396 1.46285 1.28972 1.36859
1.34704 1.47417 1.45734 1.45817 1.52639
1.36076 1.50232 1.42489 1.36967 1.41718
1.46469
Blocked % 9.63506 12.16818 10.12523 14.57283
13.91587 9.05745 13.4199 10.84542 10.53417
10.24553 11.6296 11.41466 10.35174 11.46366
12.57558
Stopped % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Number Completed Jobs 18 20 19 19 19 19 20
20 20 19 21 20 18.99315 19.5 20.00685
Minimum use 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Average use 13.07915 18.72598 14.03293 25.86829
24.20024 10.32915 23.33744 12.65073 13.33037
14.9261 16.72049 16.41463 13.76577 16.96796
20.17015
Maximum use 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1
Current Contents 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0
Change Over % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
B 3 imp Waiting % 78.67613 73.04505 73.23394 73.37234
81.0824 75.9607 74.74558 76.61207 75.6176
79.03558 79.03631 74.30321 74.52323 76.22674
77.93025
Working % 1.3421 1.24765 1.45667 1.29314 1.31392
1.28976 1.31726 1.61121 1.43763 1.40804
1.20103 1.11332 1.2533 1.33598 1.41866
Blocked % 19.98177 25.7073 25.30939 25.33452
17.60367 22.74953 23.93717 21.77672 22.94477
19.55638 19.76266 24.58346 20.72563 22.43728
24.14893
Stopped % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Number Completed Jobs 18 17 18 17 18 19 17
19 19 19 20 17 17.51232 18.16667 18.82101
Minimum use 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Average use 24.98171 46.43878 48.03256 48.06939
25.17841 33.29293 41.10951 34.22817 35.12366
23.57012 21.48098 41.40634 28.99697 35.24271
41.48846
Maximum use 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1
Current Contents 0 0 98 257 0 66 0 480
0 0 71 0 0 81 174.20704
Change Over % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Off Shift % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Resource Starved % 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0

B 2 Exp Average Time in System 7570.84704 7537.33997 7581.12158
7527.33057 7528.80912 7674.41955 7627.27164 7517.89161
7597.6499 7700.69564 7589.68345 7572.50588 7548.62546
7585.46383 7622.3022
Number Completed 4073 4176 4091 4112 4119 4011 4118 4041
4085 3982 4089 3999 4038.52762 4074.66667 4110.80572
"In System less than" time 10 10 10 10 10 10 10
10 10 10 10 10 10 10 10
% In System less than time limit 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0
St Dev of 5467.0592 5445.35815 5458.28729 5503.94291
5414.87541 5707.86333 5625.23324 5456.55284 5531.98339
5629.32978 5524.76517 5499.58236 5465.76908 5522.06942
5578.36976
Maximum Time in System 31788.169 31911.76305 31932.12821
31947.0698 32034.14328 31982.0228 31997.71514 32032.61599
31919.50419 31990.06473 32006.11875 31961.23301 31915.65681
31958.54566 32001.43451
Minimum Time in System 1475.34021 1470.60304 1480.39974
1481.05198 1478.48808 1476.67163 1480.38888 1486.46934
1485.3083 1496.55248 1474.1889 1469.52678 1474.85026
1479.58245 1484.31463
B 3 exp Average Time in System 7433.07277 7729.81268 7437.41671
7764.20892 7372.15038 7491.13983 7807.53489 7594.29761
7391.53768 7461.24313 7523.87556 7363.62569 7430.9252
7530.82632 7630.72744
Number Completed 2127 2001 2033 2043 2054 2018 2034 2002
1996 2006 2022 2033 2008.2892 2030.75 2053.2108
"In System less than" time 10 10 10 10 10 10 10
10 10 10 10 10 10 10 10
% In System less than time limit 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0
St Dev of 5351.59431 5729.42381 5335.10615 5535.51784
5215.9893 5285.08233 5715.51497 5485.77182 5275.24359
5345.47821 5570.31709 5306.65816 5318.699 5429.30813
5539.91726
Maximum Time in System 31546.38713 31845.60945 31862.66225
31970.67009 31917.64839 31890.27636 31743.92743 31894.3757
31591.09164 32016.99594 31990.69183 31720.49653 31735.98545
31832.5694 31929.15334
Minimum Time in System 1492.95507 1479.49228 1479.28938
1492.47587 1515.86356 1492.59529 1484.41816 1487.14595
1473.81153 1482.57729 1480.739 1485.00298 1480.32035
1487.1972 1494.07405
Berth 1 Exports Average Time in System 7633.31352 7564.43192 7451.12987
7442.11721 7521.66576 7583.26422 7296.00622 7581.25444
7568.39944 7746.0813 7533.7147 7496.62386 7464.41852
7534.83354 7605.24855
Number Completed 4108 4030 4066 4078 4079 4141 4037 4125
4082 3978 4086 4028 4040.78772 4069.83333 4098.87894
"In System less than" time 10 10 10 10 10 10 10
10 10 10 10 10 10 10 10
% In System less than time limit 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0
St Dev of 5577.48224 5602.13468 5442.60402 5390.86448
5485.36756 5377.62793 5164.34479 5445.48444 5403.18218
5612.38379 5468.52622 5359.09489 5365.61575 5444.09144
5522.56712
Maximum Time in System 31985.04581 32029.738 32024.57981
31821.66688 31763.3778 31968.57229 31979.38154 31978.87502
31803.80049 31956.44305 31925.31229 31888.98332 31870.97792
31927.14802 31983.31813

Minimum Time in System 1487.77518 1465.55102 1476.03418
1476.18881 1479.03349 1476.22847 1483.59602 1482.25877
1467.54803 1470.24741 1472.10049 1480.80144 1472.18735
1476.44694 1480.70653
Exp entry gate Number Entered 10270 10290 10169 10174 10215 10201 10222
10275 10210 10123 10209 10189 10181.71702 10212.25 10242.78298
Number Lost 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Net Number Entered 10270 10290 10169 10174 10215 10201 10222 10275
10210 10123 10209 10189 10181.71702 10212.25 10242.78298
Exp lifters Resources Utilization % 54.03128 53.00043 52.54928
52.71188 53.2994 54.22355 53.91408 53.36523
53.17893 52.16205 53.16875 53.09407 52.83843
53.22491 53.61138
Minimum Use 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Current Use 6 3 3 3 1 7 2 6 2
6 2 1 2.1319 3.5 4.8681
Average Use 3.78219 3.71003 3.67845 3.68983
3.73096 3.79565 3.77399 3.73557 3.72252
3.65134 3.72181 3.71659 3.69869 3.72574
3.7528
Maximum Use 7 7 7 7 7 7 7 7 7
7 7 7 7 7 7
Traveling % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Exp Lifters dangerous yard in Waiting % 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0
Working % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Blocked % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Stopped % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Number Completed Jobs 223 183 170 207 196 206 198
191 209 209 203 226 191.76937 201.75 211.73063
Minimum use 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Average use 0.10927 0.08951 0.0811 0.10024 0.0961
0.10073 0.09585 0.09146 0.10037 0.09976
0.09768 0.11061 0.0926 0.09772 0.10285
Maximum use 3 3 2 3 3 2 3 2 2
3 2 3 2.25616 2.58333 2.91051
Current Contents 0 0 1 0 0 0 0 0
0 0 0 0 0 0.08333 0.26675
Change Over % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Off Shift % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Resource Starved % 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0
Exp Lifters yards out Waiting % 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0
Working % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Blocked % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Stopped % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Number Completed Jobs 6250 6120 6065 6132 6178 6210 6212
6086 6177 5925 6146 6042 6071.65603 6128.58333 6185.51064

