Developing a Tool for Designing a Container Terminal Yard

Master Thesis Project

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This report is the final result of Master of Science Hydraulic Engineering at Delft University of Technology. The study was done at Maritime Division of Royal Haskoning B.V. (RHMD), in Rotterdam. The subject for the thesis was offered by RHMD.

The aim of this research is to provide RHMD with a tool for engineers to prepare a concept design of a container terminal layout. The package should provide RHMD with information on the required total area for a new container terminal.

First of all my thanks go to my graduation committee: Prof. Ir. Tiedo Vellinga who provided overall guidance of my work on this research, and Ir. Joppe Burgers from RHMD who help me as the daily supervisor. I am very grateful to Dr. Ir. H. P. M. Veeke and Ir. Michiel de Jong for their kind cooperation and their invaluable feedbacks on my master thesis project. Furthermore, my colleagues at Royal Haskoning have been very helpful, friendly and cooperative with my occasional setbacks. Special thanks to Ir. J. Beeman for providing me with constructive inputs and valuable references during my time at RHMD. Last but not least, this project has been facilitated thanks to Royal Haskoning B.V..

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Summary

Background

Container traffic has grown exponentially since 1980 and has become a reliable and efficient means of transportation of goods. In addition, world wide containerization and the availability of cheap and frequent container transport to all corners of the world have had a profound influence on industrial production, transport and the environment. All these aspects result in increasing the pressure on container terminals to provide good service to shipping companies.

The problem

The Royal Haskoning Maritime Division (hereafter, RHMD) deals internationally with design of different types of terminals, such as container, liquid and dry bulk. Due to involvement of numerous stakeholders in a port planning project, different design concepts may be considered to satisfy interests of different stockholder; therefore, various scenarios should be studied quantitatively at the start of a project, and in more details in the following phases. As an international maritime consultant, it is of crucial importance to own a simple, cheap and easy to use tool to estimate the dimensions of a container terminal yard based on different scenarios.

Objective

The goal of this study is to develop a tool for engineers to prepare concepts of terminal layout, and estimate the required areas of those concepts. These concepts can be developed for sake of comparison in design of a new container terminal.

Analysis of container terminal design tool

Container terminal design is divided into design of "waterside" and "landside" areas. The waterside consists of a quay for serving vessels. The landside consists of a storage yard for stacking containers, and a hinterland area for serving truck and trains (*e.g.* see Figure 0-1).

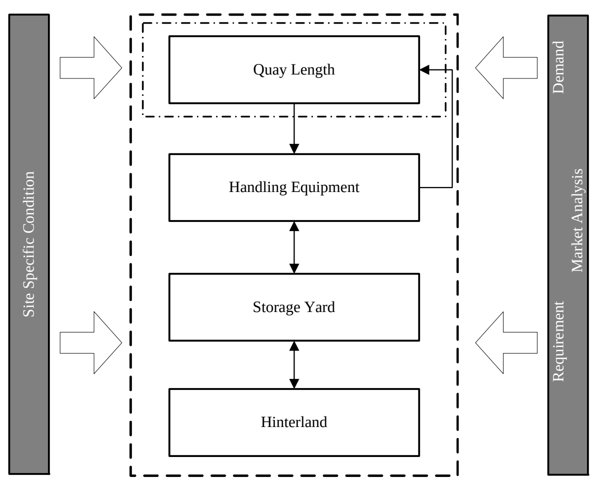


Figure 0-1: design process (Saanen, 2004)

Structure of the model

The developed package, in four consecutive steps, first, accepts the waterside, landside and cost estimation information, such as terminal throughput, downtime, stack occupancy, and second, requires the possible equipment concepts, such as ship to shore cranes and reach stackers etc. In the third step, the input data is used to estimate the performance of the terminal concepts which are presented in the forth step. Based on the above input data, the performance of the terminal concepts is quantitatively evaluated. Eventually, the dimensions of the container terminal yard are presented. Figure 0-2 shows the structure of the container terminal design tool.

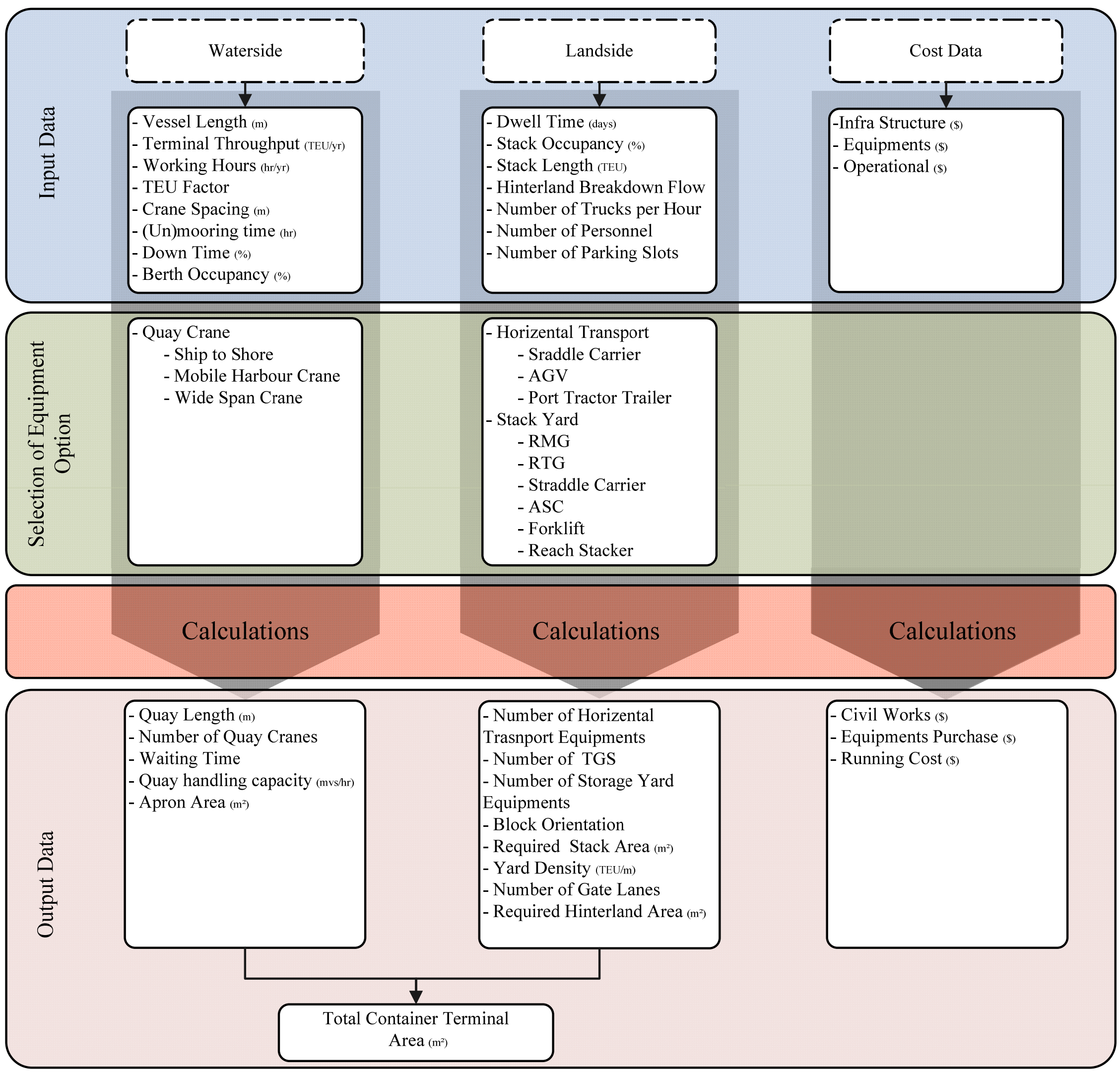


Figure 0-2: Structure of the container terminal design tool

Validation and case study

The container terminal design tool is verified against two formerly performed projects (in India and Guatemala) that have been successfully designed at RHMD. The validation showed good performance of the tool, with justified differences compared to actual designed values. As a case study, the package is also applied on design of a container terminal for a port in Angola. In this case study, four scenarios which are different in basic factors such as annual throughput, dwell time and berth occupancy are defined. In addition, for each scenario, three different concepts that have been selected for each type of quay and yard handling equipment combination are considered. Finally, their impacts on layout dimensions are considered and analyzed.

Final remark

The aim of this study was to provide Royal Haskoning Maritime Division with a model to support container-terminal designers in calculating the required total area for a new container terminal. The model is developed to assist the designer in assessing various design scenarios. The scenarios can differ in terms of land allocation to different parts of the terminal, and selection of a proper combination of handling equipments both on the waterside and the landside.

CONTENTS

Terms and abbreviations

AGV	Automated Guided Vehicle; internal movement vehicle that can operate without human control.
Aisle	The space between stacks of containers allowing access for mobile equipment.
Apron	Area of the terminal between the quay and the container stacking area.
Bay	Row of containers placed end-to-end.
Beam	The width of a vessel at its broadest point.
Berth	Slot on the quay for mooring and service of a single vessel.
Block stack	Grouping of containers without leaving easy access to all containers, often used for storage of empty containers.
Call size	Volume of containers (TEU) that is to be loaded onto or unloaded from a vessel calling at a terminal.
CFS	Container Freight Station; Warehouse facility where containers are packed and unpacked.
Container	Metal box structure of standard design, used for carrying general cargo in unitised form.
Container yard	Container stacking area of the terminal.
Discharge	Removal of unloading of a container from a vessel.
Downtime	Period during which a certain equipment item, or terminal component can not be used for its primary function.
Dwell time	The time in days that containers remain in the container yard.
FEU	Forty-foot equivalent unit. A term used in indicating container
Gate	The entrance point of road trucks entering and leaving the terminal.
Ground slot	The area required for the footprint of a container.
Hatch cover	Watertight means of closing the openings in the deck of a vessel (Hatchway) through which cargo is loaded into, or discharged from the hold.
LOA	Length Over All, full length of the vessel.
MCA	Multi Criteria Analysis, decision tool for objectively weighing options on a number of criteria.
MHC	Mobile Harbour Crane
Mooring	Securing a ship to a fixed place by means of lines and cables.
Moves	Actual containers handled as opposed to TEU handled.
MT	Abbreviation for empty containers.
MTS	Multi-trailer system, internal movement equipment of multiple chassis pulled by a single tractor.
Parcel size	See Call size
Phase	The period between two predefined physically build out steps of the master plan of the infrastructure. For the sake of this model, the total throughput of the system during one phase is considered to be constant.
Port Authority	The recognized statutory body responsible to the government for overall governance of the port
PTT	Port tractor trailer
Quay	The area parallel to the shoreline, accommodating ships on only one side.
QC	Quay crane, specialized crane located on the quay for the purpose of loading and unloading (containerized) cargo
Reefer container	Refrigerated container requires an external power source.

RMG	Rail mounted gantry
RTG	Rubber tired gantry
Slot	Place to store a single container, no to be confused with ground slot.
Spreader	A framework device enabling the lifting of containers by their corner castings
STS	Ship-to-Shore Gantry crane
Stack	The stack of containers in the yard
TGS	TEU ground slot, area required for the footprint of a twenty-foot ISO container, including surrounding safety margins.
TEU	Twenty-foot equivalent unit
Throughput	Sum of all handled cargo handled by the terminal, normally measured at the quay.
Transhipment cargo	Cargo landed at the terminal and shipped out again on another vessel without leaving the port area
Twistlock	Device that is inserted into the corner castings of a container and is turned or twisted, interlocking locking the container for the purpose of securing or lifting.
Vessel	General term for any watercraft or ship.

Symbols

C	Annual Throughput	(TEU/yr)
C_q	Quay handling capacity	(TEU/yr)
D_t	Downtime	(%)
f	TEU factor	
$\hat{h}$	Maximum operational stacking height	(-)
L_b	Berth use (Vessel length+ Berthing gap)	(m)
L_{br}	Berth length requirement	(hrs.m/week)
L_q	Quay length	(m)
L_v	Average vessel length	(m)
N_b	Number of berths	
N_c	Number of cranes per vessel	(-)
N_{dw}	Number of working days per week	(-)
N_{TGS}	Number of TEU ground slots	(-)
N_v	Vessel arrival	(No/week)
P	Peak factor per week	(-)
S	Stack visits	(TEU/yr)
S_p	Parcel Size	(TEU)
T_b	Annual berth working hours	(hrs/yr)
T_{bw}	Berth working hours per week	(hrs/week)
T_d	Working hours per day	(hrs/day)
T_{dw}	Average Dwell time	(days)

T_s	Total Service time	(hrs/week)
T_w	Total working hours	(hrs/yr)
Q_c	Quay productivity	(mvs/hrs)
Q_{cr}	Crane productivity	(TEU/hr)
U_{berth}	Berth occupancy	(%)
W_{ct}	working crane time due to ship total berthing time	(-)
μ	Transhipment factor	(-)

1 INTRODUCTION

1.1 Preface

This study presents the graduation project (as part of the TUDelft MSc. program), which reports the development of a tool for design of a container terminal yard. The project has been carried out in corporation of TUDelft and Royal Haskoning.

Royal Haskoning is internationally acclaimed as a world leader in waters edge and maritime/marine sector (Royal Haskoning Maritime Division, 2011). Founded in 1881 in the Netherlands, Royal Haskoning consists of 11 divisions, 57 offices and has presence in 17 countries. The Maritime division has significant experience in design of container terminals, Ro-Ro facilities, liquid and dry bulk terminals, jetties, shipyards, dockyards, naval bases, fishing harbours and cruise terminals.

Nowadays, demand for transportation especially in the form of containers transport is growing annually. Large part of these containers is transported overseas with container vessels and overland with trucks and/ or trains. Terminals are used as the interface between transport over land and sea. The growth of the global container port throughput is increasing the pressure on the container terminal to provide an efficient service to shipping companies. Therefore, a port that provides better service can attract more shipping companies and can increase its container volumes.

1.2 Problem definition

In the design of a container terminal, the first step is to establish the boundary conditions and the second step is to select handling equipment. In the handling operation, the characteristics of quay crane and the characteristics of different equipment types for transferring container between quay-yard and inside the yard are of crucial importance. Selecting the equipment is based on boundary conditions and requirements. Because of the variety of parameters, inputs and case-sensitive complexities, designing the container terminal is a time consuming process. In order to increase design process efficiency, several tools have been developed to design or optimize the layout of container terminals, most of these tools are cost and labour intensive.

The need for a simple and inexpensive tool to estimate the dimension of a container terminal yard is the motivation for this study.

1.3 Goal of the study

In order to find the optimal design of a container terminal yard, this study presents a tool comprised of Excel worksheets that based on existing empirical formulations, defines the dimensions of a terminal yard. The goal of this study is to develop a standardized and user-friendly tool that is accessible to Royal Haskoning container terminal designers. The present package aims to provide an easy model for engineers to compare and prepare a concept design of a terminal layout and estimate the required total area for the new container terminal. It assists the engineers to make a first selection of cargo handling equipment. By using different equipment for different throughput magnitudes, the total area for container terminal will be calculated.

The tool helps the engineer to answer following questions:

At waterside:

- What is the best Quay handling system and how many of that is needed to meet performance requirements?
  - Following equipment will be included:
    - Ship to shore crane
    - Mobile harbour crane
    - Wide span crane
- What is the best horizontal transport equipment and how many of that is needed to meet performance requirements?
  - Following equipment will be included:
    - Port tractor terminal
    - Straddle Carrier
    - AGV
- What is the required area for the apron?

At landside

- What is the best storage yard handling system and how many of that is needed to meet performance requirements?
  - Following equipment will be included:
    - Forklift truck
    - Reach stacker
    - Straddle Carrier
    - Rubber Tyred Gantry
    - Rail Mounted Gantry
- What is the required area for a storage yard?
- What is the required area for buildings?
- What is the required total area for a new container terminal?

1.4 Approach

In order to provide concrete answers for the above mentioned questions, this study consists of two phases: research and case study.

In phase one, the history development of the container industry, the container terminal operation, terminal layout and the handling equipments will be explained. The development of the tool and its validation will be presented. Figure 1-1 indicates the overview of the primary phase.