Minimum use 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Average use 0.75854 0.74061 0.73439 0.74061
0.75537 0.75268 0.76402 0.7389 0.75305 0.71732
0.75427 0.73707 0.73727 0.74557 0.75387
Maximum use 5 6 6 6 6 5 5 6 6
6 6 6 5.46264 5.75 6.03736
Current Contents 2 1 0 1 1 1 0 0
1 4 0 0 0.17677 0.91667 1.65656
Change Over % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Off Shift % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Resource Starved % 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0
Exp tractors Resources Utilization % 10.39395 10.34113 10.35937
10.5739 10.40263 10.22715 10.33351 10.30706
10.31479 10.04581 10.33871 10.16521 10.23406
10.31693 10.39981
Minimum Use 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Current Use 0 1 0 1 0 1 1 4 1
5 0 1 0.23178 1.25 2.26822
Average Use 1.35121 1.34435 1.34672 1.37461
1.35234 1.32953 1.34336 1.33992 1.34092
1.30596 1.34403 1.32148 1.33043 1.3412 1.35197
Maximum Use 9 8 8 11 9 8 8 8 12
8 9 9 8.08345 8.91667 9.74988
Traveling % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Exp Truck Waiting % 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0
Working % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Blocked % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Stopped % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Number Completed Jobs 10270 10289 10169 10177 10216 10202 10223
10278 10211 10122 10210 10188 10182.24657 10212.91667 10243.58676
Minimum use 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Average use 1.31988 1.32122 1.30707 1.31195
1.33354 1.32341 1.31768 1.32598 1.31671
1.29354 1.32378 1.31305 1.3108 1.31732 1.32383
Maximum use 3 3 3 3 3 3 3 3 3
3 3 3 3 3 3
Current Contents 0 1 1 0 0 2 2 0
2 3 1 1 0.45037 1.08333 1.7163
Change Over % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Off Shift % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Resource Starved % 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0
Export tractors Waiting % 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0
Working % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Blocked % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0

Stopped % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Number Completed Jobs 10307 10206 10190 10234 10251 10172 10189
10167 10164 9967 10199 10060 10119.5428 10175.5 10231.4572
Minimum use 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Average use 1.35756 1.34768 1.35049 1.37159
1.35305 1.32841 1.3439 1.34305 1.34012 1.30841
1.34439 1.31866 1.33142 1.34228 1.35314
Maximum use 9 8 8 11 9 8 8 8 12
9 9 9 8.18723 9 9.81277
Current Contents 0 1 0 1 0 1 1 4
1 5 0 1 0.23178 1.25 2.26822
Change Over % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Off Shift % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Resource Starved % 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0
Export yard 1 Waiting % 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0
Working % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Blocked % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Stopped % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Number Completed Jobs 4501 4594 4512 4530 4571 4472 4548
4480 4514 4432 4557 4531 4491.39272 4520.16667 4548.94061
Minimum use 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Average use 740.46768 740.47524 740.28256 740.16793
739.585 740.78817 740.30561 740.67085 740.34244
740.69366 740.19854 740.65598 740.17906 740.38614
740.59322
Maximum use 744 744 744 744 744 744 744 744 744
744 744 744 744 744 744
Current Contents 712 744 744 739 744 738 743 738
738 741 741 742 733.11878 738.66667 744.21456
Change Over % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Off Shift % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Resource Starved % 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0
export yard '1 Utilization % 99.52476 99.52555 99.49968 99.48468
99.40633 99.5681 99.50294 99.55213 99.5086
99.5557 99.48945 99.5502 99.48619 99.51401
99.54183
Minimum Use 712 725 714 716 722 724 717 722 714
718 719 727 716.1035 719.16667 722.22983
Current Use 712 744 744 739 744 738 743 738 738
741 741 742 733.11878 738.66667 744.21456
Average Use 740.4642 740.47012 740.27764 740.16603
739.58308 740.78668 740.30186 740.66782 740.34397
740.69437 740.20148 740.65346 740.17723 740.38423
740.59122
Maximum Use 744 744 744 744 744 744 744 744 744
744 744 744 744 744 744
Traveling % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0

Export yard 2 Waiting % 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0
Working % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Blocked % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Stopped % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Number Completed Jobs 1275 1111 1128 1120 1128 1275 1206
1139 1216 1054 1157 1059 1108.97143 1155.66667 1202.36191
Minimum use 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Average use 207.31354 185.81134 184.4561 180.86524
183.3428 200.00976 197.51598 190.08817 203.8611
175.76463 183.70159 177.49207 182.50643 189.18519
195.86396
Maximum use 278 252 242 238 242 248 267 250 266
230 241 229 238.99147 248.58333 258.1752
Current Contents 188 162 128 152 114 186 133 197
150 228 166 187 145.0758 165.91667 186.75753
Change Over % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Off Shift % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Resource Starved % 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0
export yard '2 Utilization % 37.5567 33.66162 33.41581 32.76499
33.21383 36.23288 35.78124 34.43643 36.9313
31.84268 33.27855 32.15453 33.06276 34.27255
35.48233
Minimum Use 120 131 116 127 113 146 127 134 140
108 132 143 120.44702 128.08333 135.71964
Current Use 188 162 128 152 114 186 133 197 150
228 166 187 145.0758 165.91667 186.75753
Average Use 207.31299 185.81212 184.45529 180.86274
183.34032 200.00552 197.51243 190.08909 203.86078
175.77157 183.69761 177.49303 182.50643 189.18446
195.86248
Maximum Use 278 252 242 238 242 248 267 250 266
230 241 229 238.99147 248.58333 258.1752
Traveling % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
QC 5 exp Waiting % 89.58905 90.21974 90.08708 90.0642
90.07679 90.18862 90.07728 90.28159 90.19667
90.14051 90.13831 90.12491 89.98838 90.09873
90.20908
Working % 10.41095 9.78026 9.91292 9.9358 9.92321
9.81138 9.92272 9.71841 9.80333 9.85949
9.86169 9.87509 9.79092 9.90127 10.01162
Blocked % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Stopped % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Number Completed Jobs 2127 2001 2033 2043 2054 2018 2034
2002 1996 2006 2022 2033 2008.2892 2030.75 2053.2108
Minimum use 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Average use 0.10085 0.09171 0.10159 0.10305
0.09634 0.10171 0.09744 0.0961 0.09366 0.09841
0.09707 0.10073 0.09601 0.09822 0.10043
Maximum use 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1

Current Contents 0 0 0 1 0 1 0 0
1 0 1 0 0.0205 0.33333 0.64617
Change Over % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Off Shift % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Resource Starved % 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0
QC3 exp Waiting % 90.06833 89.60073 90.14504 90.08538
90.33732 90.28239 89.7822 90.31109 90.14444
90.36606 89.8344 90.32202 89.94867 90.10662
90.26456
Working % 9.93167 10.39927 9.85496 9.91462
9.66268 9.71761 10.2178 9.68891 9.85556
9.63394 10.1656 9.67798 9.73544 9.89338
10.05133
Blocked % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Stopped % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Number Completed Jobs 2028 2132 2019 2042 2001 1999 2092
1996 2011 1960 2084 1989 1997.74694 2029.41667 2061.08639
Minimum use 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Average use 0.09756 0.10293 0.09732 0.10024
0.09671 0.09659 0.09878 0.09854 0.10024
0.0989 0.10232 0.09622 0.09746 0.09886 0.10026
Maximum use 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1
Current Contents 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0
Change Over % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Off Shift % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Resource Starved % 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0
Queue for exp trucks Minimum queue size 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0
Average queue size 0.12402 0.115 0.11902 0.11329
0.11037 0.11829 0.10683 0.11622 0.1039 0.08951
0.1161 0.10366 0.10547 0.11135 0.11724
Maximum queue size 7 7 8 9 7 9 8 10
8 7 9 7 7.33637 8 8.66363
Minimum Queuing Time 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0
Minimum (non-zero) Queuing Time 0.00355 0.00047 0.00007
0.00168 0.00091 0.00507 0.00031 0.00417
0.00165 0.00198 0.0025 0.00606 0.00113 0.00237
0.00361
Average Queuing Time 0.48502 0.45232 0.46701 0.46537
0.43582 0.47106 0.43475 0.48133 0.42113
0.3491 0.4536 0.40565 0.4192 0.44351 0.46783
Average (non-zero) Queuing Time 2.64254 2.4797 2.59794
2.67796 2.36553 2.67403 2.42707 2.70404
2.48684 2.30523 2.66137 2.38362 2.44371
2.53382 2.62394
Maximum Queuing Time 18.49382 16.46873 21.62402
19.95191 17.19185 20.23261 18.07156 27.79876
17.8134 18.73257 19.06468 16.79914 17.41547
19.35359 21.2917

Number of non zero queuing times 1885 1877 1828 1768 1882 1797
1831 1829 1729 1533 1740 1734 1723.87125 1786.08333
1848.29541
% Queued less than time limit 99.37683 99.60155 99.45914
99.3218 99.66716 99.39222 99.72608 99.37713
99.52008 99.73328 99.43187 99.63686 99.42689
99.52033 99.61378
"Queued less than" time 10 10 10 10 10 10 10 10
10 10 10 10 10 10 10
St Dev of Queuing Time 1.57991 1.41152 1.56927 1.57782
1.35463 1.58026 1.33656 1.6372 1.40846 1.21905
1.53022 1.32196 1.37502 1.46057 1.54613
Current Contents 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0
Items Entered 10270 10290 10169 10174 10215 10201 10222 10275 10210
10123 10209 10189 10181.71702 10212.25 10242.78298
Reefer yard exp Waiting % 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0
Working % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Blocked % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Stopped % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Number Completed Jobs 242 232 244 274 274 248 259
268 242 220 236 238 237.17057 248.08333 258.9961
Minimum use 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Average use 40.49489 38.74078 38.93526 46.78649
42.9641 43.33892 38.88614 47.46396 39.08421
38.40934 41.51768 39.5958 39.34384 41.35146
43.35909
Maximum use 54 50 49 65 55 56 53 58 53
49 53 54 51.30113 54.08333 56.86553
Current Contents 49 39 41 43 47 54 40 49
38 48 40 45 41.22875 44.41667 47.60459
Change Over % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Off Shift % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Resource Starved % 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0
Dangerous space Utilization % 30.39583 34.11361 33.765 37.49706
33.59276 37.11405 32.31127 30.79692 34.56718
33.6095 32.38301 32.59889 32.19381 33.56209
34.93036
Minimum Use 91 100 93 111 98 86 91 91 99
99 89 87 90.07866 94.58333 99.088
Current Use 107 126 108 124 130 95 128 123 99
110 124 129 109.04839 116.91667 124.78495
Average Use 105.77747 118.71535 117.50218 130.48977
116.90282 129.15688 112.44322 107.17329 120.29377
116.96104 112.69289 113.44414 112.03447 116.79607
121.55767
Maximum Use 121 139 149 148 138 163 141 136 133
136 131 137 132.67866 139.33333 145.98801
Traveling % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Dangerous yard exp Waiting % 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0
Working % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0

Blocked % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Stopped % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Number Completed Jobs 234 184 179 209 205 218 199
197 205 223 195 214 195.12478 205.16667 215.20855
Minimum use 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Average use 37.6139 30.89317 26.86085 34.99756
30.32841 35.70878 31.1489 33.05378 34.02085
37.89988 35.93085 34.71207 31.51994 33.59742
35.6749
Maximum use 53 42 49 46 40 48 40 44 47
51 46 49 43.62154 46.25 48.87846
Current Contents 36 34 26 30 28 28 30 33
31 28 44 41 28.9003 32.41667 35.93303
Change Over % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Off Shift % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Resource Starved % 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0
Dangerous yard imp Waiting % 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0
Working % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Blocked % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Stopped % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Number Completed Jobs 203 262 251 267 256 280 231
223 259 245 234 222 230.28579 244.41667 258.54754
Minimum use 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Average use 68.16329 87.82146 90.64049 95.49159
86.57329 93.45122 81.29293 74.11854 86.27305
79.06122 76.76049 78.73024 77.97099 83.19815
88.42531
Maximum use 81 103 115 110 104 117 110 99 97
92 91 95 94.35663 101.16667 107.9767
Current Contents 71 92 82 94 102 67 98 90
68 82 80 88 77.1525 84.5 91.8475
Change Over % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Off Shift % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Resource Starved % 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0
Empty space Utilization % 70.20072 74.18977 71.25072 73.48385
73.11489 71.43021 71.52567 71.61027 70.79445
72.43038 72.76342 72.78836 71.38073 72.13189
72.88305
Minimum Use 953 975 949 969 967 966 938 947 925
986 982 945 946.69534 958.5 970.30466
Current Use 1003 1111 1012 1040 1088 997 1081 1049 1022
1061 1079 1043 1025.79069 1048.83333 1071.87598
Average Use 1010.89035 1068.33271 1026.01035 1058.16745
1052.85448 1028.59505 1029.9697 1031.18791 1019.44013
1042.99748 1047.79318 1048.15241 1027.88257 1038.69927
1049.51597
Maximum Use 1084 1143 1075 1147 1118 1100 1123 1096 1105
1113 1119 1107 1097.28215 1110.83333 1124.38452

Traveling % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Empty yard exp Waiting % 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0
Working % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Blocked % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Stopped % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Number Completed Jobs 4057 4085 4125 4102 4072 3962 3977
4085 3989 4047 4052 4019 4015.0348 4047.66667 4080.29853
Minimum use 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Average use 890.20488 921.03524 892.6361 892.02683
903.96829 887.4572 887.66085 902.74988 885.14134
911.75793 911.18146 899.12122 891.43758 898.7451
906.05263
Maximum use 938 987 927 949 944 955 939 941 954
970 950 971 941.39827 952.08333 962.7684
Current Contents 885 954 888 873 906 868 925 923
904 922 912 911 890.38521 905.91667 921.44812
Change Over % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Off Shift % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Resource Starved % 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0
Empty yard imp Waiting % 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0
Working % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Blocked % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Stopped % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Number Completed Jobs 526 633 634 723 680 658 653
583 615 598 606 645 597.69724 629.5 661.30276
Minimum use 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Average use 120.68268 147.28829 133.37049 166.13829
148.87695 141.13866 142.30159 128.43146 134.29476
131.23244 136.59963 149.0278 132.34551 139.94859
147.55166
Maximum use 158 181 182 206 189 189 223 160 176
160 194 187 171.53097 183.75 195.96903
Current Contents 118 157 124 167 182 129 156 126
118 139 167 132 129.0083 142.91667 156.82503
Change Over % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Off Shift % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Resource Starved % 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0
General Yard `1 Utilization % 42.53201 45.75798 50.94375 59.77454
44.95985 49.5993 46.31273 46.41243 45.4921
44.00819 43.23783 47.20516 44.23718 47.18632
50.13547
Minimum Use 454 497 472 603 535 510 495 529 544
521 481 567 490.6981 517.33333 543.96857
Current Use 538 713 658 617 715 550 763 598 570
573 680 640 588.50989 634.58333 680.65678