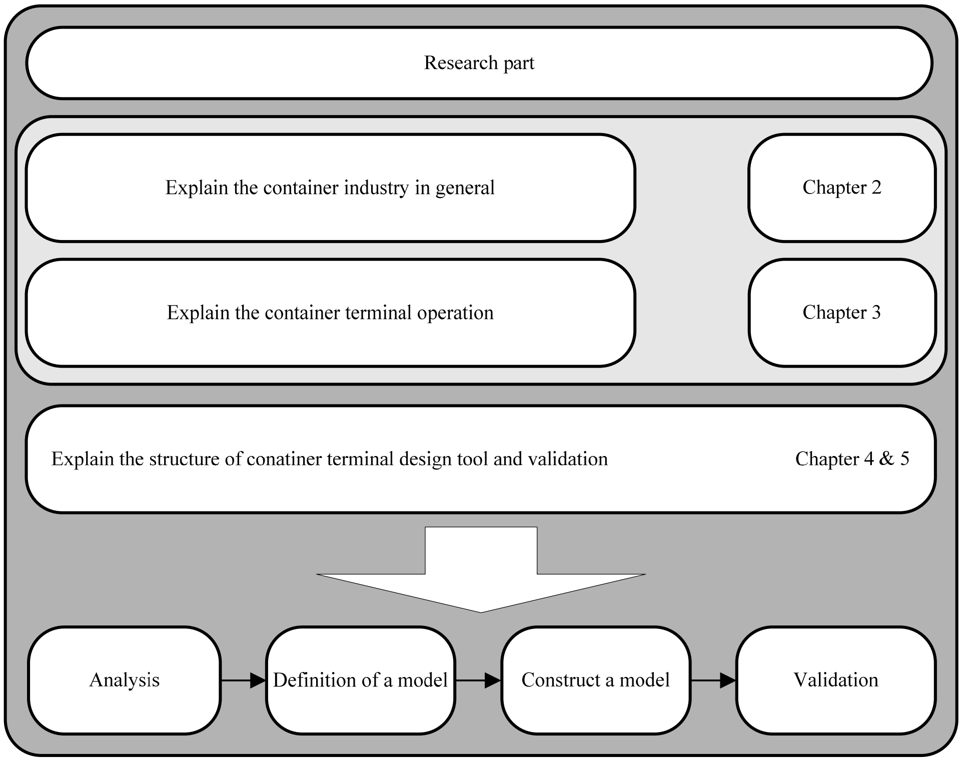


Figure 1-1: Approach of the research part

The second phase of this study consists of an application of the developed package, to a real-world design process for a port in Angola. The design includes different functionalities such as supply base, storage and handling oil and containers.

1.5 Outline

This report starts with introduction in Chapter 1 and gives some general information about container industry in Chapter 2. The container terminal operations and handling equipments are described in Chapters 3. The structure of the tool is described in Chapter 4. Chapter 5 is a validation of the present package against two previously performed projects of Royal Haskoning. Chapter 6 is an application of the tool in design of a container terminal in Angola. Conclusions and recommendations are presented in Chapter 7. The report is completed by the appendices and the references.

2 THE CONTAINER INDUSTRY

2.1 History and Development of Containerisation

There is no single point in history that can be considered as the definite start of containerisation. However their use has been reported as far back as the 19th century. Those containers were much smaller than the current containers and came in a variety of shapes and sizes due to the lack of an industry standard.

The establishment of railway systems in the 19th century, especially into areas where inland shipping was not possible, enabled the transportation of large cargo volumes. The increased used of containers in the early 20th century led to a new generation of containers, which eventually resulted in the standardization of containers; as we know today. In 1929 sea containers were transported between New York and Cuba. Starting a period of rapid container development in 1951, the Danish United Shipping company built the first specialized container vessel for the distribution of Danish beer and food and in 1960 the first cellular containership was designed. Container traffic hassince grown exponentially and has become a reliable means of goods.

Recently (2002 to 2011) the number of containers shipped internationally, has grown from 77.8 to 140 millions TEUs. It is expected that container traffic will grow (Figure 2-1) to 177.6 million TEU by 2015 despite a slower rate of annual growth. (approximately 6.6% between 2002-2015compared to 8.5% during 1980-2002 (adapted from Drewry Shipping Consultants, 2007)).

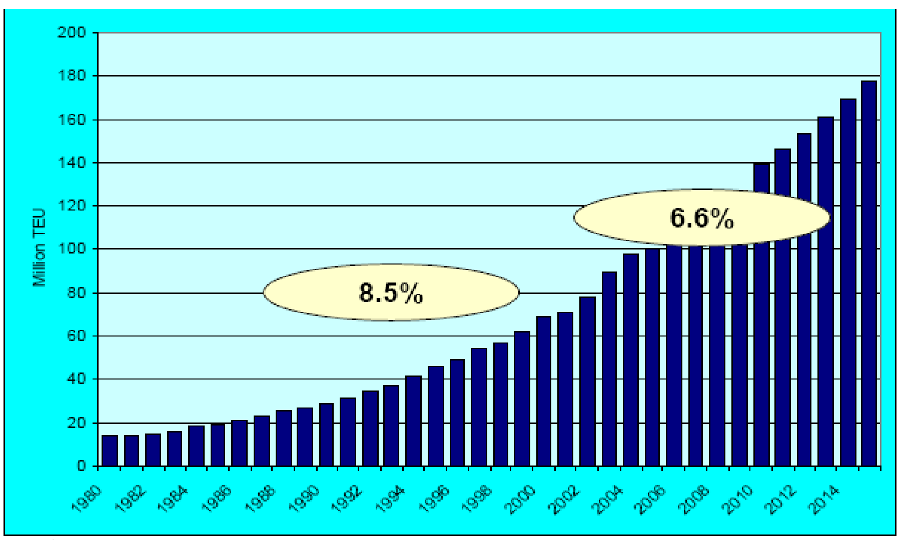


Figure 2-1: Past and forecast global container volumes between 1980 and 2015, the empty containers are not included in the container volumes presented in the figure and every container is counted only once per transportation (Drewry Shipping Consultants, 2007)

The early generation of container ships could transport 750-1100 TEU. In order to handle the increasing number of containers in the world, new generations of container ships were developed. Nowadays, container ships with capacities of 6000-15000 TEU sail the seas. Figure 2-2 shows the development of container vessels with their corresponding construction year.

The latest generation of container vessels includes two types of vessels. The first type (New Panamax), has a width that exactly fits within the after-expansion Panama Canal, and has a capacity of up to 14500 TEU (Figure 2-3). The second type (Post New Panamax, Emma Maersk, Triple class E) with Four-hundred meters long, 59 meters wide and 73 meters high and can handle up to 18000 TEU. It was introduced as the largest vessel of all the types in 2011.

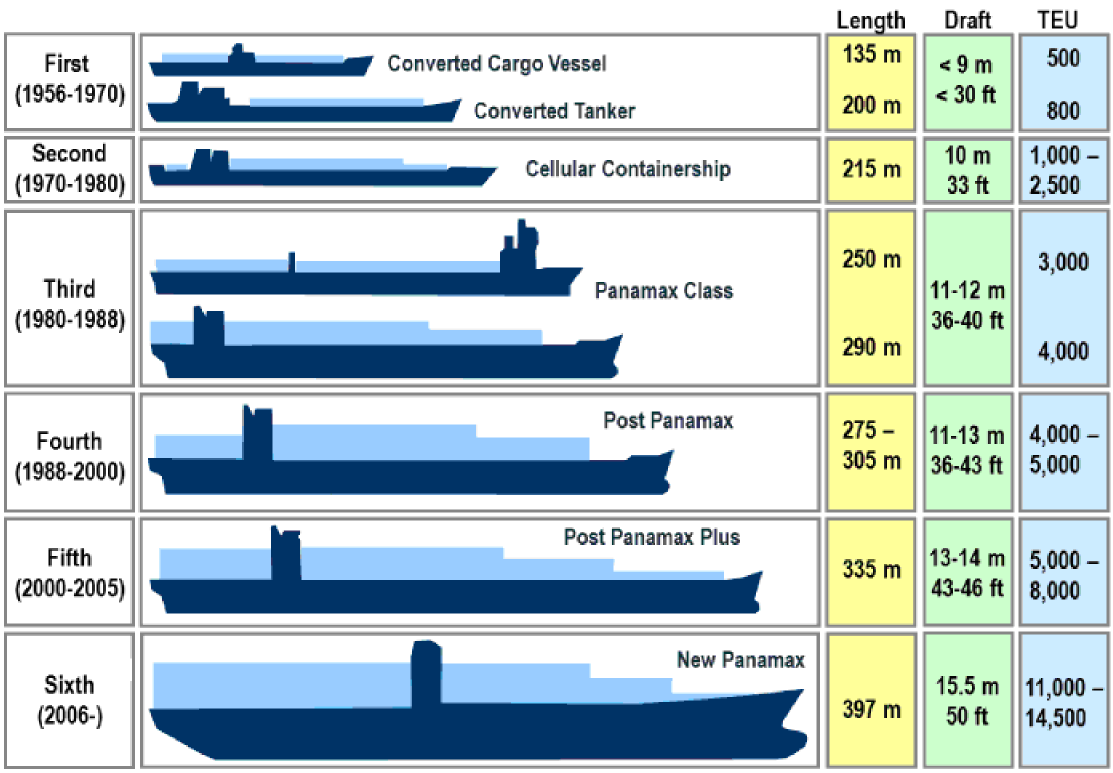


Figure 2-2: Six generation of containerships (from Jean-pual rodrigue, 2009)

Figure 2-3: the Elly Maersk,sixth generation (launched in 2007)

2.2 The Effect of Containerisation on the World's Industry

2.2.1 Global Production

Prior to containerisation, the expensive cost of transportation over long distances inhibited (financially) the separation of local market and the production factory. This promoted localized industries.

Containerization played a fundamental role in changing how industrial production and distribution occurs around the world. The decline of sea transportation costs resulted in the labour costs becoming the decisive factor for the location of manufacturers and not the market location. In addition, cost effective transport enabled the location of production of parts, components and assembly be separated. Consequently, the local markets have merged into one global market with cheap and frequent transport of containers to all corners of the world. This has resulted in a higher rate of growth in container transportation when compared to other modes of transportation. For instance, China is a recognized location for low cost production. However, it has also become an important market for luxury goods from EU and USA. Figure 2-4 shows the approximate distribution of global container volumes by 2015.

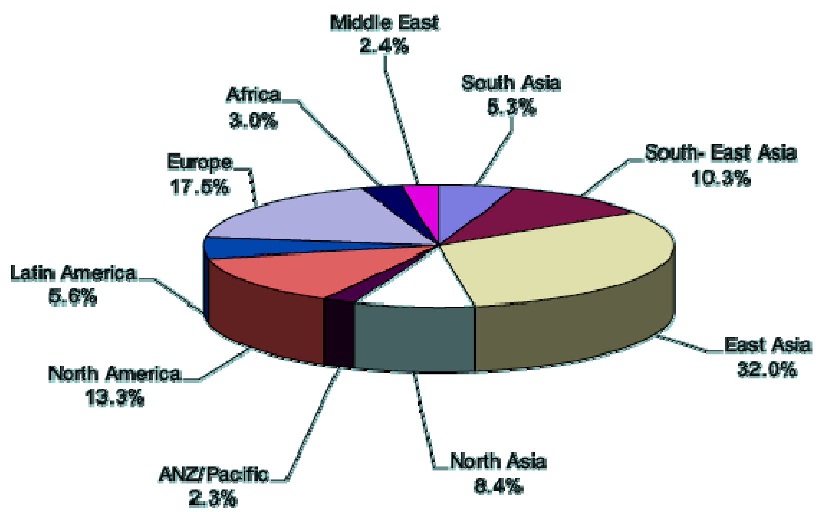


Figure 2-4: Distribution of containers volumes in 2015 (from United nation ESCAP)

2.2.2 Multifaceted Transport Chains

In the previous decades, the costs of loading and unloading general cargo were higher than the cost of transport itself. Furthermore the cost of transferring the cargo from one vessel to another was too high to allow complex transhipment routes. The low handling cost associated with the use of containers allowed complex transhipment routes to become feasible. As a result, containerisation offers the opportunity for distributes goods from small ports to main ports and vice versa by feeders.

3 CONTAINER TERMINAL ANALYSIS AND OPERATIONS

3.1 Function and operations of container terminal

Container terminals can be described as a system that links two external processes:

- Quayside process: water based transport
- Landside process hinterland transport (including inland waterways)

The primary function of a container terminal is a traffic functions and the traffic functions are done by connecting the water and land side transportation by providing intermodal connection. This process is schematized in Figure 3-1. The traffic functions required at both interfaces are as follows:

- Loading and unloading of containers to and from vessels
- Storage for containers
- Verification of container information
- Checking or recording of container damage
- Verification of container content
- Providing supporting services

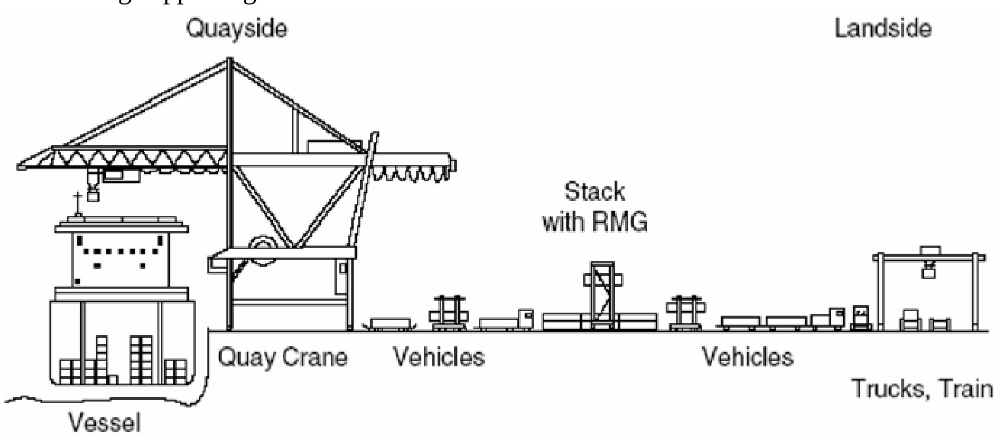


Figure 3-1: Transportation and handling chain of a container (Steenken et al. (2004))

1. Loading and unloading of containers to and from vessels

Container handling at the quayside and the landside is one of the core logistic and business of container terminals. When a ship arrives at the port, quayside cranes load and unload containers. On the landside, terminals load and unload containers from other modes of transport such as trucks, trains and barges for further transportation to and from the hinterland.

2. Storage for containers

Temporary storage is an essential function of a terminal in which the "Import" and "Export" containers remain for a certain period of time awaiting transfer to the next mode of transport. Perfect equivalence between the land and the sea side transport is not feasible for two reasons: (1), it is not possible in practice, and (2), because without a storage yard, the system becomes extremely vulnerable to any disturbance. Therefore, after unloading at the seaside/landside, the containers are moved to the storage yard, by means of terminal tractors, straddle carriers or automatic vehicles. The logistic process to/from storage yard in a container terminal is summarized in Figure 3-2.

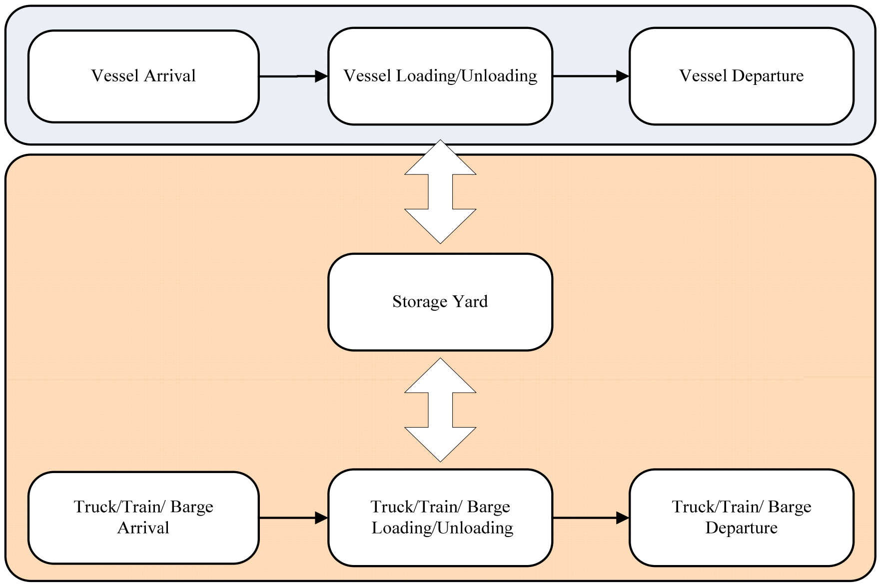


Figure 3-2: Container terminal logistics processes. (A Saanen (2004))

3. Verification container information

To ensure containers reach their intended destination safely and surely, an important function of a terminal is to verify the containers information. Prior to the development of the internet and other ICT applications[1], all information about the containers was transferred on the same vessel as the cargo itself and was handed over upon arrival of the ship. Recent developments have allowed cargo-data to be transferred faster via internet and to be available at the destination ahead of the cargo. This has enabled the efficiency of containerisation to further improve “handling” and “cost reduction”.