Average Use 581.83788 625.9692 696.91046 817.71568
615.0508 678.51837 633.5582 634.92198 622.33197
602.03204 591.49349 645.76656 605.16459 645.50889
685.85318
Maximum Use 699 741 1097 1060 740 918 938 734 717
716 722 737 726.29198 818.25 910.20802
Traveling % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
general yard '3 Utilization % 53.87039 79.84896 73.13904 87.09745
68.70503 71.86607 61.20798 68.45557 69.71136
63.40691 55.94292 70.87229 62.7256 68.677 74.62839
Minimum Use 474 667 507 577 566 459 439 525 577
488 494 525 484.53035 524.83333 565.13631
Current Use 486 1018 843 803 1022 519 1080 529 764
578 827 814 642.08103 773.58333 905.08564
Average Use 604.42576 895.90535 820.62004 977.23335
770.87039 806.33726 686.75354 768.07145 782.16148
711.42552 627.67962 795.18714 703.78129 770.55591
837.33053
Maximum Use 759 1122 1122 1122 1029 1122 1122 1122 1028
941 863 1122 961.11408 1039.5 1117.88592
Traveling % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
general yard '4 Utilization % 83.24902 94.86583 88.47253 96.40473
94.82662 89.59761 86.07687 90.47034 93.91689
92.7056 86.78762 92.21771 88.21547 90.79928
93.3831
Minimum Use 712 861 655 747 906 820 702 715 907
853 744 618 708.37379 770 831.62621
Current Use 728 1049 1006 1071 1082 940 1063 1043 1004
1027 1025 1015 944.15048 1004.41667 1064.68285
Average Use 909.07928 1035.93488 966.12003 1052.73964
1035.50674 978.40586 939.95947 987.93614 1025.57248
1012.34516 947.72076 1007.01744 963.31291 991.52816
1019.74341
Maximum Use 1092 1092 1092 1092 1092 1092 1092 1092 1092
1092 1092 1092 1092 1092 1092
Traveling % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
general yard '5 Utilization % 96.29224 97.70486 97.71096 98.67622
97.50563 97.8915 97.15956 98.02112 97.97247
97.37382 97.40431 97.99543 97.27285 97.64234
98.01184
Minimum Use 635 658 678 692 663 685 625 683 690
641 654 691 651.22133 666.25 681.27867
Current Use 724 717 737 743 738 743 741 731 713
732 723 722 723.74517 730.33333 736.9215
Average Use 716.41424 726.92413 726.96954 734.15106
725.44188 728.31279 722.86715 729.27712 728.91516
724.46119 724.68808 729.086 723.71 726.45903 729.20806
Maximum Use 744 744 744 744 744 744 744 744 744
744 744 744 744 744 744
Traveling % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
general yard'2 Utilization % 54.16606 64.76628 65.92158 81.18579
58.72266 65.37413 61.64075 57.27676 54.75226
56.37318 54.85287 58.0864 56.25519 61.09323
65.93126
Minimum Use 481 534 509 586 530 427 450 522 509
496 492 523 478.78481 504.91667 531.04852
Current Use 526 719 691 657 711 458 855 563 610
637 633 612 574.59923 639.33333 704.06744

Average Use 591.49339 707.24783 719.8637 886.54887
641.25147 713.88555 673.11697 625.46225 597.8947
615.5951 598.9933 634.30345 614.30668 667.13805
719.96941
Maximum Use 702 972 1092 1092 740 1092 1092 789 724
751 707 717 760.04109 872.5 984.95891
Traveling % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Imp Exit gate Number Completed 11484 13255 12834 14602 12744 13367 11775
12396 12541 12406 11607 12283 12059.40632 12607.83333 13156.26034
"In System less than" time 10 10 10 10 10 10 10
10 10 10 10 10 10 10 10
% In System less than time limit 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0
St Dev of 7459.67622 7669.06345 7377.55787 7504.87996
7658.46999 7759.50697 7567.41826 7769.71999 7633.24461
7718.82629 7657.71795 7636.0386 7541.57105 7617.67668
7693.78231
Maximum Time in System 32450.7918 33134.74111 32956.55925
33231.61736 32810.34916 33219.64803 32660.90182 32745.54031
32844.17675 32652.60083 32848.06908 32814.31806 32713.24065
32864.10947 33014.97828
Minimum Time in System 2981.77047 2997.76858 2986.10901
2978.43957 2961.59894 2977.82684 2999.75287 2991.86145
3009.15954 3007.77815 2974.21187 2988.67756 2978.9026
2987.9129 2996.92321
Imp Lifter empty yard in Waiting % 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0
Working % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Blocked % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Stopped % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Number Completed Jobs 508 661 643 771 718 626 691
611 580 598 635 662 598.91451 642 685.08549
Minimum use 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Average use 0.06183 0.08183 0.0789 0.09207 0.08829
0.0761 0.08439 0.07488 0.07049 0.07232 0.07841
0.08061 0.07317 0.07834 0.08352
Maximum use 3 3 4 4 4 3 3 3 4
3 3 3 3.0205 3.33333 3.64617
Current Contents 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0
Change Over % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Off Shift % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Resource Starved % 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0
Imp lifters Resources Utilization % 39.01134 45.38541 43.11251
47.99505 44.34483 44.00325 40.51592 42.27918
43.03242 42.54407 40.36139 42.2057 41.36969
42.89925 44.42882
Minimum Use 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Current Use 1 0 2 2 5 2 2 2 5
2 3 2 1.42127 2.33333 3.2454
Average Use 2.34068 2.72312 2.58675 2.8797 2.66069
2.6402 2.43096 2.53675 2.58195 2.55264 2.42168
2.53234 2.48218 2.57396 2.66573

Maximum Use 6 6 6 6 6 6 6 6 6
6 6 6 6 6 6
Traveling % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Imp Lifters yards out Waiting % 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0
Working % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Blocked % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Stopped % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Number Completed Jobs 3920 4295 4044 4353 4275 4257 3853
4089 4189 4174 4011 4055 4026.88163 4126.25 4225.61837
Minimum use 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Average use 1.92037 2.08695 1.98195 2.11366
2.08683 2.08024 1.88134 1.98659 2.0539 2.04366
1.95268 1.975 1.96634 2.0136 2.06085
Maximum use 6 6 6 6 6 6 6 6 6
6 6 6 6 6 6
Current Contents 1 0 1 1 5 2 2 1
5 2 1 2 0.92276 1.91667 2.91057
Change Over % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Off Shift % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Resource Starved % 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0
Imp Queue for Berths Minimum queue size 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0
Average queue size 0.02683 0.02732 0.0278 0.02683
0.02683 0.02829 0.02732 0.02878 0.02878
0.0278 0.02976 0.02854 0.02731 0.02791 0.0285
Maximum queue size 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1
Minimum Queuing Time 20 20 20 20 20 20 19.99997
20 19.99979 20 20 20 19.99994 19.99998
20.00002
Minimum (non-zero) Queuing Time 20 20 20 20 20 20
19.99997 20 19.99979 20 20 20 19.99994
19.99998 20.00002
Average Queuing Time 20 20 20 20 20 20 20 20
20 20 20 20 20 20 20
Average (non-zero) Queuing Time 20 20 20 20 20 20
20 20 20 20 20 20 20 20 20
Maximum Queuing Time 20 20 20 20 20 20 20
20 20 20 20 20 20 20 20
Number of non zero queuing times 55 56 57 55 55 58
56 59 59 57 61 58 55.96011 57.16667
58.37322
% Queued less than time limit 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0
"Queued less than" time 10 10 10 10 10 10 10 10
10 10 10 10 10 10 10
St Dev of Queuing Time 0 0 0 0 0 0 0 0
0.00003 0 0 0 -0 0 0.00001
Current Contents 0 0 0 0 0 0 0 0
0 0 0 1 0 0.08333 0.26675
Items Entered 55 56 57 55 55 58 56 59 59
57 61 59 56.00478 57.25 58.49522