4. Checking or recording of container damage

In long and complex transport chains, due to involvement of various parties, damage to the cargo may occur. Therefore, damage inspection of the containers is carried out at two points; the entrance and the exit of container terminals. This step is to determine the responsible party for the damage.

5. Verification of container content

In principle, the containers are not opened between the origins and the destination. However, due to increase in the global flow of containers, containers are randomly selected based on statistic and

[1] 'ICT application' is a technical term for a standard computer program. Common ICT applications are Word processors, Desktop Publishing (DTP) software, Spreadsheets, Databases and Presentational software.

intelligent methods for inspected (*e.g* by X-ray scanning). If scanning identifies suspicious items, the container will be unpacked for physical inspection.

6. Providing supporting services

Before 21st century, container terminals provided support services such as container repair, container cleaning, pre-tripping of reefers to the industry. Nowadays, because of the high price of land close to the terminal area, many support services are provided by small specialised organisations ate sites near the terminals.

3.2 Container Terminal Elements

A number of elements are essential to a terminal:

1. Quay wall
2. Apron
3. Storage Area
4. Landside traffic system
5. Buildings

The complex relationship between these elements (Figure 3-3) can influence the efficiency and profitability at a terminal. For an example, a barge terminal can be planned perpendicular to the deep-sea quay. It reduces internal transport distances and providing a more compact terminal layout.

1. Quay Wall

The quays are the interface between a ship and the land. Container vessels berth along the quay wall of the container terminal. Quay walls for container terminals do not necessarily differ from quay walls for other vessel types.

2. Apron

The apron is an open area adjacent to the quay wall. The apron supports two functions: (1) an area for quay cranes to operate on and (2) an internal traffic circulation area for vehicles moving containers between the quay cranes and the storage area. The width of the apron varies from a minimum of about 40m to more than 100m and often depends on the width of the crane rail track and the type of horizontal waterside transport.

3. Storage Yard

In the storage yard "import", "export", "empties" and "transhipment" containers are kept for a certain period. For reefers and hazardous containers special areas with special equipment have to be considered. It also includes a special area for stripping and stuffing of cargo called Container Freight Station (CFS).

4. Landside Traffic System

Landside traffic system enables trucks to bring and collect containers at container exchange points. The trucks enter the landside area through the truck gate where administrative activities such as inspection and recording the physical condition of containers are carried out. The trucks then precede to the exchange points before exiting terminal. Note to avoid grid lock inside and on public roads outside the terminal, sufficient queuing space has to be included in the planning of the truck gate.

5. Buildings

Numbers of buildings are provided in a terminal for repair and maintenance of the equipment. Although, most of the maintenance activities are carried out outside the terminals, workshops on the terminals are unavoidable, since most of the equipment that operates in a terminal is too large to be moved to external workshops. In addition, every terminal needs office buildings for management, staff facilities and supporting functions.

6. Other

In addition to essential elements described above, a number of other elements may exist at a terminal such as:

- Rail Terminals
- Barge Terminals
- Empty Container Depot
- Container Repair and Cleaning Facilities

Figure 3-3 schematically indicates the arrangement of the basic plus optional terminals elements.

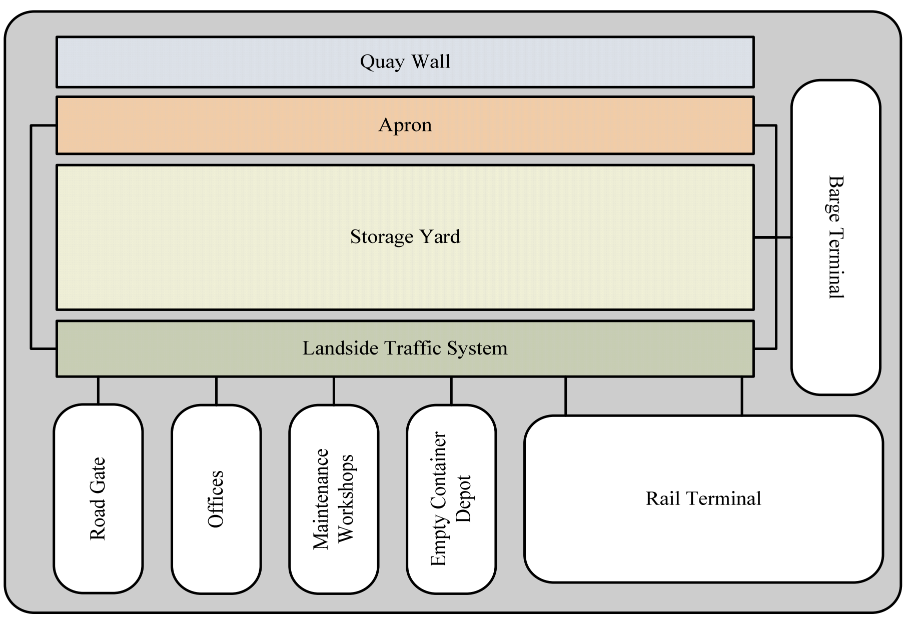


Figure 3-3: arrangement of the basic terminal elements

3.3 Terminal operation forecast

Design of a container terminal starts with forecast/determination of the container flow (described below). Since the market is flexible and the economy is ever/changing, actual developments will always be different from the forecast. Therefore, the design should be robust and be profitable within a certain range of circumstances. The container flow will be considered in great detail in chapter 5 in relation to the design of a terminal.

3.3.1 Unit and Factor

Since the containers have different sizes, for planning a terminal yard, a standard unit of size is needed to which all containers can be converted. This standard size is Twenty feet Equivalent Unit or TEU. The common sizes of containers read as:

- A 20ft-long container equals 1 TEU.
- A 40ft-long container equals 2 TEU.

The following quantities are used for terminal calculations and are carried out in TEU.

- Throughput of the terminal
- Throughput waterside (quay)
- Throughput of the stack
- Storage capacity of the stack
- Surface area of the stack
- Throughput landside
- Technical handling capacity waterside, landside and stack (equipment)

To calculate the surface area of a storage yard, the division between 40ft and 20ft containers has to be known. A TEU- factor is used to define this division and is derived from Eq.3-1 (Ligteringen, 2007).

$$f = \frac{N_{20} + 2N_{40}}{N_{tot}} \qquad \text{(Eq.3-1)}$$

In which:

N_{20} = number of TEU`s

N_{40} = number of FEU`s

N_{tot} = sum of containers

3.3.2 Throughput of the Terminal

Throughput of the terminal is divided into waterside, stack and landside throughput and is generally expressed in form of TEU/annum.

The waterside throughput is defined as the volume of containers, loaded and unloaded over the quay wall. The waterside throughput is of crucial importance for calculating the quay length, number of

quay cranes, number and type of horizontal transport equipments and the capacity of waterside traffic circulation.
The throughput of the storage yard is the sum of number of TEU visits by all flows passing through the storage yard per year. The throughput of the stack yard is required to determine the capacity of the storage yard and the type of storage yard handling equipment.

The landside throughput is the sum of all TEU which move through the road (hinterland) gate. The landside throughput is required to calculate the stack handling capacity plus the capacity of traffic circulation system.

3.4 Container terminal flows

When assessing the terminal flow, in most cases, the terminal planner and operators do not have sufficient information about flows. In these cases, due to the required coherence, missing data should be replaced by alternative data or realistic assumptions.

The main flow does not provide sufficient information for detailed terminal planning. Therefore, the main flow will be divided in relevant sub-flows such as: laden containers, empty containers, reefer containers and dangerous cargo. The volumes of each type of container are necessary for terminal planning. For example, stack height affects the storage yard capacity and accessibility to the individual containers within the storage yard. For empty containers, accessibility of individual containers is not important and they can be stacked higher with larger width than laden containers. Therefore, they can be stacked in a more economical way than laden containers. In addition, empty containers can be handled with cheaper and lighter equipments.

Terminal throughput is divided into import, export and transhipment. This division of the containers is called modal split (Figure 3-4) and is an important input for the detailed design of a terminal. The import flow is the flow of containers being discharged from a vessel and transported into the hinterland. The export flow is the flow of containers coming from the hinterland and being loaded on a vessel. The water-to-water flow is the flow of transhipment containers, discharged from a deep-sea or feeder vessel and are loaded on another deep-sea or feeder vessel. Transhipped containers occupy one TEU ground slot in the storage yard, while counting twice in moves over the quay.

Quay wall throughput is defined as the volumes of the container that are loaded and discharged over the quay, from and to container vessels or feeders. Note that, in the container yard (dotted rectangle), four different flows are presented; import, export, transhipment and domestic (land to land).

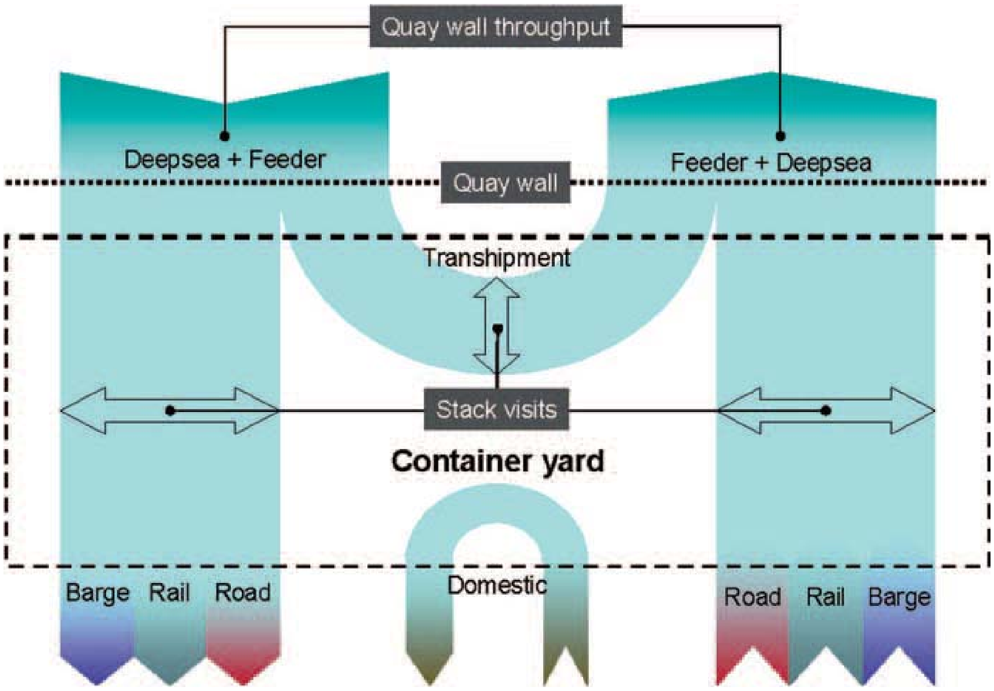


Figure 3-4: container terminal flows (saanen (2004))

4 STRUCTURE OF THE CONTAINER TERMINAL DESIGN TOOL

In this chapter, the structure of the presented tool, including theoretical aspects and required equations for design of terminals are discussed. In addition, basic terminal elements, handling equipments and their characteristics are described.

In sections 4.6 and 4.7, substantial references have been made to Kap Hwan Kim and Hans-Otto Günther (2007), Carl A. Thoresen (2010), W.C.A. Rademaker (2007), Ligteringen (2009) and Royal Haskoning reports. In section 4.9 an overview of the developed container terminal design tool is presented.

4.1 Design process

A successful layout for a container terminal lowers the operation cost, improving service quality, operational efficiency and loading/unloading berthing/unberthing performance. Container terminal design is divided into waterside and landside areas. Detailed design of these areas consists of two components: (1) determination of the surface areas /dimensions, and (2) selection of the handling systems (Figure 4-1).

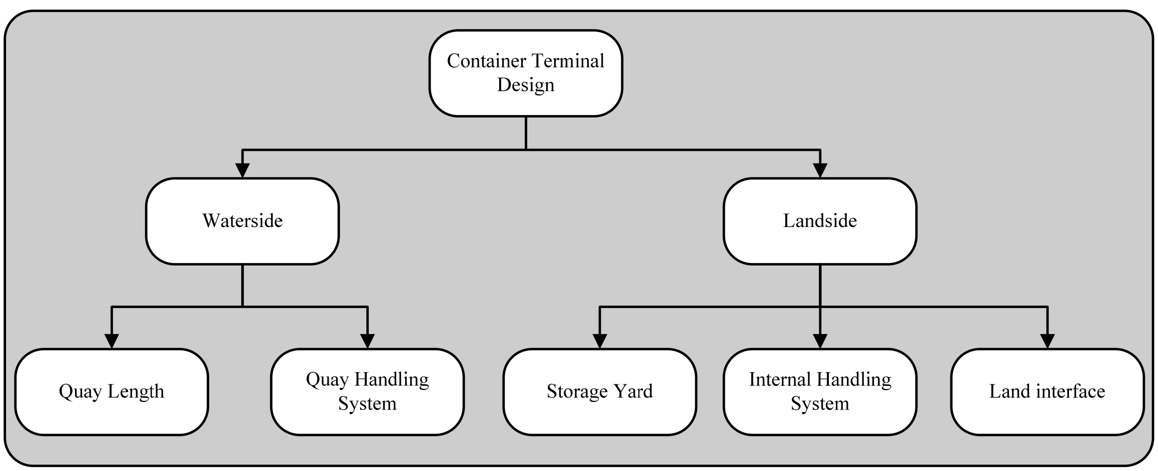


Figure 4-1: functional terminal design

On the waterside, quay wall is the most critical and expensive infrastructure investment (especially in regions with high tidal range or large water depth). Quay walls may be built to enormous dimensions and the cost per running meter can be as high as 65,000 EUR (HPA, 2008). Therefore, the quay length is of crucial importance and various parameters contribute to its estimation.

The selection of handling systems for the waterside and landside is crucial to the achievement of an economical and efficient port. The components that make up these systems are summarized in this chapter.

The functional design process of a container terminal is summarized in Figure 4-2. In this process in each step, a backwards iteration is included to optimize the layout result. Note that, many other factors such as site condition, soil condition and market analysis, can influence the layout of the terminal.

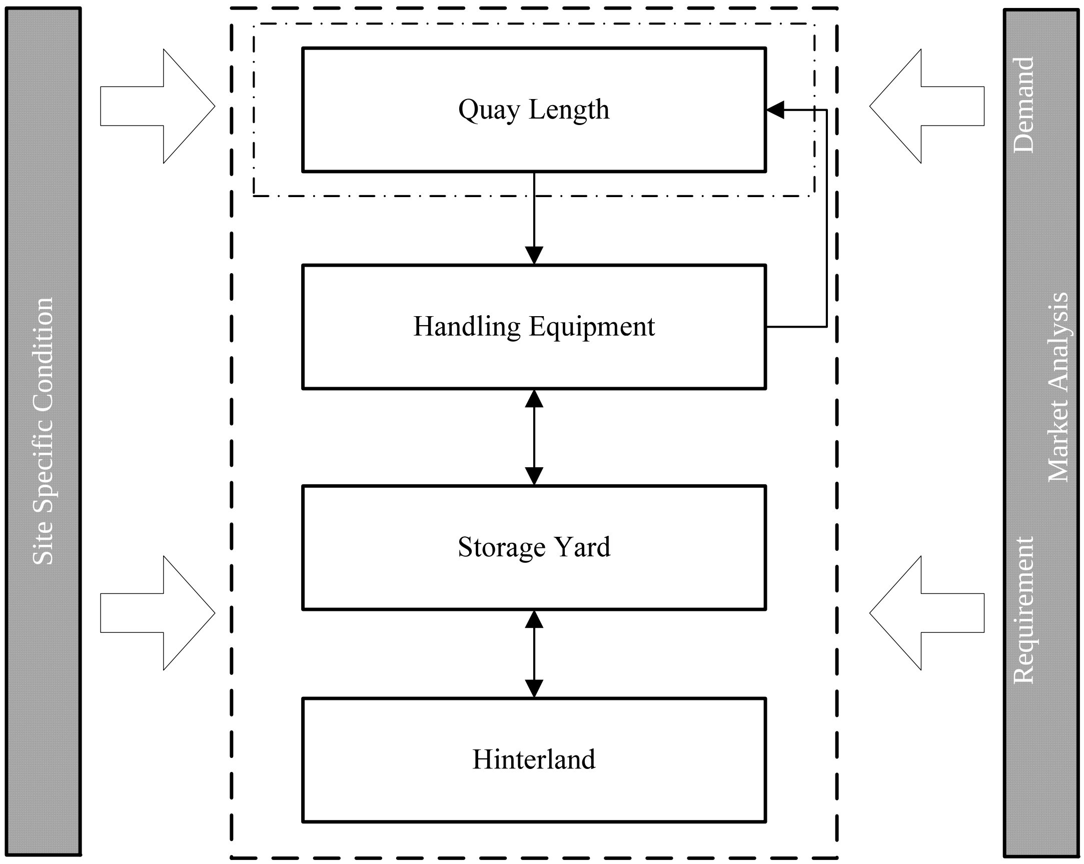


Figure 4-2: design process (Saanen, 2004)

Figure 4-3 shows the structure of the container terminal design tool.

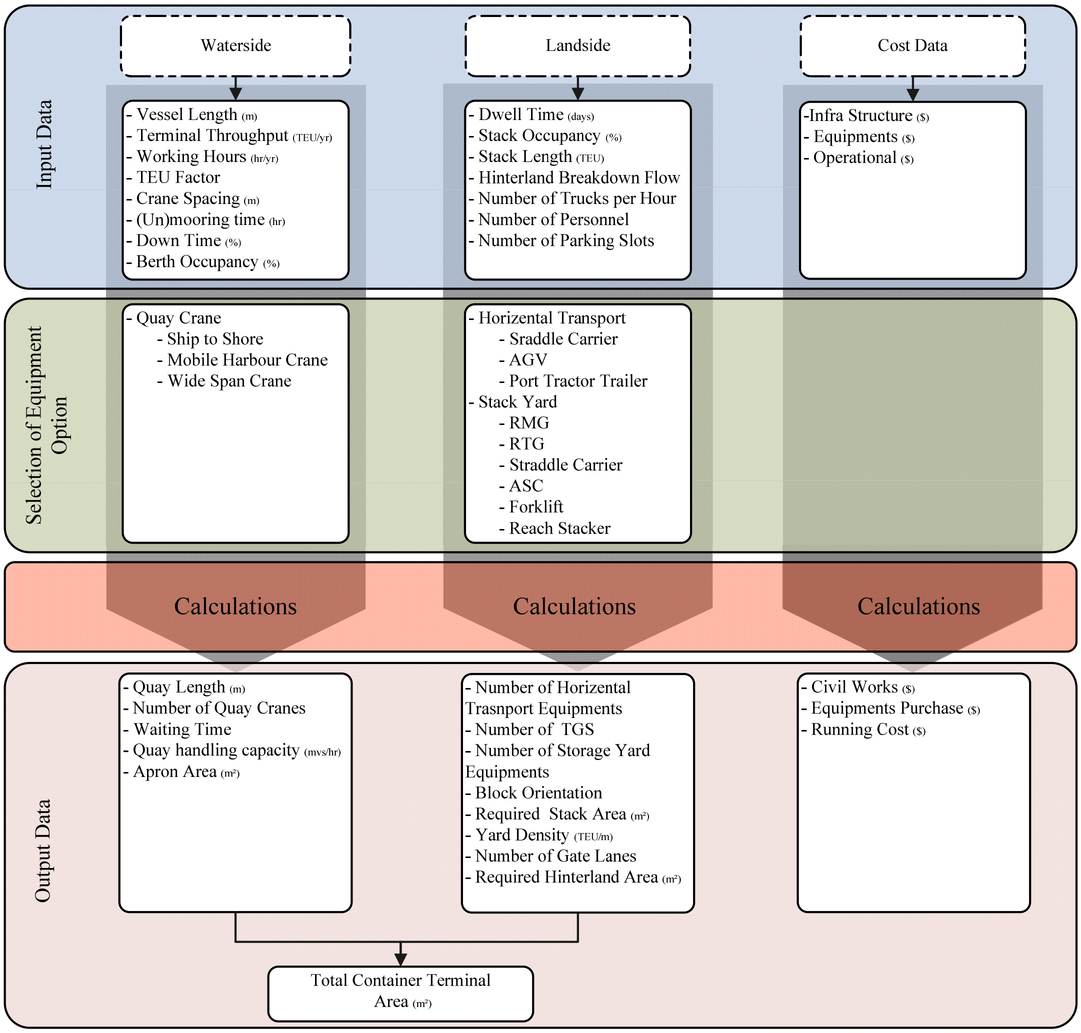


Figure 4-3: Structure of the container terminal design tool

The first step requires the input data at waterside, landside and cost estimation sections to be defined. In the second step, the possible equipment concepts at waterside and landside are determined. In the third step, the input data is used to estimate the performance of the terminal concepts which are presented in the forth step.

4.2 Overview of Handling Equipment Operations

This section describes the various equipment types (and their specific properties) useful in container terminals. Substantial reference has been made to Chapter 5 of “Container Terminal Automation, Feasibility of terminal automation for mid-sized terminals” by W.C.A Rademaker (2007), Chapter 1 of “Simulation Modelling and Research of Marine Container Terminal Logistics Chains” by Andrejs Solomenkovs (2006), “Port and Terminals” by Ligteringen (2009) and Kalmar, Liebherr, Gottwald, Konercranes Industries websites.

The handling process in container terminal can be divided into three operational areas:

1. Area between waterside and storage yard (Apron)
2. Stacking area (storage yard)
3. Area of landside operations. This area includes the gate, administration buildings, container maintenance and etc.

For each of above areas, specific equipment is available to establish a link in the handling process. The choice of handling system depends on several criteria, such as required storage capacity vs. space available, labour costs, required selectivity both in vessel and landside operation, shape of terminal, ground limitations and size of operation. Figure 4-4 illustrates the equipment for each operational area. Each area will be considered in the following sections with the key equipment discussed.

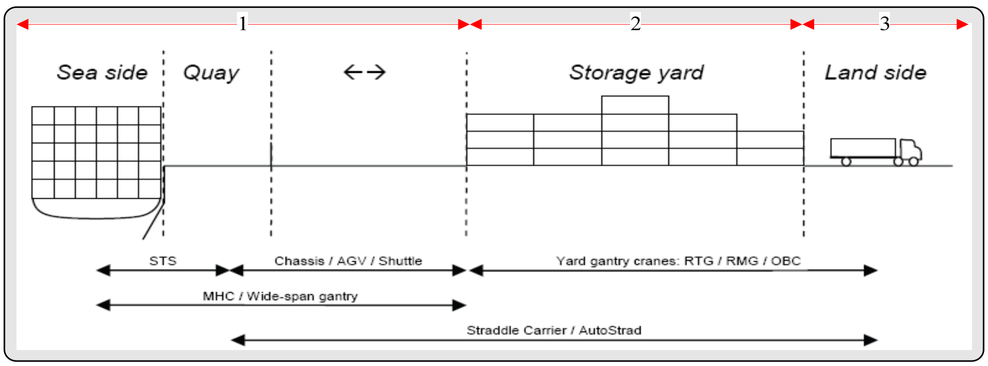


Figure 4-4: Work area terminal equipment (W. Bose, Dr. Jurgen, 2010)

4.3 At the Seaside

Following the berthing of a container vessel, the containers to be discharged are identified and the quay cranes commence unloading. Quay cranes come in different types are expensive, and their performance is essential for well-organized terminal operations (Figure 4-5). Three main types of quay cranes exist: Ship to Shore gantry crane, Mobile Harbour Crane and Wide Span Crane. Each will be discussed.

Figure 4-5: Unloading of the ship (Amsterdam)

4.3.1 Ship to Shore (STS) gantry crane

A ship-to-shore rail mounted gantry crane (STS) is a specialized version of a gantry crane, produced in different sizes. It is designed with a rigid structure to handle containers between a ship and quay in a straight line. Two types of STS can be introduced: single trolley cranes (Figure 4-6) and dual trolley cranes. The trolley system is a rope system that travels along the arm and is equipped with a main trolley and two catenaries trolleys (spreaders). These trolleys run along the bridge and boom girders, which are constructed as double-box girders. The operator cabin is suspended from the main trolley.

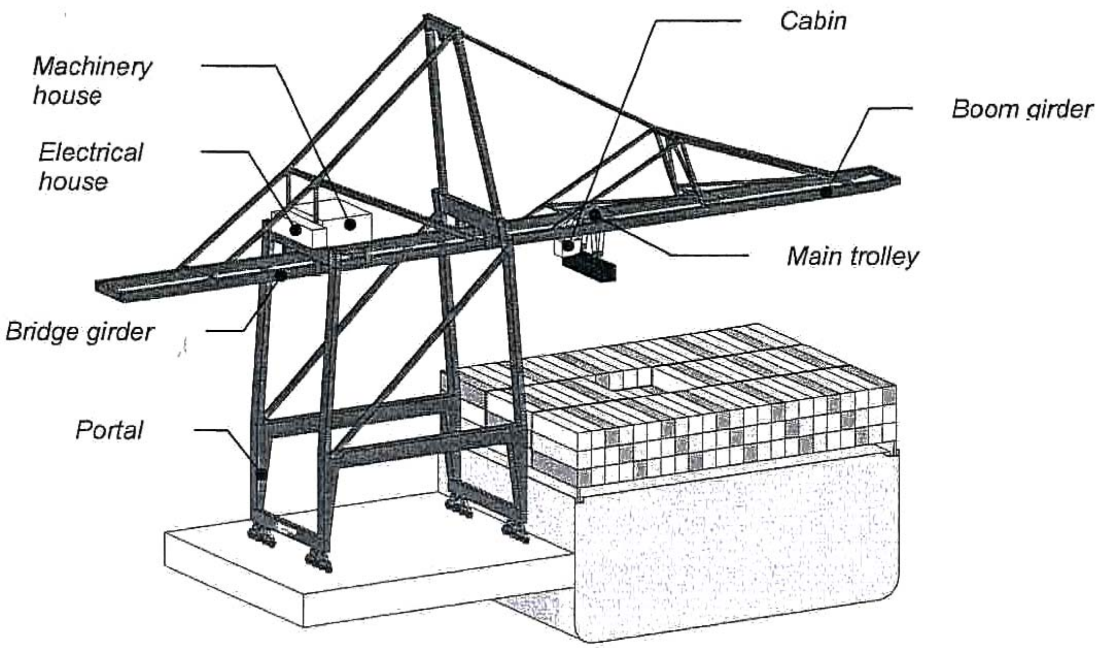


Figure 4-6: Quay crane (single-trolley crane)

Single trolley cranes move the containers directly from the ship to the horizontal transport equipments on the quay, and vice versa. These cranes require skilled operators who are supported by a semi-automatic system.

In modern terminal yards, the inability of terminal equipment to keep up with ship to shore cranes creates a bottleneck and limits the cranes productivity. **Dual trolley cranes** are an alternative for single trolley cranes with higher productivity. This equipment, the main trolley moves the containers from the ship to the quay, while the second trolley loads the horizontal transport equipment. A similar result achieved if a single trolley crane is equipped with a second trolley. The attached trolley moves automatically as the operator picks-up and places the containers with the crane. Figure 4-8 schematizes the single and double trolley cranes operations.

Figure 4-7: STS cranes (Georgia Ports Authority)

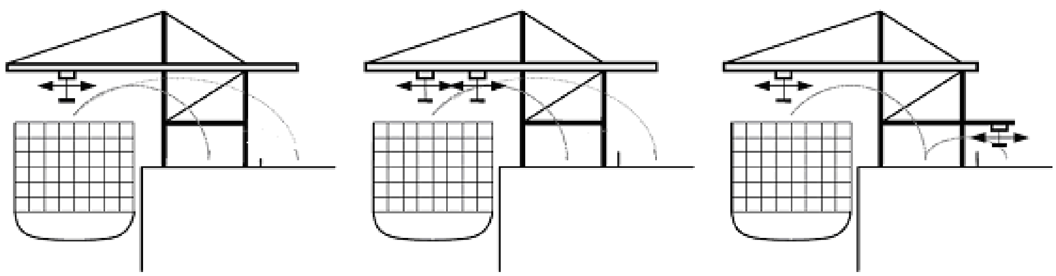


Figure 4-8: single trolley, twin trolley and dual trolley crane

The maximum performance of quay cranes depends on many parameters such as hoisting/lowering speed and trolley travelling speed. For example, trolley travelling speed varies between 45 m/min (Panamax) and 240 m/min (Super-Post Panamax). The technical performance is in the range of 50-60 containers per hour, however while in operation, range of 22-30 containers per hour is often observed (Steenken, 2004). A recent study has found that crane productivity increases to 36and 42 containers per hour in the 4th and 5th generation of STS crane respectively (C. Davis Rudolf, 2010).

The key advantages and disadvantages of STS cranes are summarized in Table 4-1.

Table 4-1- Quay crane advantages and disadvantages

Advantages	Disadvantages
High throughput capacity	High Investment and maintenance costs
Limited space between cranes	Limited flexibility
	High Surface loads

Table 4-2 indicates the typical dimensions and operating data of an STS based on the Kalmar STS (Nelcon)

Table 4-2: Kalmar (Nelcon) STS specification

Outreach	47	m
Rail span	30.48	m
Back reach	15	m
Hoisting height of spreader above top of rail	32.3	m
Hoisting height of spreader beneath top of rail	32.3	m
Max. hoisting/lowering speed with 50 tons on ropes	60	m/min
Max. hoisting/lowering speed with 15 tons on ropes	120	m/min
Max. trolley travelling speed	60	m/min
Max. gantry travelling speed	5	m/min

4.3.2 Mobile Harbour Crane (MHC)

MHC`s are wheeled and can be equipped with different types of spreaders. This flexibility offers practical solutions to various customer needs in different market fields such as container handling, bulk operations, from heavy lifts and handling of general cargo. Although, a MHC productivity is less than an STS, unique technical features make MHC a cheap alternative for STS. These features include an optimized undercarriage concept, lifting capacities from 40 tonnes up to 208 tonnes, the in-house designed crane control system and turning motion of the cranes, make MHC a cheap alternative for STS. The technical performance of mobile harbour crane is approximately 15 containers per hour (W.C.A Rademaker, 2007); however, newer MHC`s (Gottwald) have been reported to deliver a handling rate of 25 to 28 containers per hour (Figure 4-9).

Figure 4-9: Mobile harbour crane (Gottwald)

A key feature of MHC is the large back reach, which allows it to place the containers within the transfer points of storage yard, immediately after unloading. This feature decreases the number of horizontal transport equipment units required (Figure 4-10). Table 4-3 summarises the typical technical data of a mobile harbour crane based upon the Gottwald (model HMK 260) with the advantages and disadvantages summarized in table 4-4.

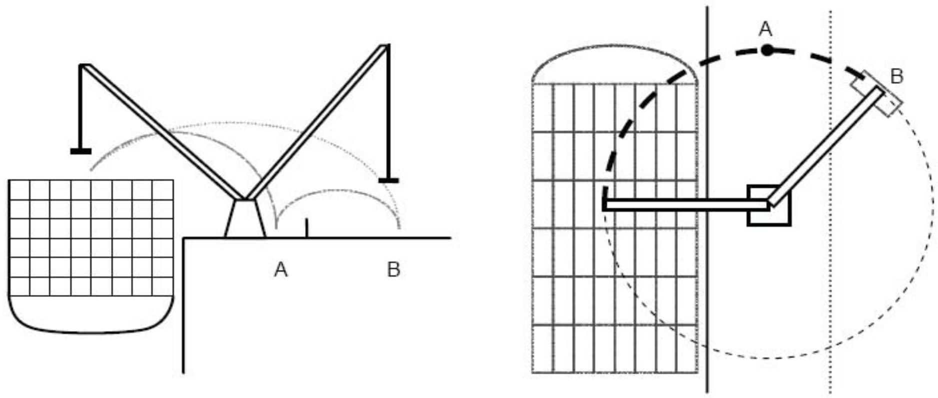


Figure 4-10: mobile harbour crane operation

Table 4-3- HMK 260 Mobile harbour crane specification

Capacity heavy lift	100 ton
Standard lift	45 ton
Hoisting/lowering	85 m/min
Traveling	80 m/min
Hoisting height	
Above ground level	36 m
Below ground level	12 m
Dimensions	
Propping base	12.5 m × 12 m
Crane in travel mode	17.2 m × 8.7 m
Crane productivity	15 move/hr

Table 4-4- Mobile harbour crane advantages and disadvantages

Advantages	Disadvantages
Flexibility	Low throughput capacity
Low investment equipment	Much workspace
Possibility to skip horizontal transport because of large back reach	Less accuracy because of sway

4.3.3 Wide-Span Crane (WSC)

To handle the containers in medium and small-sized terminals, where the space available for stacking containers is limited, wide-span cranes can increase storage capacity by increasing container stacking density. Wide-span cranes are considerably wider than other types of cranes and have the capability to stack containers under one crane span (Figure 4-11). This eliminates the horizontal transport between the quay and storage yard and allows a more compact terminal density (Figure 4-12).