Imp tractors Resources Utilization % 11.361 14.61507 14.38074 16.26314
13.97304 13.05227 13.79275 13.20608 12.84033
12.66122 12.44404 13.90385 12.74611 13.54113
14.33615
Minimum Use 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Current Use 0 0 2 2 0 2 0 2 0
0 1 0 0.13667 0.75 1.36333
Average Use 1.36332 1.75381 1.72569 1.95158
1.67677 1.56627 1.65513 1.58473 1.54084
1.51935 1.49328 1.66846 1.52953 1.62494
1.72034
Maximum Use 12 12 12 12 12 12 12 12 12
12 12 12 12 12 12
Traveling % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Imp Truck 1 Waiting % 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0
Working % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Blocked % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Stopped % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Number Completed Jobs 3618 4037 4235 5084 3873 4338 3782
3852 3818 3748 3576 3768 3713.24922 3977.41667 4241.58411
Minimum use 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Average use 0.4461 0.4872 0.5122 0.61622 0.4722 0.53463
0.4578 0.47524 0.46756 0.46244 0.43305 0.4578
0.45361 0.4852 0.51679
Maximum use 4 4 4 4 4 4 4 4 4
4 4 4 4 4 4
Current Contents 1 0 0 0 0 0 0 0
0 0 0 0 0 0.08333 0.26675
Change Over % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Off Shift % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Resource Starved % 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0
Imp Truck 2 Waiting % 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0
Working % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Blocked % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Stopped % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Number Completed Jobs 3419 4291 3921 4443 3917 4115 3486
3872 3920 3887 3416 3817 3671.45139 3875.33333 4079.21528
Minimum use 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Average use 0.41488 0.52012 0.47841 0.54 0.47683
0.50439 0.42671 0.47573 0.47756 0.47537
0.41829 0.47561 0.44921 0.47366 0.49811
Maximum use 4 4 4 4 4 4 4 4 4
4 4 4 4 4 4
Current Contents 0 0 1 0 2 0 1 1
0 0 0 0 0 0.41667 0.84145
Change Over % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0

Off Shift % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Resource Starved % 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0
Imp Truck 3 Waiting % 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0
Working % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Blocked % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Stopped % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Number Completed Jobs 4447 4927 4678 5075 4954 4914 4507
4672 4803 4771 4615 4698 4635.2225 4755.08333 4874.94416
Minimum use 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Average use 0.54183 0.59207 0.57476 0.61732
0.6039 0.59646 0.54756 0.56707 0.58573 0.58317
0.56598 0.5778 0.56549 0.57947 0.59345
Maximum use 5 5 5 5 5 5 5 5 5
5 5 5 5 5 5
Current Contents 0 1 0 0 2 1 0 1
1 0 2 0 0.17203 0.66667 1.1613
Change Over % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Off Shift % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Resource Starved % 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0
import tractors Waiting % 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0
Working % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Blocked % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Stopped % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Number Completed Jobs 10938 13936 13426 15287 13311 12404 13198
12659 12223 12069 11901 13155 12167.44463 12875.58333 13583.72204
Minimum use 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Average use 1.35902 1.75622 1.72159 1.9528 1.68305
1.55854 1.65841 1.58317 1.54244 1.52098
1.49354 1.66329 1.52829 1.62442 1.72055
Maximum use 12 12 12 12 12 12 12 12 12
12 12 12 12 12 12
Current Contents 0 0 2 2 0 2 0 2
0 0 1 0 0.13667 0.75 1.36333
Change Over % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Off Shift % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Resource Starved % 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0
QC1 exp Waiting % 89.90964 90.16694 90.11685 89.91612
90.41465 89.96936 90.2839 90.16636 89.96562
90.33701 90.19153 90.20732 90.03101 90.13711
90.2432
Working % 10.09036 9.83306 9.88315 10.08388
9.58535 10.03064 9.7161 9.83364 10.03438 9.66299
9.80847 9.79268 9.7568 9.86289 9.96899

Blocked % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Stopped % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Number Completed Jobs 2064 2012 2025 2075 1982 2062 1994
2026 2047 1965 2012 2013 2001.47474 2023.08333 2044.69192
Minimum use 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Average use 0.09829 0.09671 0.09854 0.1028 0.09695
0.10061 0.09512 0.09707 0.0989 0.09866 0.10061
0.0939 0.09662 0.09818 0.09974
Maximum use 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1
Current Contents 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0
Change Over % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Off Shift % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Resource Starved % 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0
QC2 imp Waiting % 82.81738 87.36829 81.26975 85.90924
86.7297 82.30588 74.38498 82.16695 84.40879
83.19254 79.99563 88.20477 80.82616 83.22949
85.63282
Working % 9.1125 11.42212 12.40476 12.7185 11.95384
11.66818 9.26328 11.10677 9.99027 11.28792
9.66798 10.62724 10.16859 10.93528 11.70197
Blocked % 0.03096 0.05538 0.00643 0.10787
0.02689 0.01832 0.01869 0.00903 0 0.0285
0.02383 0.03642 0.01206 0.03019 0.04833
Stopped % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Number Completed Jobs 1869 2352 2556 2623 2443 2397 1894
2273 2043 2294 1986 2174 2082.41405 2242 2401.58595
Minimum use 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Average use 0.09293 0.11463 0.1228 0.12878 0.11976
0.11707 0.09463 0.11354 0.10061 0.11402
0.09707 0.10622 0.10273 0.11017 0.11761
Maximum use 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1
Current Contents 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0
Change Over % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Off Shift % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Resource Starved % 8.03917 1.15421 6.31907 1.2644
1.28958 6.00762 16.33305 6.71725 5.60094
5.49104 10.31257 1.13157 2.95129 5.80504
8.65879
Queue for YC RTGs Minimum queue size 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0
Average queue size 0.00707 0.02427 0.02963 0.0322
0.0189 0.02037 0.01378 0.01695 0.0172 0.01561
0.01293 0.02256 0.01478 0.01929 0.0238
Maximum queue size 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1
Minimum Queuing Time 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0

Minimum (non-zero) Queuing Time 0.00514 0.00021 0.00286
0.00106 0.00027 0.00092 0.00251 0.00053
0.00113 0.00109 0.00196 0.00228 0.00077
0.00166 0.00255
Average Queuing Time 0.0285 0.07987 0.09467 0.09793
0.06547 0.07533 0.04504 0.05795 0.06473
0.05895 0.046 0.07458 0.05282 0.06575 0.07868
Average (non-zero) Queuing Time 0.73395 0.70937 0.75334
0.77958 0.74906 0.74697 0.7 0.69985 0.71035
0.76566 0.72942 0.76477 0.71951 0.73686
0.75421
Maximum Queuing Time 3.79498 5.85637 6.24524
6.79435 6.65325 4.35351 4.4749 4.66898 4.40341
4.98896 5.12695 4.82242 4.56122 5.18194
5.80267
Number of non zero queuing times 386 1427 1533 1738 1042 1130
768 952 1011 841 679 1166 815.1963 1056.08333
1296.97037
% Queued less than time limit 100 100 100 100 100 100 100
100 100 100 100 100 100 100 100
"Queued less than" time 10 10 10 10 10 10 10 10
10 10 10 10 10 10 10
St Dev of Queuing Time 0.19926 0.32883 0.35969 0.36619
0.30837 0.32028 0.24626 0.26987 0.29134
0.2822 0.24718 0.32373 0.26398 0.29527 0.32656
Current Contents 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0
Items Entered 9939 12674 12199 13835 11922 11205 11935 11497 11095
10924 10766 11957 11023.00501 11662.33333 12301.66166
Reefer space Utilization % 47.62187 47.68203 47.19501 56.89827
54.22464 52.19336 47.02393 48.68487 48.81794
45.10933 46.25764 45.59779 46.63537 48.94222
51.24907
Minimum Use 108 129 121 120 130 123 109 123 127
98 109 113 111.16651 117.5 123.83349
Current Use 126 142 148 140 179 136 161 150 128
135 137 136 133.75099 143.16667 152.58234
Average Use 142.86561 143.04608 141.58504 170.69481
162.67393 156.58007 141.07179 146.0546 146.45382
135.328 138.77293 136.79338 139.90612 146.82667
153.74722
Maximum Use 180 158 165 201 192 196 170 163 167
159 166 164 163.87467 173.41667 182.95866
Traveling % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Reefer yard imp Waiting % 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0
Working % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Blocked % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Stopped % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Number Completed Jobs 300 319 316 381 352 362 294
288 332 308 290 295 300.17747 319.75 339.32253
Minimum use 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Average use 102.37071 104.3053 102.64978 123.90833
119.70982 113.24115 102.18566 98.59063 107.36961
96.91866 97.25526 97.19758 99.75103 105.47521
111.19939

Maximum use 134 123 124 156 143 155 129 114 129
116 121 117 120.94608 130.08333 139.22059
Current Contents 77 103 107 97 132 82 121 101
90 87 97 91 88.74733 98.75 108.75267
Change Over % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Off Shift % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Resource Starved % 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0
Resource QC1 Utilization % 19.09036 21.38392 22.30685 22.71642
21.62554 21.69247 19.08294 21.02404 20.04038
20.92484 19.27254 20.65831 20.03709 20.81822
21.59934
Minimum Use 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Current Use 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Average Use 0.1909 0.21384 0.22307 0.22716 0.21626
0.21692 0.19083 0.21024 0.2004 0.20925 0.19273
0.20658 0.20037 0.20818 0.21599
Maximum Use 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1
Traveling % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Resource QC2 Utilization % 19.14527 21.31613 22.38648 22.6915
22.16567 21.82155 19.29446 21.3539 19.90827
21.25514 19.83897 20.58198 20.20969 20.97994
21.7502
Minimum Use 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Current Use 0 0 0 0 0 0 0 0 0
0 1 0 0 0.08333 0.26675
Average Use 0.19145 0.21316 0.22386 0.22692
0.22166 0.21822 0.19294 0.21354 0.19908
0.21255 0.19839 0.20582 0.2021 0.2098 0.2175
Maximum Use 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1
Traveling % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Resource QC3 Utilization % 18.71728 21.32366 18.93266 23.14
22.17829 18.03897 22.34775 19.6221 19.39223
19.02472 20.68153 20.07553 19.25036 20.28956
21.32876
Minimum Use 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Current Use 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Average Use 0.18717 0.21324 0.18933 0.2314 0.22178
0.18039 0.22348 0.19622 0.19392 0.19025
0.20682 0.20076 0.1925 0.2029 0.21329
Maximum Use 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1
Traveling % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Resource QC4 Utilization % 18.84321 20.97258 19.21211 23.33757
22.7501 18.13571 21.96154 19.86945 19.77038
19.16513 20.33408 20.22355 19.36551 20.38128
21.39706
Minimum Use 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0

Current Use 0 0 0 0 0 0 0 0 1
1 0 0 0 0.16667 0.41399
Average Use 0.18843 0.20973 0.19212 0.23338
0.2275 0.18136 0.21962 0.19869 0.1977 0.19165
0.20334 0.20224 0.19366 0.20381 0.21397
Maximum Use 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1
Traveling % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Resource QC5 Utilization % 28.35622 32.86753 32.77341 32.76616
25.91854 30.47845 31.69095 29.43565 30.48437
27.68695 27.8152 32.12777 28.70708 30.2001
31.69312
Minimum Use 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Current Use 0 0 1 1 0 1 0 1 1
0 1 0 0.16819 0.5 0.83181
Average Use 0.28356 0.32868 0.32773 0.32766
0.25919 0.30478 0.31691 0.29436 0.30484
0.27687 0.27815 0.32128 0.28707 0.302 0.31693
Maximum Use 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1
Traveling % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Resource YC RTG1 Utilization % 54.20976 59.33785 62.82583
71.53585 58.10473 61.82036 57.39124 58.41289
58.7592 56.69402 55.12338 58.67719 56.5338
59.40769 62.28158
Minimum Use 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Current Use 0 0 0 1 1 1 1 0 1
1 1 0 0.25616 0.58333 0.91051
Average Use 0.5421 0.59338 0.62826 0.71536 0.58105
0.6182 0.57391 0.58413 0.58759 0.56694 0.55123
0.58677 0.56534 0.59408 0.62282
Maximum Use 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1
Traveling % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Resource YC RTG2 Utilization % 53.61344 59.01107 63.01084
71.63278 58.19106 61.94309 56.0419 57.78919
58.35139 56.34289 54.48773 58.9557 56.07369
59.11426 62.15482
Minimum Use 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Current Use 1 1 1 0 0 0 1 0 0
1 1 0 0.16819 0.5 0.83181
Average Use 0.53613 0.59011 0.63011 0.71633
0.58191 0.61943 0.56042 0.57789 0.58351
0.56343 0.54488 0.58956 0.56074 0.59114
0.62155
Maximum Use 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1
Traveling % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Resource YC RTG3 Utilization % 54.89197 63.04535 62.88667
74.14985 60.04707 65.18064 58.6462 58.12459
56.49032 56.05408 54.85685 57.09057 56.59617
60.12201 63.64786
Minimum Use 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0

Current Use 0 0 0 1 1 0 1 0 0
0 1 0 0.0205 0.33333 0.64617
Average Use 0.54892 0.63045 0.62887 0.7415 0.60047
0.65181 0.58646 0.58125 0.5649 0.56054 0.54857
0.57091 0.56596 0.60122 0.63648
Maximum Use 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1
Traveling % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Resource YC RTG4 Utilization % 54.65782 63.25873 62.67123
74.45498 59.94585 64.52503 58.27138 57.90597
57.07802 56.60909 54.07291 56.97644 56.46504
60.03562 63.6062
Minimum Use 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Current Use 0 0 1 1 0 1 1 1 0
0 1 0 0.16819 0.5 0.83181
Average Use 0.54658 0.63259 0.62671 0.74455
0.59946 0.64525 0.58271 0.57906 0.57078
0.56609 0.54073 0.56976 0.56465 0.60036
0.63606
Maximum Use 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1
Traveling % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Resource YC RTG5 Utilization % 55.49806 74.017 67.60197 78.58013
66.0375 70.38327 58.83651 66.35054 65.49516
64.68794 56.21389 65.71344 61.48676 65.78462
70.08247
Minimum Use 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Current Use 0 0 1 1 1 0 1 1 0
0 1 0 0.16819 0.5 0.83181
Average Use 0.55498 0.74017 0.67602 0.7858 0.66037
0.70383 0.58837 0.66351 0.65495 0.64688
0.56214 0.65713 0.61487 0.65785 0.70082
Maximum Use 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1
Traveling % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Resource YC RTG6 Utilization % 55.82133 74.4123 67.34108
78.21872 65.51177 70.24769 58.78407 65.89815
65.79905 64.53085 55.95013 65.12712 61.36085
65.63686 69.91286
Minimum Use 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Current Use 0 0 1 1 1 1 0 1 0
0 1 0 0.16819 0.5 0.83181
Average Use 0.55821 0.74412 0.67341 0.78219
0.65512 0.70248 0.58784 0.65898 0.65799
0.64531 0.5595 0.65127 0.61361 0.65637 0.69913
Maximum Use 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1
Traveling % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
YC RTG 1 Waiting % 44.51402 47.20811 47.9734 37.92978
46.37277 42.31427 44.90067 43.21356 51.79577
44.60697 51.86201 48.53388 43.42553 45.93543
48.44534
Working % 10.26923 12.03409 11.88661 11.51737
11.30484 11.1805 11.40529 11.90984 11.38459

10.66592 10.92486 12.09528 11.02351 11.38153
11.73956
Blocked % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Stopped % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Number Completed Jobs 837 984 960 939 935 922 934
969 928 873 888 992 901.00915 930.08333 959.15752
Minimum use 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Average use 0.10293 0.12073 0.11695 0.11744
0.11598 0.11244 0.11451 0.12098 0.11537
0.10561 0.10829 0.12159 0.11055 0.1144 0.11825
Maximum use 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1
Current Contents 0 0 0 0 0 1 0 0
0 0 0 0 0 0.08333 0.26675
Change Over % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Off Shift % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Resource Starved % 45.21675 40.7578 40.13999 50.55285
42.32239 46.50523 43.69404 44.87661 36.81965
44.72711 37.21314 39.37084 40.1232 42.68303
45.24286