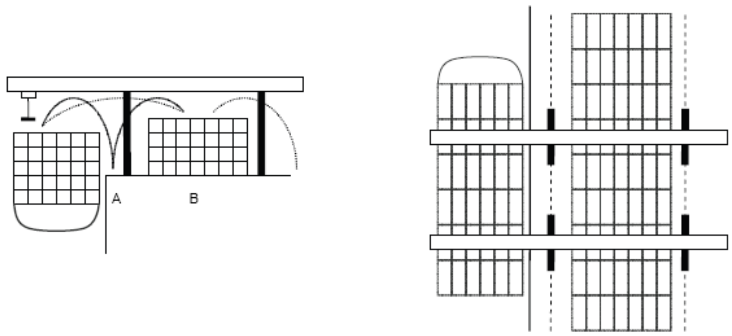


Figure 4-10: wide-span crane operation

A second advantage is the shorter cycle time due to the elimination of horizontal transport from the system. This increases the productivity of the cranes during unloading.

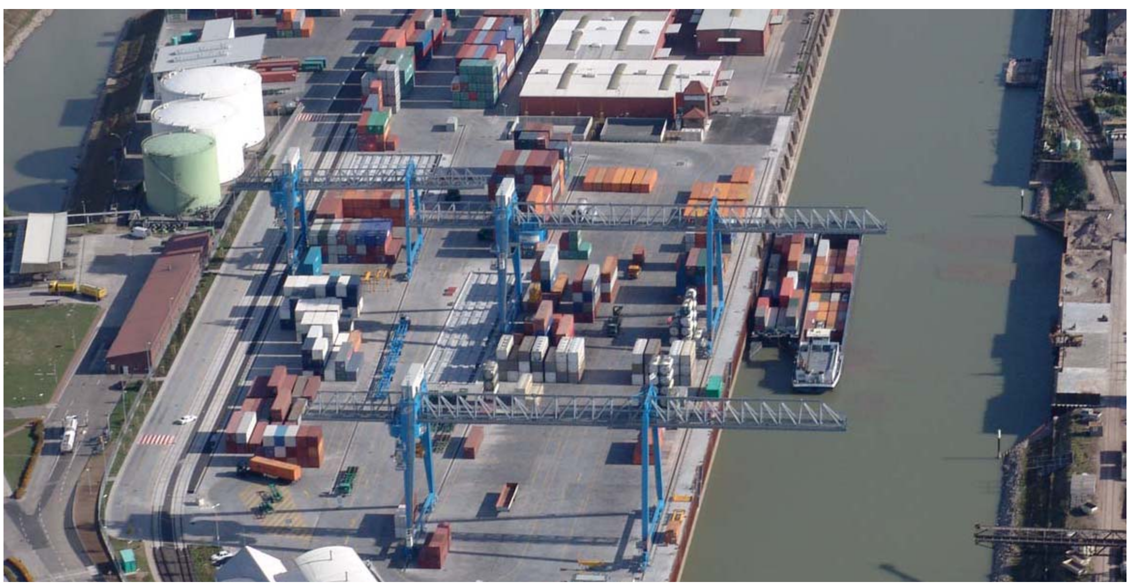


Figure 4-12: Wide-span crane, Port of Ludwigshafen, Germany

Table 4-5 summarizes the specifications of a wide span crane (delivered to the port of Helsinki in Finland by Liebherr) and Table 4-6 summarizes the advantages and disadvantages of wide-span crane.

Table 4-5- Liebherr wide span gantry crane specification

Lifted load	40 ton
Outreach	30 m
Rail span	48 m
Back reach	16 m
Hoisting speed	40/100 m/min
Trolley speed	180 m/min
Gantry speed	120 m/min
Handling capacity per crane per year	100,000 TEU/yr

Table 4-6- wide-span crane advantages and disadvantages

Advantages	Disadvantages
Compact Design	Less flexibility
Possibility to skip horizontal transport	Not well suited for expansion

4.4 Horizontal transport

In 4.4 high capacity container terminals, a variety of vehicles are employed to transport containers between the quay and the storage yard. Selecting the most appropriate option depends on the size and the throughput magnitude of the container terminal. The equipment used can be separated into two types of “passive” and “non-passive” vehicles.

4.4.1 Passive vehicles

This type of vehicles does not have the ability to lift containers by themselves and therefore, loading/unloading is done by other equipments such as cranes or straddle carriers. Two typical vehicles fall into this category (1) Port Tractor vehicles and (2) Automated Guided Vehicles.

Port Tractor vehicles:

These tractors can be loaded by cranes on quayside and transport the containers to the storage yard. In practice, the containers have to be stacked in the yard, but in small terminals that do not have enough space, the trailers are often used as a stacking place.

For increasing capacity multi trailer systems (MTS) are often used. In these systems, a series of trailers (up to six) are pulled by one tractor (Figure 4-13). A typical port tractor specification is summarized in Table 4-7 with advantages and disadvantages summarized in Table 4-8.

Figure 4-13: trailers and multi trailers

Table 4-7- port tractor trailer specification

Width	2.5 m
Overall length	5.2 m
Travel speed	35 km/hr
Dead weight (tractor)	9.5 ton
Turning circle radius	5.9 m

Table 4-8- MTS advantages and disadvantages

Advantages	Disadvantages
High throughput capacity	Less flexible in operations
Low investment cost	
Low labour cost	

Automated Guide Vehicles (AGV)

An AGV is a driverless vehicle (developed by Gottwald) and used for the first time on the Delta-Sealand terminal of the Maasvlakte II (Figure 4-14). The driverless AGV follow a standard track that consists of electric wires or transponders in the pavement between quay and storage yard. AGVs can either hold 20', 40' and 45' containers. AGV`s can move faster than tractor trailers and their positioning accuracy is good but because of safety, they do not travel as fast as tractor trailers.

Figure 4-14: AGVs at Rotterdam port

Another type of AGV is Lift AGV. It is a further developed model of existing AGV technology. Lift AGVs can raise the container, place it automatically on racks in transfer area in front of stacking cranes and pick up containers from the racks and transport them to waterside. The AGV has a very good record, but demand high investment and maintenance costs and are therefore often only suitable where labour costs are high. Table 4-10 summarizes the advantages and disadvantages of AGVs.

Figure 4-15 Lift AGV (Gottwald)

Table 4-9-Gottwald AGV specification

Loaded types	2*20/ 1*40/ 1*45 ft
Max. weight a single container	40 ton
Max. weight of 2×20 container	60 ton
Dead weight	25 ton
Width	3 m
Length	14.8 m
Max. travel speed	6 m/s
Max. speed in curves	3 m/s

Table 4-10- AGVS advantages and disadvantages

Advantages	Disadvantages
Very low labour costs	High investment and maintenance costs
High throughput capacity	Complicated and sensitive equipment

4.4.2 Non-Passive Vehicles

Non-passive vehicles are equipment that can lift containers by themselves. Forklifts, reach stackers and straddle carrier belong to this type. The advantage of these equipments is the decoupling of quay and yard crane cycles. They reduce the cycle duration by eliminating the waiting time during handovers between quay and storage equipments.

Forklift Truck and Reach Stacker

The high flexibility of a forklift truck enables it to be used for any container handling operation in storage yard. In addition, due to low price, it is an economical solution for small and multi-purpose terminals. In large ports, usually forklifts are used for handling empty containers. Modern forklifts are equipped with special spreaders that can stack and retrieve containers from a stack 8 containers high (Figure 4-16).

Figure 4-16- Kalmar forklift truck

Reach stackers are similar to forklifts, but differ in the method of operation. Reach Stackers move containers by means of boom with spreaders. Modern reach stackers such as Kalmar model DRF100-52S8 can achieve high density container stacking (up to 8-high and 3-rows deep) as shown in Figure 4-17.

Reach stackers can be easily transported between terminals and can be used to handle many types of cargo. This means this equipment well suited for small/medium-sized and multi-purpose terminals. Table 4-11 indicates advantages and disadvantages of forklift and reach stacker.

Figure 4-17: Typical reach-stacker terminal (ITR, Rotterdam)

Table 4-11- forklift and reach stacker advantages and disadvantages

Advantages	Disadvantages
Flexibility	Low throughput capacity
Low investment equipment	Much workspace
Mostly used for empties	

Straddle carrier

The straddle carrier is one of the most popular pieces of equipment. These carriers can undertake a variety of handling operations such as loading, unloading, stacking and transport of containers between the landside and waterside. Its popularity is due to its space efficiency and flexibility. It can move containers from quay to stack area directly (and visa versa) and covers all kinds of horizontal and vertical movements. Straddle carriers can lift a container 1 over 2 and 1 over 3 (Figure 4-18). Table 4-12 indicates the specification of a typical straddle carrier (Kalmar straddle carrier model CSC450).

Figure 4-18: Kalmar straddle carriers

Table 4-12- straddle carrier specification (Kalmar CSC450)

Lifted load	50 ton
width	4.9 m
Inside clear width	3.5 m
Overall length	5 m
Maximum travel speed	20 km/hr
Lifting height	1-over- 3 TEU

A straddle carrier stacks containers into rows, separated by a lane wide enough for the wheels of straddle carrier. Typically the blocks are divided by an access road of about 20m wide of 14 to 18 TEU long and Table 4-13 shows advantages and disadvantages of straddle carriers.

Table 4-13- straddles carrier advantages and disadvantages

Advantages	Disadvantages
High throughput capacity	High investment and maintenance costs
One type equipment for entire terminal	High qualified operators
Flexibility	Complicated equipment

4.5 Within the storage yard

The equipments described in section 4.4, deliver containers to the storage yard. For handling and stacking containers inside the storage yard, various types of gantry cranes are used (Note that, apart from gantry cranes, straddle carrier, forklift and reach stacker are also used inside a storage yard). Gantry cranes are designed to increase yard density and productivity. Three types of gantry cranes are often used, (1) Rubber Tyred Gantry, (2) Rail Mounted Gantry, (3) Automated Stacking Crane and each will be discussed below.

4.5.1 Rubber Tyred Gantry (RTG)

RTG cranes are commonly used on large and very large terminals because they are very flexible and have very high stacking density (Figures 4-19 and 4-20). RTG ride on wheels. It can move between the storage yard and the hinterland and therefore can be used for handling of containers on either side.

RTG can stack the containers in blocks up to eight containers wide plus a traffic lane and 1 over 4 to 7 boxes high. In order to reduce travel distances in RTG operated terminals, the common yard layout for this type of terminals is parallel to the quay (Figure 4-19).

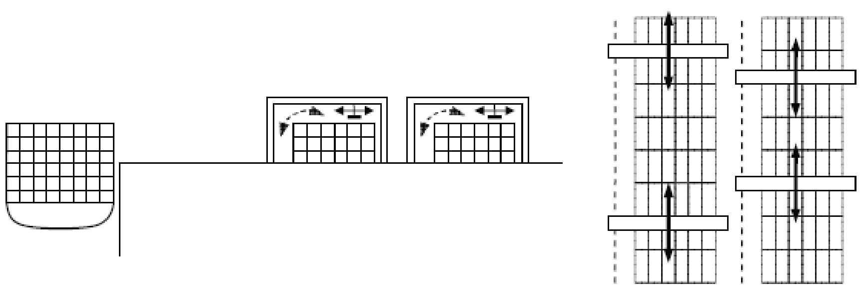


Figure 4-19: typical RTG stack orientations

The advantage/disadvantages of an RTG and technical details of a typical RTG (the Kalmar RTG) are given in Table 4-14 and Table 4-15 respectively.

Table 4-14- RTGs advantages and disadvantages

Advantages	Disadvantages
Low space requirement	High maintenance
High flexibility	Need good subsoil and pavement
High productivity	Require two handover procedure

Table 4-15: Kalmar RTG specification

Capacity under spreader	40 ton
Lifting height	1-over-5 TEU
Stacking width	7 + vehicle lane
Hoisting speed empty	40 m/min
Hoisting speed full	20 m/min
Trolley speed	70 m/min
Gantry speed	135 m/min

Figure 4-20: Kalmar RTG crane

4.5.2 Rail Mounted Gantry (RMG)

In very large container terminals, RMG concept is more popular due to its speed and ability to stack wider than an RTG concept. RMG can generally stack up to twelve containers wide and one over three to five boxes high. This enables the crane to use the container storage space under the crane more efficiently (Figure 4-21). Because rails can spread loads better than wheels, RMG`s are suitable equipment where the subsoil condition is not optimal. Figure 4-22 illustrates the typical yard layout for RMG terminals (perpendicular to the quay).

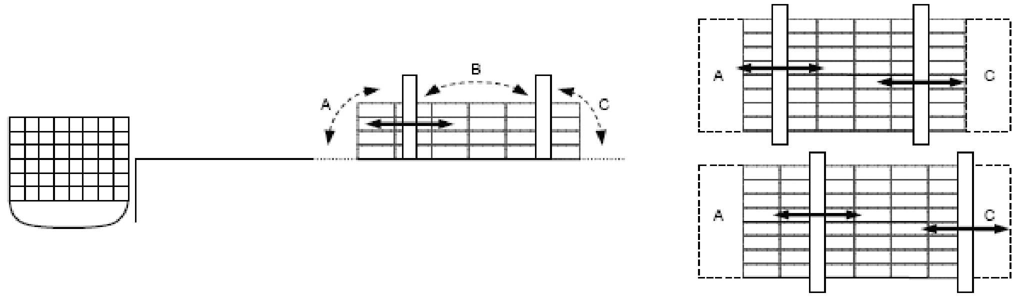
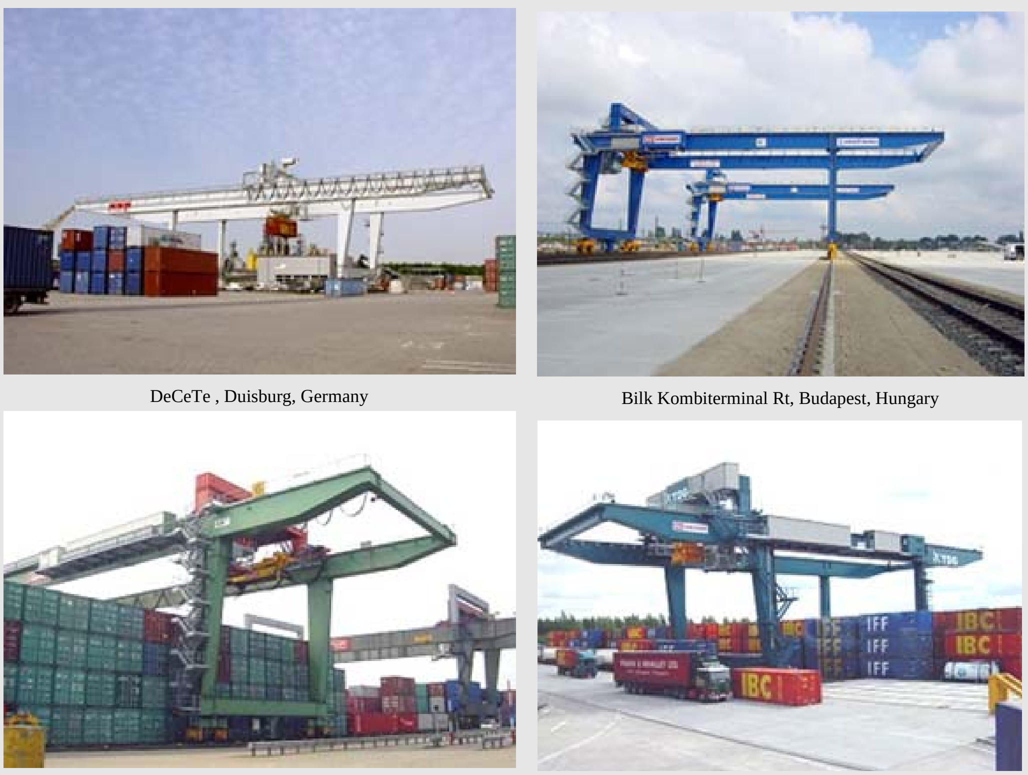


Figure 4-21: typical RMG stack orientation RMG



DeCeTe , Duisburg, Germany

Bilk Kombiterminal Rt, Budapest, Hungary

Uniport, Rotterdam, the Netherlands

TDG , Scotland, UK

Figure 4-22: different types of Konecranes RMG

Table 4-16 and Table 4-17 show advantages and disadvantages of RMG and the basic features an RMG (based upon the Konecranes RMG crane) respectively.

Table 4-17- RMGs advantages and disadvantages

Advantages	Disadvantages
Suitable solution for automation	High maintenance
High productivity	Rail needed
	Flexibility

Table 4-16: Konercranes RMG specification

Capacity under spreader	Up to 50.8 ton
Lifting height	1-over- up to 5 TEU
Crane span	19 to 50 m
Hoisting speed empty	60 m/min
Hoisting speed full	30 m/min
Trolley speed	Up to 150 m/min
Gantry speed	Up to 2 m/min

4.5.3 Automated Stacking Crane (ASC)

ASC`s are automated RMG`s used for yard stacking of containers in the storage area. In this system, the handover positions for straddle carriers, port truck trailers or AGV`s are located at the front-end of the stacking blocks. ASC reduces operating costs and increases the utilization rate of equipment. ASC can stack containers with higher stacking density (in blocks up to 10 containers wide and 1 over five to 6 boxes high) as shown in Figure 4-23. Table 4-18 shows the basic technical data of a typical (Gottwald) automated stacking crane.

Table 4-18: Gottwald ASC specification

Capacity under spreader	40 ton
Lifting height	1-over-5 TEU
Crane span	32.5 m for 9 container rows
Hoisting speed empty	72 m/min
Hoisting speed full	39 m/min
Trolley speed	60 m/min
Gantry speed	240 m/min

Table 4-19 shows advantages and disadvantages of ASC.

Table 4-19- ASC advantages and disadvantages

Advantages	Disadvantages
Low labour cost	High investment
High productivity	Inflexible
High yard utilisation	

Figure 4-23: Typical Automated stacking crane terminal (Antwerp Gateway in Belgium)

4.6 Container terminal layout calculation

In this section, the formulations applied to calculate different assets of container terminal are presented. These formulas use the input of the first and second step of Figure 4-3.

4.6.1 Quay length

The quay concept is a crucially important part of the model which has to be calculated first. The quay wall is the most expensive asset in the terminals. Therefore, all designers try to limit the required berth; while still allowing the design vessel.

To determine the quay length, the annual throughput magnitude is the first parameter which has to set in the model. Each waterside flow in this model is divided in relevant sub-flows:

- General containers
- Empty containers
- Reefer containers
- Transhipment containers

In the present package, there are two methods to input the throughput data. In the first method, the input is defined as the total number of TEU loading and unloading over the quay wall. In the second method, the throughput magnitude is defined in terms of annual number of calls and the volume of containers loading and unloading per call.

Other important factors to determine the required quay length are service time and annual berth working hours. To calculate the service time, the number and productivity of cranes per berth, parcel size and number of calls are necessary. The service time can be calculated as follows:

Total service time (hour/vessel) = (Un)loading time + (Un)mooring time (Eq.4-1)

The following formula can be used to determine the (Un)loading time (Thorsen, 2010):

$$\text{(Un)loading time} = \frac{S_p}{N_c \times Q_{cr} \times W_{ct}} \qquad \text{(Eq.4-2)}$$

Where:

S_p : Parcel Size (TEU)

N_c : Number of cranes per vessel (-)

Q_{cr} : Crane productivity (TEU/hr)

W_{ct} : working crane time due to ship total berthing time varies between .65 and 1

Given the downtime factor and total working hours, the berth working hours per week can be calculated as follows:

$$T_{bw} = (1 - D_t) \times T_d \times N_{dw} \qquad \text{(Eq.4-3)}$$

Where:

T_{bw} : Berth working hours per week (hrs/week)

D_t : Downtime (%)

T_d : Working hours per day (hrs/yr)

N_{dw} : Number of working days per week (-)

The berth length requirement for loading and unloading a vessel is expressed as:

$$L_{br} = T_s \times N_v \times L_b \qquad \text{(Eq.4-4)}$$

Where:

L_{br} : Berth length requirement (hrs.m/week)

T_s : Total Service time (hrs/week)

N_v : Vessel arrival (No/week)

L_b : Berth use (Vessel length+ Berthing gap) (m)

To determine the sufficient quay length with a given berth occupancy, the following equation is used (Thorsen, 2010):

$$L_q = \frac{L_{br} \times P}{T_b \times U_{berth}} \quad \text{(Eq.4-5)}$$

Where:

L_q : Quay length (m)

L_{br} : Berth length requirement (hrs.m/week)

P : Peak factor per week (-)

T_{bw} : Berth working hours per week (hrs/week)

U_{berth} : Berth occupancy (%)

The quay length is used to determine the number of quay cranes and the number of berths. The rule of thumb formula to calculate the number of quay cranes states that 1 quay crane is needed for each 80-100 meters of quay length. The number of berths can then be calculated as follows (Ligteringen, 2009):

$$N_b = \frac{L_q - \text{(Berthing Gap)}}{(L_v + \text{Berthing Gap}) \times 1.1} \quad \text{(Eq.4-6)}$$

Where:

N_b : Number of berths

L_v : Average vessel length (m)

L_q : Quay length (m)

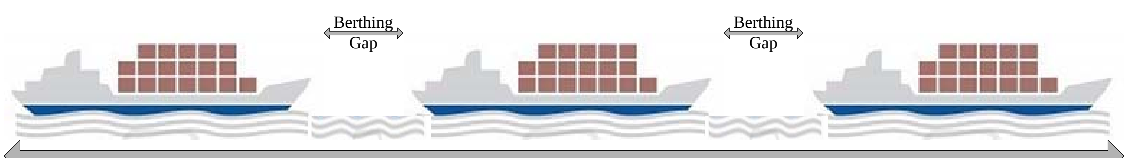


Figure 4-24: Quay length

The quay productivity can be estimated as follows:

$$Q_c = \frac{C}{f \times N_b \times T_b} \qquad \text{(Eq.4-7)}$$

Where:

Q_c	: Quay productivity	(mvs/hrs)
C	: Annual Throughput	(TEU/yr)
f	: TEU factor	
N_b	: Number of berths	
T_b	: Annual berth working hour	(hrs/yr)

By applying queuing theory, average waiting times in units of the service time can be calculated. If the calculated average waiting time is more than the acceptable value for port authority or client, a variation of the design parameters such as number of cranes per vessel or operational working hours is required.

4.6.2 Horizontal transport equipment

To ensure no interruption in quay operations and to keep waiting time within the expected range, the horizontal transport capacity should be at least equal to maximum quay handling capacity. The horizontal transport equipments considered in this tool are mentioned in Figure 4-3.

To determine the required number of horizontal transport equipment units, the unit per quay crane values are used based on previously performed projects of Royal Haskoning and W.C.A. Rademaker, 2007 (Table 4-20).

Table 4-20- Required number of horizontal transport units per crane

Horizontal transport equipment	Equipment units per quay crane
Reach Stacker	0.3
Straddle Carrier	5.5
Shuttle Straddle Carrier	5
Port Tractors Vehicle	5
AGV	5

After determination of the required number of horizontal transport equipments the traffic lane width can be calculated from the performance data. For example, Figure 4-25 shows the relation between the number of traffic lanes and width for AGV.

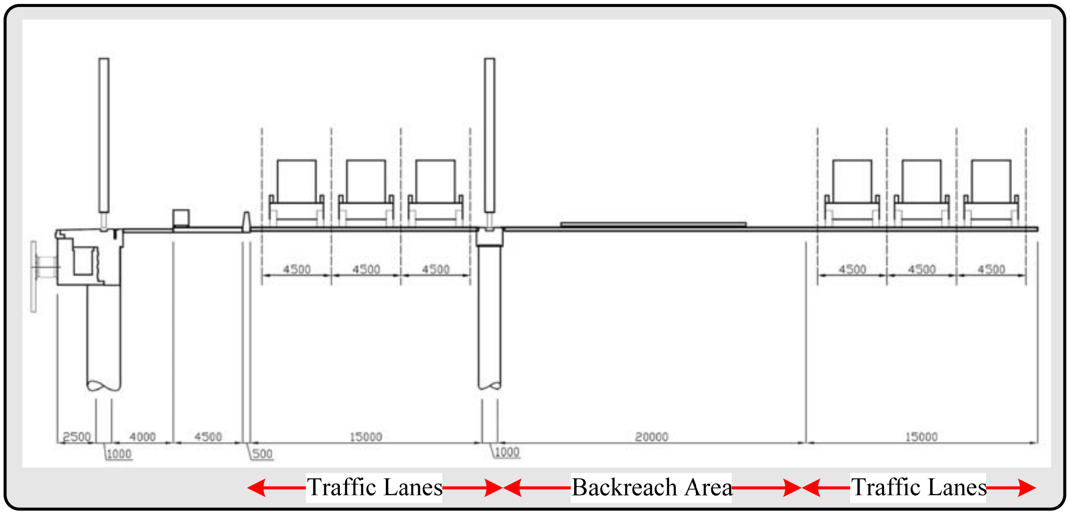


Figure 4-25: Cross section of quay area

4.6.3 Apron area

The apron area can be divided into the different areas parallel to the quay wall:

- Quay wall
- Waterside and landside rail
- Rail span
- Backreach area
- Internal road
- Light boundary
- Margin

Table 4-21 summarizes the typical cross-sectional dimensions, of these areas based on previously performed projects of Royal Haskoning.

Table 4-21- dimensions of the sub areas of the waterside area

Sub Area	Dimension (m)
Quay wall	3
Rail Span	30.5
Internal traffic lanes	12
Back reach area	15
Margins	6
Light Boundary	3

In the presented package, the areas above are defined as variable input data, which allows the user the options to replace the default values.

4.6.4 Storage yard capacity

In the presented package, the storage yard is divided into different stacks such as general, reefers and empty. The following formula is used to calculate the required storage yard capacity.

$$C_s = \frac{S \times t_d \times P}{365} \quad \text{(Eq.4-7)}$$

$$S = C_q(1 - 0.5\mu)$$

Where:

S	: Stack visits	(TEU/yr)
C_q	: Quay handling capacity	(TEU/yr)
t_d	: Average Dwell time	(days)
μ	: Transhipment factor	(-)

TEU ground slots can be calculated by dividing the storage yard capacity by the maximum stacking height. The following equation can be used to determine the number of TEU ground slots.

$$N_{TGS} = \frac{C_s}{\hat{h}} \quad \text{(Eq.4-8)}$$

Where:

N_{TGS}	: Number of TEU ground slots	(-)
$\hat{h}$	: stacking height	(-)

The required storage yard area can be decreased by reducing the number of TEU ground slots. Equation 5-8 shows that this can be achieved by increasing the operational stack height. However, by increasing the stack height, the number of equipments increases as well.

4.6.5 Storage Yard Equipment

Various types of equipments can be combined with each other to handle containers in a terminal. Each equipment has its own performance data and characteristic (*e.g.* see Figure 4-3).

In this presented package, equipment benchmarks are defined as variable input data in a separate Excel worksheet. The user can replace the default values when the characteristics of the equipment changes. After any change, the outputs such as number of stacks and the required stack area that are related to equipment characteristics are changed automatically. It helps the designer to compare the results of different equipment combinations and eventually to choose the appropriate combination.

Note that, using different types of storage yard equipment will change the yard layout. For instance, the storage blocks can be arranged parallel (in RTG terminals) or perpendicular (in RMG terminals) to the quay. Figure 4-26 shows two different container terminal layout structures.

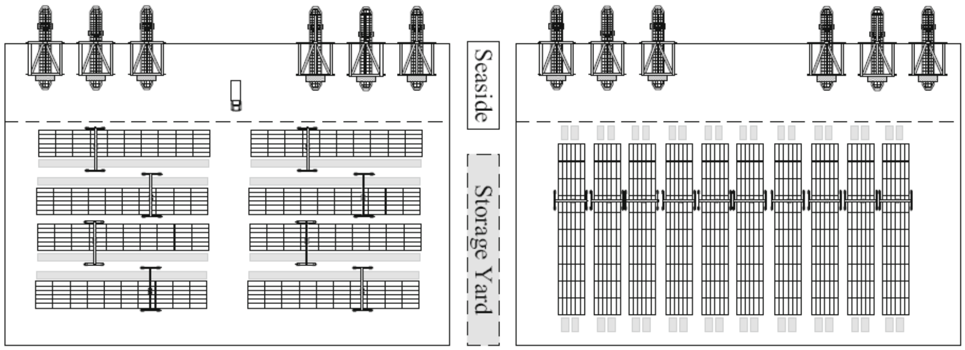


Figure 4-26: Parallel and perpendicular layout (Jürgen W. Böse, 2010)

Another example of storage yard layout based on equipment is the block structure. Block is defined by the number of rows; bays and tiers containers, stacked on each other. The block structure depends on the types of equipment. Therefore, the technical handling system selected for the stacking yard has great influence on the overall terminal layout, the stacking capacity, area required and the cost of the terminal. For example, Figure 4-27 shows different block structures for an RMG, RTG and Straddle carrier.

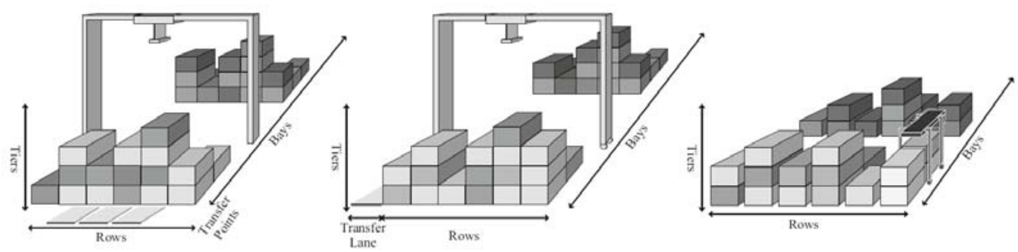


Figure 4-27: Block structures for an RMG with transfer point, RTG with transfer lane and Straddle carrier (Jürgen W. Böse, 2010)

4.6.6 Landside area and buildings

The landside area consists of three basic parts as follows:

- Gate area
- Workshop and Service buildings
- Terminal offices

Gate area

The gate area consists of traffic lanes, parking area reception building and terminal gate. All functions mentioned in section 3.1 (parts 3, 4 and 5) are applied in this area. To design a gate area, the average size of trucks and peak rate of service calls of vehicles per hour are necessary factors.

In the present tool, two methods are used to determine the appropriate number of traffic lanes for a gate area. In the first method, the number of lanes is calculated by using a queuing theory for vehicle traffic (see Itsuro Watanabe, 2001). In this method, the number of gate lanes is calculated based on arrival rate and service rate of trucks at a gate. The arrival and service rate is summarized in Appendix I. In the second method, the number of lanes is calculated base on a certain capacity (vehicle per hour) that can be assumed for a gate. The required parking area is calculated based on the number of parking slots which a user input selected (as shown in Figure 4-3).

Workshop, service buildings and offices

The maintenance and repair works of the equipment are carried out in workshops and service buildings. In the presented package, the basic dimensions (from David Adler, 2008) of the mentioned buildings are inserted as a separate Excel worksheet. The model uses these dimensions to calculate the required area .For example; Table 4-21 shows the basic dimensions of the gate reception buildings.

Table 4-21- basic dimensions of workshops and stores (David Adler, 2008)

Buildings	Width (m)	Length (m)	Area (m²)
Reception	4	5	20
Customs office	3	4	12
Waiting area	4	5	20
facilities	3	4	12

The office area depends on the number of personnel. These offices are used for management operations, vessel planning, finance and custom administrations. Some assumptions based on David Adler (2008), consider for each staff member a required office space of 20 m².

4.7 Cost Estimation

In this section, the cost estimation on master plan level is discussed. The cost estimation is divided into three steps. The first step is an estimate of the required investment cost for the civil works. In the second step, an estimate of the equipment purchases is explained and in the third step, the annual running cost of the terminal is discussed. These steps are further elaborated in the following paragraphs.