YC RTG 2 Waiting % 46.41036 45.84687 39.00693 37.4404
51.15234 43.60397 48.41447 52.32343 48.8928
44.46249 46.04555 50.48391 43.26234 46.17363
49.08492
Working % 10.20286 12.81997 11.44847 11.69845
11.83097 10.88163 11.6322 11.50133 10.98602
11.08146 11.0999 11.78581 11.0046 11.41409
11.82357
Blocked % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Stopped % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Number Completed Jobs 838 1060 927 969 979 882 955
948 905 901 908 973 900.86402 937.08333 973.30265
Minimum use 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Average use 0.10354 0.12683 0.11512 0.11451
0.1189 0.11244 0.11415 0.11659 0.11098 0.10976
0.11305 0.11854 0.11093 0.11453 0.11814
Maximum use 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1
Current Contents 0 0 1 0 0 0 0 0
0 0 1 0 0 0.16667 0.41399
Change Over % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Off Shift % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Resource Starved % 43.38678 41.33316 49.5446 50.86115
37.01669 45.51439 39.95333 36.17524 40.12118
44.45605 42.85455 37.73028 39.44697 42.41228
45.37759

YC RTG1 Waiting % 51.67257 48.46962 44.06088 35.5832
49.33654 44.18364 50.35787 49.08997 47.87369
49.95283 51.93589 48.47862 44.71599 47.58294
50.4499

Working % 43.94054 47.30376 50.93922 60.01848
46.79989 50.63986 45.98595 46.50306 47.37461
46.0281 44.19852 46.58191 45.28 48.02616 50.77231
Blocked % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Stopped % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Number Completed Jobs 905 969 1051 1234 958 1050 936
961 972 943 897 948 927.23011 985.33333 1043.43656
Minimum use 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Average use 0.44024 0.47171 0.51098 0.60317
0.46768 0.50585 0.46317 0.46512 0.47463
0.45878 0.4461 0.46659 0.45348 0.48117 0.50886
Maximum use 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1
Current Contents 0 0 0 1 1 0 1 0
1 1 1 0 0.16819 0.5 0.83181
Change Over % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Off Shift % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Resource Starved % 4.38689 4.22662 4.9999 4.39832
3.86357 5.1765 3.65618 4.40697 4.7517 4.01907
3.86559 4.93947 4.07736 4.3909 4.70443
YC RTG2 Waiting % 52.51047 48.34238 43.93574 35.99831
48.62337 44.59365 50.41273 49.63274 48.16886
49.7126 51.05059 47.96775 44.79212 47.5791
50.36608
Working % 43.41059 46.1911 51.56237 59.93208
46.36009 51.06145 44.4097 46.28786 47.36537
45.26144 43.38783 47.1699 44.75657 47.69998
50.64339
Blocked % 0 0 0 0.00225 0 0 0 0
0 0 0 0 0 0.00019 0.0006
Stopped % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Number Completed Jobs 884 946 1053 1242 946 1043 914
954 970 932 885 960 914.97142 977.41667 1039.86192
Minimum use 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Average use 0.4328 0.46183 0.51902 0.5978 0.46366
0.50976 0.44488 0.46463 0.47366 0.45098
0.43402 0.47122 0.44763 0.47702 0.50642
Maximum use 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1
Current Contents 1 1 0 0 0 0 1 0
0 1 0 0 0.0205 0.33333 0.64617
Change Over % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Off Shift % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Resource Starved % 4.07894 5.46652 4.50189 4.06736
5.01654 4.3449 5.17757 4.07939 4.46577 5.02596
5.56158 4.86235 4.37927 4.72073 5.06219
QC 4 imp Waiting % 90.28655 83.13687 89.79332 85.35765
86.00687 90.85039 82.47495 89.08369 83.64626
83.53918 88.30065 79.83484 83.7453 86.02593
88.30657
Working % 8.78903 11.08719 9.00043 13.14534
12.44824 8.29265 12.18304 9.77332 9.57673
9.32763 10.53344 10.37356 9.3893 10.37755 11.3658

Blocked % 0.01553 0.00855 0.15223 0.03899
0.00549 0.03184 0.03308 0.00284 0.056 0.02297
0.02547 0.09423 0.01313 0.0406 0.06807
Stopped % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Number Completed Jobs 1800 2279 1852 2703 2550 1704 2487
2008 1961 1897 2165 2133 1925.42097 2128.25 2331.07903
Minimum use 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Average use 0.08744 0.11122 0.09341 0.1328 0.12524
0.08378 0.12207 0.09793 0.09598 0.09427
0.1078 0.10561 0.09492 0.1048 0.11468
Maximum use 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1
Current Contents 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0
Change Over % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Off Shift % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Resource Starved % 0.90889 5.7674 1.05403 1.45801
1.53939 0.82512 5.30894 1.14015 6.72102
7.11022 1.14043 9.69738 1.55406 3.55591
5.55777
Resource YC RTG7 Utilization % 49.69735 55.44012 52.70739
57.38682 53.47041 53.32095 50.93673 52.16948
53.23097 53.46996 50.54037 51.24733 51.44166
52.80149 54.16133
Minimum Use 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Current Use 0 1 1 1 0 0 0 1 1
1 1 0 0.25616 0.58333 0.91051
Average Use 0.49697 0.5544 0.52707 0.57387 0.5347
0.53321 0.50937 0.52169 0.53231 0.5347 0.5054
0.51247 0.51442 0.52801 0.54161
Maximum Use 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1
Traveling % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Resource YC RTG8 Utilization % 49.58501 55.18784 52.7201
57.38101 54.14907 53.65135 51.78734 51.56955
52.85308 52.62948 50.69467 51.76523 51.50891
52.83114 54.15338
Minimum Use 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Current Use 1 0 1 0 1 0 0 0 0
0 1 0 0.0205 0.33333 0.64617
Average Use 0.49585 0.55188 0.5272 0.57381 0.54149
0.53651 0.51787 0.5157 0.52853 0.52629 0.50695
0.51765 0.51509 0.52831 0.54153
Maximum Use 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1
Traveling % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
YC RTG 7 Waiting % 52.56787 58.76652 56.89856 57.60229
47.44028 59.1874 53.78829 59.2078 51.30778
62.62997 64.70803 55.56776 53.55927 56.63938
59.71948
Working % 12.44806 16.06512 15.61845 18.83112
13.99303 14.40743 14.61904 13.86612 13.62321
13.33733 12.9439 14.35752 13.42698 14.50919
15.59141

Blocked % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Stopped % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Number Completed Jobs 1015 1313 1287 1557 1165 1186 1196
1150 1118 1078 1059 1184 1101.06184 1192.33333 1283.60483
Minimum use 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Average use 0.12354 0.1589 0.15634 0.18951 0.13817
0.14305 0.14293 0.13707 0.13659 0.13427
0.13024 0.14598 0.13374 0.14472 0.1557
Maximum use 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1
Current Contents 0 0 0 1 0 0 0 1
0 0 0 0 0 0.16667 0.41399
Change Over % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Off Shift % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Resource Starved % 34.98407 25.16836 27.483 23.56659
38.56669 26.40517 31.59266 26.92608 35.06901
24.0327 22.34807 30.07472 25.54306 28.85143
32.15979
YC RTG 8 Waiting % 54.6734 55.80631 61.64434 49.52291
61.11153 64.46705 51.50446 56.70669 57.0606
58.77994 57.12232 49.82629 53.55635 56.51882
59.48129
Working % 11.96012 15.84703 15.54596 18.45313
14.69179 14.64694 14.55756 14.03313 14.31079
13.00659 12.50896 15.0331 13.47011 14.54959
15.62907
Blocked % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Stopped % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Number Completed Jobs 984 1299 1291 1515 1200 1200 1186
1153 1156 1065 1032 1227 1103.55099 1192.33333 1281.11568
Minimum use 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Average use 0.11768 0.15915 0.15854 0.18439
0.14378 0.14939 0.14512 0.1411 0.14207 0.12963
0.12585 0.15171 0.13458 0.1457 0.15682
Maximum use 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1
Current Contents 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0
Change Over % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Off Shift % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Resource Starved % 33.36648 28.34667 22.8097 32.02396
24.19669 20.886 33.93798 29.26018 28.6286 28.21347
30.36873 35.14061 26.08625 28.93159 31.77693
YC RTG7 Waiting % 53.94114 49.25207 52.83261 48.70079
49.82918 51.1133 52.92466 51.50639 50.94065
51.94604 52.58087 52.96381 50.50566 51.54429
52.58293
Working % 37.24929 39.375 37.08895 38.5557 39.47737
38.91352 36.31769 38.30337 39.60776 40.13263
37.59647 36.8898 37.5016 38.2923 39.08299
Blocked % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0

Stopped % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Number Completed Jobs 766 815 767 790 817 792 744
785 811 830 774 761 770.88174 787.66667 804.45159
Minimum use 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Average use 0.37073 0.39476 0.37146 0.38549
0.39524 0.38927 0.36085 0.38354 0.39671
0.40073 0.37512 0.36671 0.37412 0.38255
0.39098
Maximum use 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1
Current Contents 0 1 1 0 0 0 0 0
1 1 1 0 0.08949 0.41667 0.74384
Change Over % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Off Shift % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Resource Starved % 8.80957 11.37293 10.07844 12.74351
10.69344 9.97318 10.75765 10.19025 9.45159
7.92133 9.82266 10.14638 9.39042 10.16341
10.9364
YC RTG8 Waiting % 54.28248 49.78684 51.56182 48.2181
50.35385 51.07544 53.57008 51.36532 51.21953
52.08952 53.39186 51.89187 50.49453 51.56722
52.63992
Working % 37.62488 39.34082 37.17414 38.92788
39.45729 39.00441 37.22978 37.53642 38.54228
39.62288 38.18572 36.73212 37.645 38.28155 38.9181
Blocked % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Stopped % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Number Completed Jobs 772 811 763 797 811 796 754
773 784 814 787 755 771.04186 784.75 798.45814
Minimum use 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Average use 0.37768 0.39402 0.37366 0.38866
0.39598 0.38976 0.3711 0.37488 0.38439 0.395
0.38232 0.36671 0.37649 0.38285 0.38921
Maximum use 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1
Current Contents 1 0 1 0 1 0 0 0
0 0 1 0 0.0205 0.33333 0.64617
Change Over % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Off Shift % 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Resource Starved % 8.09264 10.87235 11.26404 12.85402
10.18887 9.92015 9.20014 11.09827 10.23819
8.28759 8.42242 11.376 9.22994 10.15122 11.07251
Empty yard lifters resources Utilization % 46.72701 48.77746 48.52558
49.0566 48.70091 47.37149 47.93697 48.0817
47.65146 47.50687 48.0337 47.79842 47.58915
48.01401 48.43888
Minimum Use 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
Current Use 0 3 0 2 4 3 6 1 6
3 6 3 1.71635 3.08333 4.45032
Average Use 2.80362 2.92665 2.91153 2.9434 2.92205
2.84229 2.87622 2.8849 2.85909 2.85041 2.88202
2.86791 2.85535 2.88084 2.90633

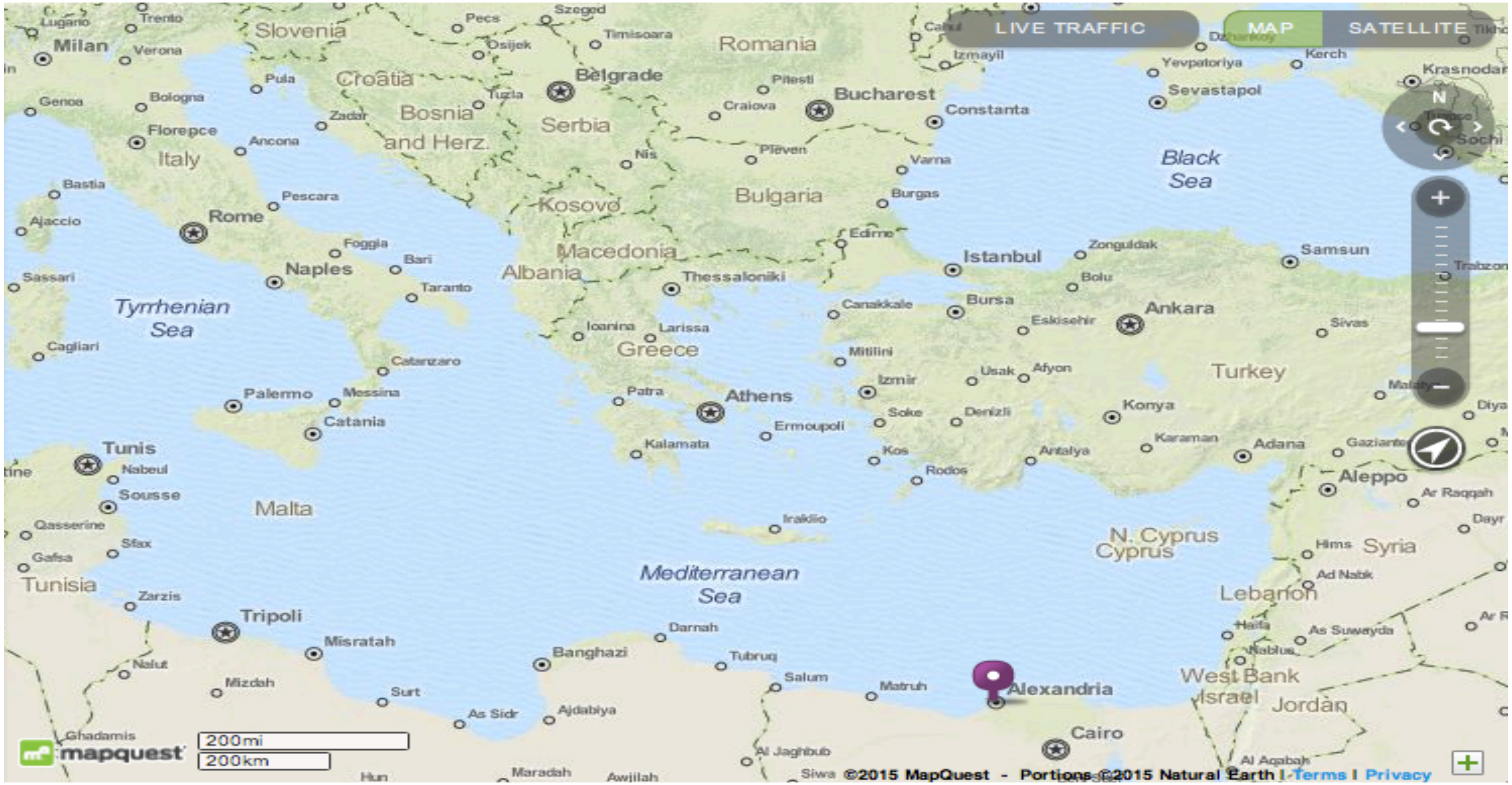
Maximum Use	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
Traveling %	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix V

A Map of Egypt Location

Appendix VI

A Map of Alexandria Location



Appendix VII

Selected Equipment employed by the case company

Yard crane

Appendix VIII

Publications Arising from this Research

- ElMesmary, H., Song, D-P. and Dinwoodie, J. (2013). Modelling Container Logistics Processes in Egyptian Container Terminals: A Case Study in Alexandria. In the *Logistics Research Network (LRN) conference*. Birmingham, UK, 5th to 7th September 2013.
- ElMesmary, H., Song, D-P. and Dinwoodie, J. (2014). Pipe flow Modelling of Container Terminal Logistics Processes: A Case Study in Alexandria. *International Journal of Logistics Research and Applications*. [Online] Available from: http://www.tandfonline.com/doi/full/10.1080/13675567.2014.986443.

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