4.7.1 Civil works

The civil works in the container terminal is divided into following main categories:

1. Quay side
2. Landside

Quay side

At the quay side, the design concept design of the structures (quay wall and apron area) depends on various factors such as site condition and operational requirements. The other important factor is the loading on the quay wall when this load consists of loads from quay cranes, quay traffic, mooring and fender loads. The apron (just behind the quay wall up to storage yard) is the most intensively used area of the container terminal. Its block pavement should be of suitable type for high terrain loads such as traffic loads, containers and spreaders. The concrete block pavement because of its strength, low maintenance cost, and long lifetime, is an appropriate type of pavement for apron area. Service and access roads in comparison with apron area need lower load bearing requirements. Therefore, asphalt is a suitable cheap pavement that can provide smooth ride condition.

Landside

The landside is divided into the storage yard and terminal buildings. Terminal buildings are described in section 4.6.6. The storage yard is divided into different areas. These areas, because of different usage, need various types of pavements. For instance, the pavement under the RMG cranes is different from the empty containers, and each of them has its own specific load requirements. Depending on the experiments and investigation, the gravel bed with concrete pads at the four corner of each container ground slot is a suitable and cost efficient pavement method for laden and empty containers.

Table 4-22 provides an overview of the estimated civil-work costs that are considered in the model.

Table 4-22- cost break up of civil works

Area	Items	Units
Quay Side	Quay wall	Per lin.m
	Block paving of the apron	Per sqr.m
	Furniture (fenders, bollards)	Per lin.m
Storage Yard	Block paving (laden and empty stacks)	Per sqr.m
	Gravel bed	Per sqr.m
	Service road	Per sqr.m
	Gate area	Per sqr.m
Terminal Buildings	Gate	Units
	Gate offices	Per sqr.m
	Parking area	Per sqr.m
	Workshop and stores	Per sqr.m
	Offices	Per sqr.m

Note that, the total civil-work cost has to multiply by two factors, preliminary and contingency. The preliminary costs include consulting and engineering cost. The contingency factor is accounted for unpredictable or undesirable costs.

4.7.2 Equipment purchase

The cost of equipment purchase is based on the number of equipment units. The required number of quay cranes, horizontal transportation and storage yard equipments are calculated by the model. Therefore, the investment cost for equipment purchase can be easily estimated.

4.7.3 Running cost

The running cost estimates the annual operating and maintenance costs of the port and is prepared for each of the development phases. The percentage and factors applied for running cost are based on consultant experience, local conditions and industry bench marks.

The running cost consists of the following main items:

- Maintenance and repair
- Labour
- Energy consumption

Maintenance and repair

The repair and maintenance costs per year are based on available figures from average annual maintenance costs over the full lifetime of the port items. The maintenance is a fixed cost per year, and therefore independent of the container throughput volumes. The repair cost factor for the equipment is considerable compared to the marine infrastructure assets such as breakwater and quay wall.

The maintenance costs per year are calculated as a percentage of the investment cost. In the presented package, maintenance and repair percentages are defined as variable input data, meaning that depending on the material and type of equipment, user can replace the default value.

Labour cost

To calculate the running costs, labour costs play a crucial role. The study of Saanen, Dobner and Rijsenbrij (2001), indicates that the labour costs account 51% of the whole running costs of a container terminal. To estimate the labour costs, the number of employees and functions has to be estimated for each department separately. Furthermore, for each function, the costs of labour are determined based on the similar projects done in that region. The total costs for labours are then determined based on the number of employees and labour costs per employee.

To estimate the number of staff, separation is made between the office employees (management & secretaries, administration and finance and engineers) who work 8 hours per day and the employees such as marine services, terminal operations, security and safety staff who work in 3 shifts for full day functions. In the present tool, the number of employees who work in the offices is a user input and the number of employees who work in shifts is calculated based on a port throughput, number of the equipments and the absence of the employees due to annual leave and sickness.

In addition, labours cost and number of labours depend on the local situations. For instance, in developed countries machines do service job such as cleaning instead of mankind. Since many parameters play role in estimation of the labour cost, to avoid complications, only rough estimation is considered in this tool.

Energy consumption

Port energy consumption is estimated for the cargo handling, port area and marine services. Costs for cargo handling are calculated by estimating the number and type of equipment that perform this job. The cost of energy for the port area and marine services are determined by applying benchmark rates for energy consumption per square meter terminal area or per trip of marine service vessel.

An alternative approach is to calculate the total operational costs introduces the various benchmarks of running costs per TEU for a terminal, in different regions. It means that the unit rate per TEU covers for the energy that all equipments need to move the containers through the terminal. As an example, in 1998, Drewry consultant estimated that the running cost for a terminal, handling 600000 TEU per year, in a developed country, is $58 per TEU, and for a terminal with 210,000 TEU throughput, is $72 per TEU. Therefore, given an inflation rate of 2% per year, the running costs for a port that handled 600,000 TEU in 2012 per TEU would be $76.5.

In the present package, the alternative approach is used to calculate the running costs and its benchmark is defined as a variable input data.

4.8 Overview of the container terminal design tool

In this section, an overview of all sheets in the model is indicated (Figure 4-28). In the present package, the total number of worksheets is 21. However, not all of them are used at the same time. The input data determines the required worksheets.

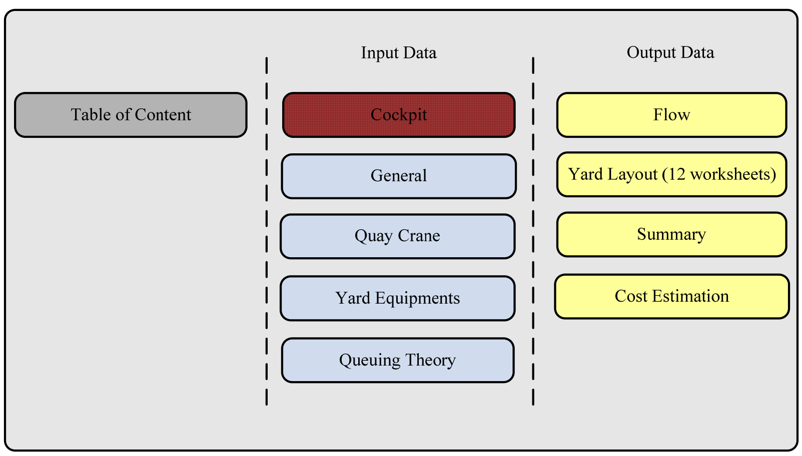


Figure 4-28: An overview of the model worksheets

Figure 4-28 shows that there are two main categories of worksheets, the input and output sheets. These two categories have their own color (Yellow and Blue) to show the function of the worksheets (Figure 4-29). The only exception in the input category is the cockpit (Red).

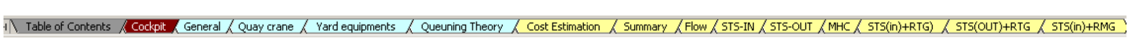


Figure 4-29: the color of model tabs

4.8.1 Input sheets

The Cockpit Sheet is the most important sheet of the model. Cockpit is a popular name used of Royal Haskoning Maritime Divison for main worksheet. It is divided into two main parts, “Input Data” and “Output Data”. Each part is separated into waterside and landside. The most basic information mentioned in Figure 4-3 is entered into the “Input Data” part. After the basic inputs have been entered, the model calculates the requested output data (Figure 4-3). The results can be found in the "Output Data" section in the cockpit.

General Sheet is separated into two parts. The first part indicates the basic dimensions of the terminal buildings and apron area. In the second part, the unit rates of civil-work items mentioned in (Table 4-22), and running costs are presented.

Quay Crane and Yard Equipments Sheets present the basic primary benchmarks used in the package. All benchmarks are defined as default variables. These values can be replaced by user-defined values.

Queuing Theory Sheet is used to calculate the waiting time. The combination M/E2/n is used where by the service rate and arrival rate are assumed to be the negative exponential distributed and Erlang-2 distributed with n service points (berths) respectively. In addition, as mentioned in Section 4.6.6, queuing theory is used to calculate the number of lanes at gate area. These tables are given in the queuing theory sheet.

4.8.2 Output sheets

Flow Sheet shows the container flow through the terminal. The annual volume of containers that import/export over the quay wall and leave from the hinterland and vice versa is summarized the annual flow of containers separated into vessels, road and rails.

Table 4-23 summarized the formulas used in the flow sheet to calculate the volume of containers at quay side, storage yard and hinterland.

Cost Estimation Sheet is divided into the required investment costs for civil-works, equipment purchases and running costs. The total terminal cost is determined at the end of the sheet.

Summary Sheet combines initial outputs such as quay length, number of equipment and total terminal area on one sheet.
Yard Layout Sheets present a top-view and a cross-section of the terminal, based on the output quantities of the summary sheet.

For further applications of the tool, the user manual can be found in Appendix II.

Table 4-23- containers flow calculation

Area	Formula	
Quay Side	$T_{ws} = L_q + D_q$	T_{ws} = Throughput waterside (TEU/yr) L_q = Loading over the quay (TEU/yr) D_q = Discharge over the quay (TEU/yr)
Storage Yard	$T_s = I_f + E_f + WTW_f + LTL_f$	T_s = Throughput stack (TEU/yr) I_f = Import flow (TEU/yr) E_f = Export flow (TEU/yr) WTW_f = Water-to-water flow (TEU/yr) LTL_f = Land-to-land flow (TEU/yr)
Hinterland	$T_{ls} = I_{ra} + I_{ro} + E_{ra} + E_{ro}$	T_{ls} = Throughput landside (TEU/yr) I_{ra} = Import by rail (TEU/yr) I_{ro} = Import by road (TEU/yr) E_{ra} = Export by rail (TEU/yr) E_{ro} = Export by road (TEU/yr)

5 TOOL VALIDATION

In this chapter, validation of the developed tool is carried out against two projects previously performed. The outputs of the tool are compared with the actual data of two terminals in India and Guatemala. The two selected cases have been successfully designed at Royal Haskoning (Maritime Division).

5.1 India Project

Based on market study on container traffic, transhipment of containers was identified as the main market potential. From Section 5.1.1 to 5.1.4 the necessary information for the calculation of the terminal requirements which are mentioned in the Royal Haskoning report, 2010 will be explained. Finally in Section 5.1.4 a comparison between the tool output and report design values is presented.

5.1.1 Port User Requirements

Container terminal throughput

Based on the market forecasts (Table 5-1) shows that the different categories are identified for the container terminal in the port:

Table 5-1- Summary of trade volume

Container terminal	Unit	Throughput
Gateway Container Traffic	TEU	138,459
Transshipment Container Traffic	TEU	683,798
Total	TEU	822,257

The following observations have been made with respect to the forecast:

- Reefers have not been included separately
- TEU factor is considered to be 1.3

Vessel mix and parcel size

Table 5-2 shows the vessel characteristics, the parcel sizes and average calls per week per vessel type. The parcel size includes the TEUs that are loaded and unloaded per vessel.

Table 5-2- Vessel characteristics, parcel size and calls per week for expected traffic

Vessels	Capacity (TEU)	Length (m)	Average calls per week	Parcel size (TEU/vessel)
Mainline 1	9000	350	1	3927
Mainline 2	6000	295	2	2618
Feeder 2	1000	155	3	1553
Feeder 3	600	130	2	932

5.1.2 Terminal requirements

Required berth length and apron area

The required berth length for the new port is related to the required competitive service level of the new port. The average berth occupancy should therefore be approximately 52% as stated in the (Royal Haskoning, 2010) report to provide such a competitive service.

To determine the quay length, information about the container throughput, the number of vessel calls and expected vessel size are necessary. All information indicated in Table 5-2 was provided by the consultant. Table 5-3 summarizes all above factors and the required quay length.

Table 5-3- calculation of berth length

Vessel type	Mainline 1	Mainline 2	Feeder 2	Feeder 3
Vessel capacity (TEU)	9000	6000	1000	600
Parcel size (TEU)	3927	2618	1553	932
Vessel length (incl. 25m spacing) (m)	375	320	180	155
No. vessels per week	1	2	3	2
Carnes per vessel	5	4	3	2
Crane productivity (mvs/hr)	27.5	27.5	27.5	27.5
Crane effectivity	0.75	0.75	0.85	0.9
(Un)mooring time (hr)	3	3	3	3
Berth working hour per week	160			
Downtime	5%			
Peak factor	20%			
Berth length (m)	650			

Table 5-4 shows the cross-sectional dimensions that the consultant considered to determine the apron area.

Table 5-4- dimensions of apron

Sections	Width (m)
Quay wall	3
Waterside and landside rail	3
Rail span	30.5
Margin	6
Hatch cover zone	15
Internal road	12
Light boundary	3
Total	69.5

Stacking yard and yard handling equipment

The calculation of the stacking requirements is divided in two parts: laden containers and empty containers. The calculation assumes that laden containers are stacked by Rubber Tired Gantry Cranes with 5+1 high stacking capacity. Empty containers are stacked using Empty Handlers stacking 6 high. The calculation of the required Twenty feet Ground Slots (TGS) is given in Table 5-5.

Table 5-5- Required number of TGS

	Laden	Empty
Required capacity (TEU)	435250	41200
Stacking height	5	6
Stacking days per annum	350	350
Average occupancy	65%	50%
Dwell time	6	20
Peak factor	20%	20%
Required of TGS (TEU Ground Slots)	2755	942

The length of the yard is based on the TGS length module, which including a small margin for handling is 6.5m long. The traffic corridors parallel to the quay include an RTG traversing lane plus an external-truck / tractor-chassis road. The width of this corridor is five TGS length modules (5 x 6.5m = 32.5m).

Based on the consultant report (RH, 2010), Table 5-6 presents the required number of equipment units for the aforementioned throughput in Table 5-1.

Table 5-6- Number of equipments

Equipment	No.
Gantry Cranes	6
RTG`s	16
Tractor Trailers	30
Reach Stackers	2

Terminal buildings

For the India container terminal, based on requirements for similar terminals, the consultant considered the following buildings:

- Terminal facilities
- Closed storage
- Custom area
- Additional facilities

In RH, (2010) report, the required area for gates, offices, custom area and additional facilities is assumed approximately two hectares.

Note that a rail connection will be developed in the new port. Therefore, sufficient space is allowed at the back of the terminal for developing a rail yard. Its surface area were not mentioned in the report but its area can be estimated from terminal layout map is approximately two and a half hectares.

5.1.3 Summary

Based on the report, the required dimensions of the container terminal for handling the required throughput is 650m x 400m (26 ha). Figure 5-1 indicates the overall terminal layout and includs the number of quay cranes, laden and empty stacks.

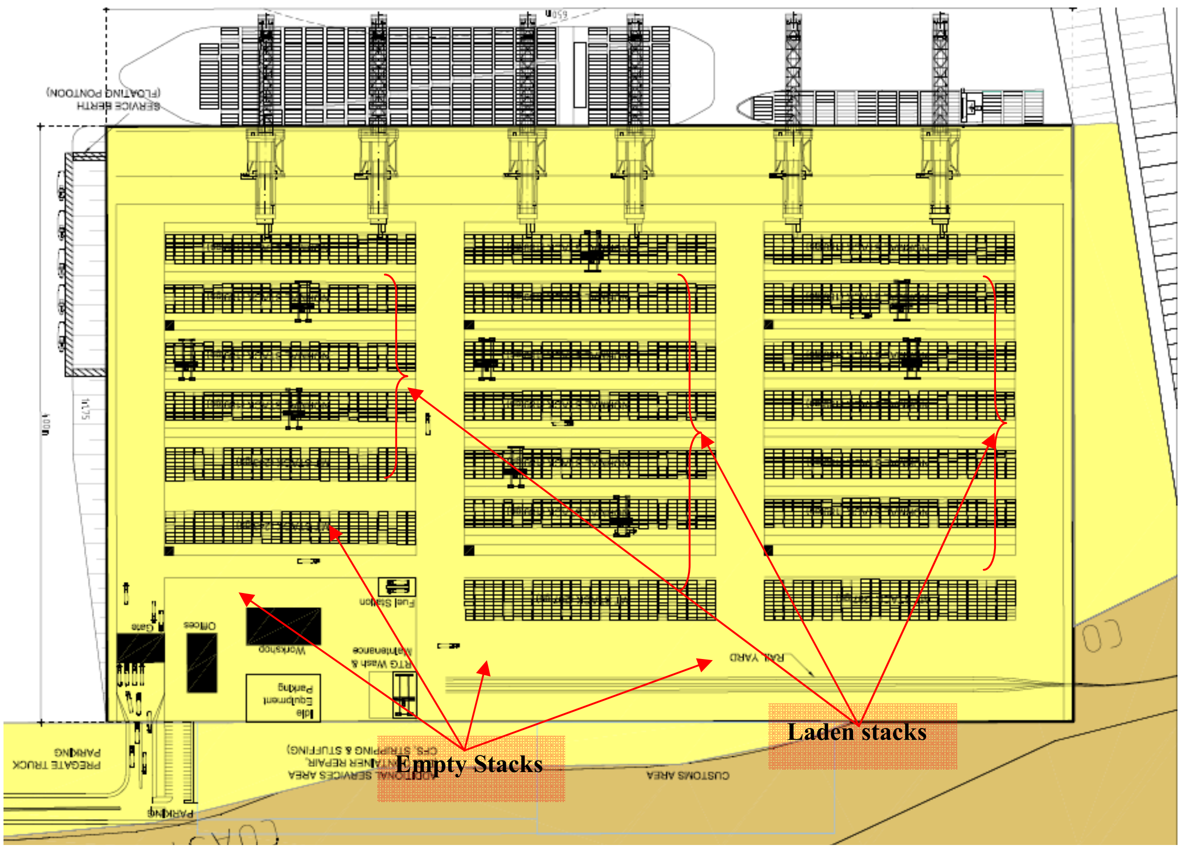


Figure 5-1: India container terminal layout

5.1.4 The tool results and comparison

In Table 5-7, the results of the tool for each container terminal element are presented. The comparison shows a good performance of the design tool, compared to the actual designed value of India port. The minor differences are explained in column “Comparison”.

Table 5-7- comparison between reported value and the tool output

Sections	Reported Results	Tool Result	Comparison
Quay Length (m)	650	655	Difference in: -Using different Crane effectivity factor values. (For example, for 5 cranes per vessel, the crane effectivity factor in the report and tool are 0.75 and 0.7 respectively)
Apron Area (m)	69.5	71	Difference in: - Quay wall width - Hatch cover width - Traffic lane - Quay crane rail width (For example, the value of 12m and 13 correspond to the reported and calculated (by tool) traffic lane respectively.)
Number of TGS	Laden: 2755 Empty: 942	Laden: 2749 Empty: 911	Difference in : - stack calls: - Using different formula in calculating of stack calls - Using different factors value
Number of Stacks	Laden: 16 Empty: 4	Laden: 16 Empty: 4	
Number of Equipments	STS: 6 RTG: 16 PTT: 30	STS: 6 RTG: 14 PTT: 30	Difference in : - Using different factors for number of equipment units per quay crane (For example, equipment units per quay crane factor in the report and tool are 2.6 and 2.3 respectively)
Total Terminal Area (ha)	26	24.5	Difference in : - The exact required area for rail yard is known - Dimension of internal access roads - Difference in various surface area (mentioned above)

5.2 Guatemala project

The port functions as the west coast gateway of Guatemala with no competition from any other ports in Guatemala itself. The port handles dry bulk, wet bulk, general cargo, containers and vehicles. In 1999 approximately 10% of the throughput tonnage was containerised cargo; in 2009 it is approximately 50% of the calls are container vessels.

The rapid growth of the container trade puts a strain on the available berths; therefore, the port authority realized the need for a dedicated container terminal providing longer quay and more yard space for containers. From section 5.2.1 to 5.2.5 the necessary information to calculate the terminal requirements are mentioned from the (Royal Haskoning, 2009) report. In section 5.2.5 a comparison is made between the tool output and the reported design values.

5.2.1 Port User Requirements

Container terminal throughput

Table 5-8 summarizes the different categories of containers are forecasted for container terminal in 2030 based on the (Royal Haskoning, 2009) report.

Table 5-8- Summary of trade volume

	Local		Transhipment		Transit	
	Import	Export	Import	Export	Import	Export
General	253744	161637	32100	32100	12124	1841
Reefers	10573	22042	0	0	9526	300
Empty	63405	155233	6157	6157	0	0

The following observations have been made with relation to the forecast:

- Dwell time is considered 4 days for laden and 15 days for empty containers
- TEU factor is considered 1.66
- Peak factor is considered 20%

Vessel mix and parcel size

The client for this port has indicated that the new container terminal should eventually be able to serve new Panamax vessels. Table 5-9 shows dimensions of the design vessel.

Table 5-9– New Panamax vessel data

Class	Max. length over all	Max beam	Max draft
New Panamax	366m	49m	15.2m

Stack occupancy

Table 5-10 shows occupancy rate defined in the (Royal Haskoning, 2009) report for different types of containers.

Table 5-10– occupancy rate

	Occupancy Rate (%)	
	Import	Export
General	60	80
Reefers	60	80
Empties	50	

5.2.2 Terminal requirements

Required berth length and apron area

To determine the required berth length and service level, the average berth occupancy is necessary section 5.1.2. As proposed by Royal Haskoning, the average berth occupancy is assumed approximately 50%, resulting a 644m quay length in final phase. The apron will follow the set up as indicated in Table 5-4.

Container handling equipment

At waterside, eventually all vessels at the new terminal will be handled by ship to shore gantry cranes.

In stacking yard, for the laden stack, Royal Haskoning assumed an RTG with a span, 7 + vehicle lane, and 1 over 5 stacking height. This is a common and mid-range type RTG providing a good balance between stacking density and easy random access to import containers. For the empty yard (Royal Haskoning, 2009) assumed Reach-stackers with stacking 7 high. In addition, it assumed the empty block stacks would be 8-9 containers deep.

Stacking yard layout

Yard calculations are divided in three parts; general, reefers and empty containers. The required number of TEU ground slots for each part is shown in Table 5-11.

Table 5-11 – Ground slot requirements

	Final Phase (2030)
General TEU ground slots	1,949
Reefer TEU ground slots	243
Empty TEU ground slots	3,254

The length of the yard is based on the TGS length module (Section 5.1.2, Part 2).

5.2.3 Summary

The final-phase yard layout is shown in Figure 5-2. The terminal area is divided in three main sections, more or less of equal size. These sections are separated by landside traffic corridors perpendicular to the quay. Parallel to the apron are the stacking runs, mostly with a length of around 200m, which provides good turnaround times for tractor-chassis. On the land side, parallel to the quay is the main traffic axis connecting all perpendicular traffic corridors with all other elements of the terminal. The terminal area, including apron is estimated to be 35.5 hectares. It is envisaged that not all land may be required. However, if possible, it would be recommended to reserve this land for future container terminal development.

Figure 5-2: Guatemala terminal layout

5.2.4 The tool results and comparison

In Table 5-12, the results of the tool for each container terminal element are presented. The comparison shows a good performance of the design tool, compared to the actual designed value of Guatemala port. The minor differences are explained in column “Comparison”.

Table 5-12- comparison between reported value and the tool output

Sections	Reported Results	Tool Result	Comparison
Quay Length (m)	644	710	Difference in: - Using different Crane effectivity factor value - Number of vessels per week - Parcel size (In the report, there was no information about above items)
Apron Area (m)	69.5	72	Difference in: - Quay wall width - Hatch cover width - Traffic lane - Quay crane rail width (For example, the value of 12m and 14m correspond to the reported and calculated (by tool) traffic lane respectively).
Number of TGS	General:1949 Reefers: 243 Empty: 3254	General:1898 Reefers: 272 Empty: 3255	Difference in : - stack calls: - Using different formula in Calculating of stack calls - Using different transhipment factor
Number of Stacks	24	23	Difference in : - Number of TGS
Total Terminal Area (ha)	35.5	28	Difference in : - The area for Buildings and gates is known - Dimension of internal access roads - Difference in areas which mentioned above - The reported area is more than the required one.

6 ANGOLA CASE INTRODUCTION

6.1 Introduction

Angola is bound from south and east by the Democratic Republic of Congo, in the north, by the Republic of Congo, and from west by the Atlantic Ocean (Figure 6-1). In this case study, the information of a port in the coast of Angola is used. For confidentiality, the actual name of the port cannot be mentioned; therefore, the port is referred to as “port of Angola” in this chapter.

Figure6-1: Angola location

6.1.1 Scope of the case study

The aim of this section is to apply the tool to the design of a container terminal for a port in Angola. In this chapter, analysis of four possible scenarios and their impacts is performed. Due to low rate of throughput in the real case, to create a good overview on how the present package can be applied in comparison of different terminal layout concepts, a larger container terminal throughput will be assumed. In this section, four different scenarios and their impacts on layout dimensions are considered and analyzed. The scenarios have variations in the input parameters such as throughput, dwell time, berth utilisation, waterside and yard handling equipment. Based on these variations, the calculated outputs of the design tool are discussed. In this case study, the action list presented below was followed:

- Determine the port requirements
- Development of different terminal concepts
- Determine the required area at the waterside and landside
- Determine the required number of equipments units

- Estimate the required total area for the Angola container terminal

6.2 Port requirement

6.2.1 Annual throughput and vessel mix

West Africa has had fast growth in container traffic over the last decade (Figure 6-2).By international standards, traffic in all categories is unbalanced and import volumes dominate export for container traffic. Table 6-1 summarizes various categories of containers; the annual volumes are identified for two development phases. The artificial throughput values given Table 6-1 are chosen to be within the reported range of Figure 6-2.

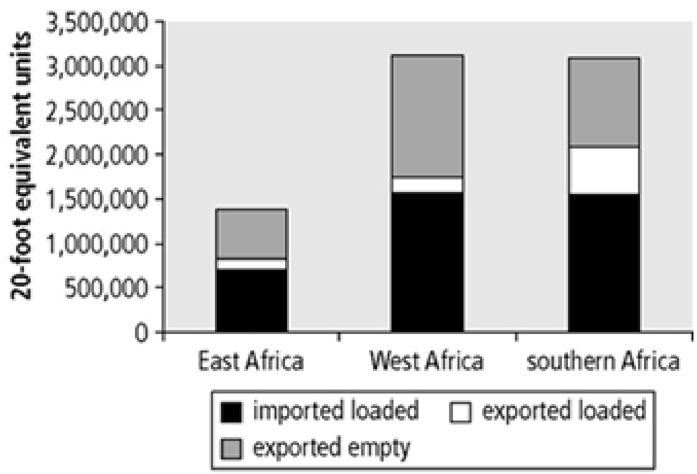


Figure6-2: African container trade (adapted from infrastructure Africa website)

Table 6-1- Summary of trade volume

Type of Container	Unit	Import	Export
		Phase 1	
General	[TEU]	180000	22500
Empty	[TEU]	0	157500
Transshipment	[TEU]	45000	45000
		Phase 2	
General	[TEU]	480000	60000
Empty	[TEU]	0	420000
Transshipment	[TEU]	120000	120000

Peak-factor and TEU-factor normally vary between 1.1-1.3 and 1.2 -1.7 respectively (C. Davis Rudolf, 2010). The TEU-factor and peak-factor are assumed 1.2 in this case study. Table 6-2 shows the feeder, vessel characteristics, parcel sizes and average calls per week per vessel type.

Table 6-2- Vessel characteristics, parcel size and calls per week

Vessels	Capacity (TEU)	Length (m)	Average calls per week	Parcel size (TEU/vessel)
		Phase 1		
Mainline	4500	250	3	1500
Feeder 1	850	134	8	300
Feeder 2	500	110	12	150
		Phase 2		
Mainline	4500	250	6	1700
Feeder 1	1700	176	11	750
Feeder 2	850	134	15	300

6.2.2 Dwell time

Based on Thorsen (2010), if no information about the dwell time is available, one can use 7 days for “import/export” and 20 days for “empty” containers. Another study by Ligteringen (2009) shows that average dwell time for developing countries is approximately between 7 and 11 days for all types of containers. In this study, for yard calculations, two scenarios per development phase are modelled. For example, in phase 1, the dwell time for all laden containers in scenario one and two are 7 and 5 days respectively. The dwell time for empty containers stands at 15 days in both scenarios. Table 6-3 shows the dwell time for two development phases.

Table 6-3- Dwell time

		Scenario 1	Scenario 2
Phase 1	Laden	7	5
	Empty	15	15
Phase 2	Laden	4	2
	Empty	15	15

6.2.3 Required data

To determine sufficient area for the waterside and landside, the other inputs such as berth occupancy, working hours and berthing gap are required for the tool. Table 6-4 summarizes the entire required data for the two phases. For example, the average berth occupancy of container terminal depends on port configuration, cargo mix, volumes of trade and vessel scheduling. Previous studies show that the berth occupancy varies between 35 and 75 percent (Thorsen, 2010 and Ligteringen, 2009). Note that, in a high proportion of vessel arrivals running to fixed schedules, the berth occupancy is higher than the ports servicing primarily unscheduled vessels. Therefore, in Table 6-4 higher values of berth occupancy are intended to refer to a more scheduled vessel arrival.

Table 6-4- Entire required data

	Unit	Phase 1		Phase 2	
		Scenario 1	Scenario 2	Scenario 1	Scenario 2
Berth occupancy	[%]	75	60	70	55
Working hours	[hr]	160		160	
Downtime	[%]	5		5	
Berthing gap	[m]	25		25	
Hinterland breakdown flow	[%]	Road (100%)		Road (100%)	
Number of Personnel		200		350	

6.3 Terminal requirements

Many different types of terminal equipment can be used to handle the containers at waterside and landside. Figure 6-2 shows the possible combinations for each type of quay crane combined with the suitable horizontal transportation and yard handling equipment for the Angola container terminal.

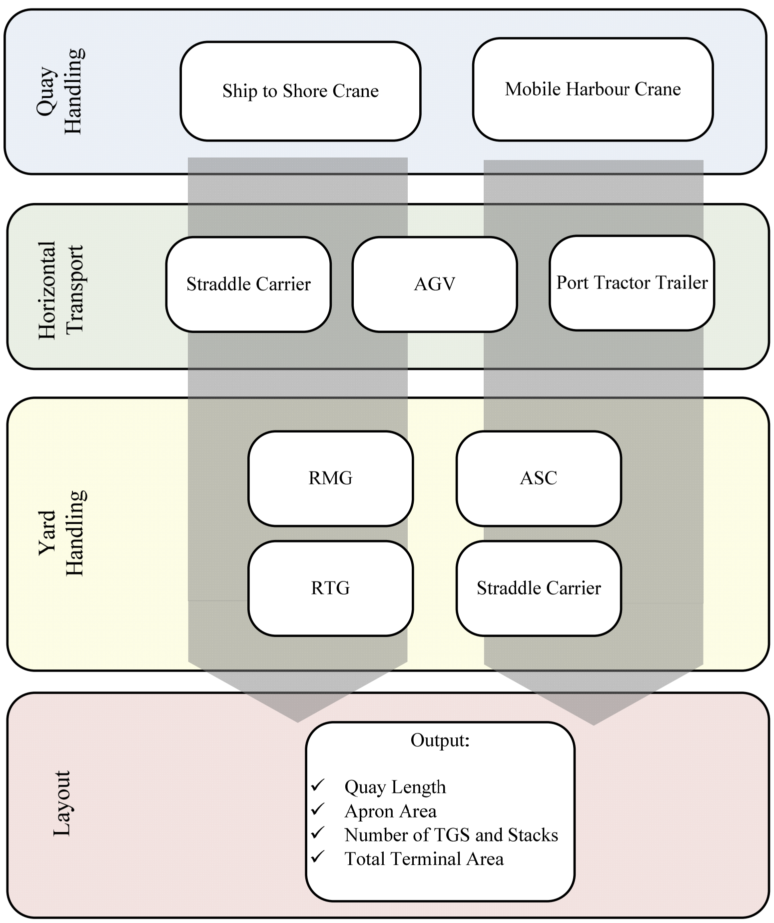


Figure6-2: Possible concepts Angola container terminal

From Figure 6-2 above, Table 6-5 summarizes the concepts that have been selected for each type of quay and yard handling equipment combination (Watanabe, 2001).

Table 6-5 – selected equipment handling concepts

Phase	Concepts	Scenario	Quay Handling	Internal Handling	Storage yard	
1	1	1	Ship to Shore	Port Tractor Trailer	RTG	Reach Stacker
	2				Straddle Carrier	Reach Stacker
	3				RMG	Reach Stacker
	4	2	Mobile Harbour Crane	Straddle Carrier	RTG	Reach Stacker
	5				Straddle Carrier	Reach Stacker
	6				RMG	Reach Stacker
2	1	1	Ship to Shore	AGV	RTG	Reach Stacker
	2				Straddle Carrier	Reach Stacker
	3				RMG	Reach Stacker
	4	2	Mobile Harbour carne	Port Tractor Trailer	RTG	Reach Stacker
	5				Straddle Carrier	Reach Stacker
	6				RMG	Reach Stacker

6.3.1 Waterside

The first and second scenarios of each phase concern changes in quay crane and berth occupancy. Figures 6-3, 6-4 show the changes of the design layout, as result of changes in the input of the two scenarios.

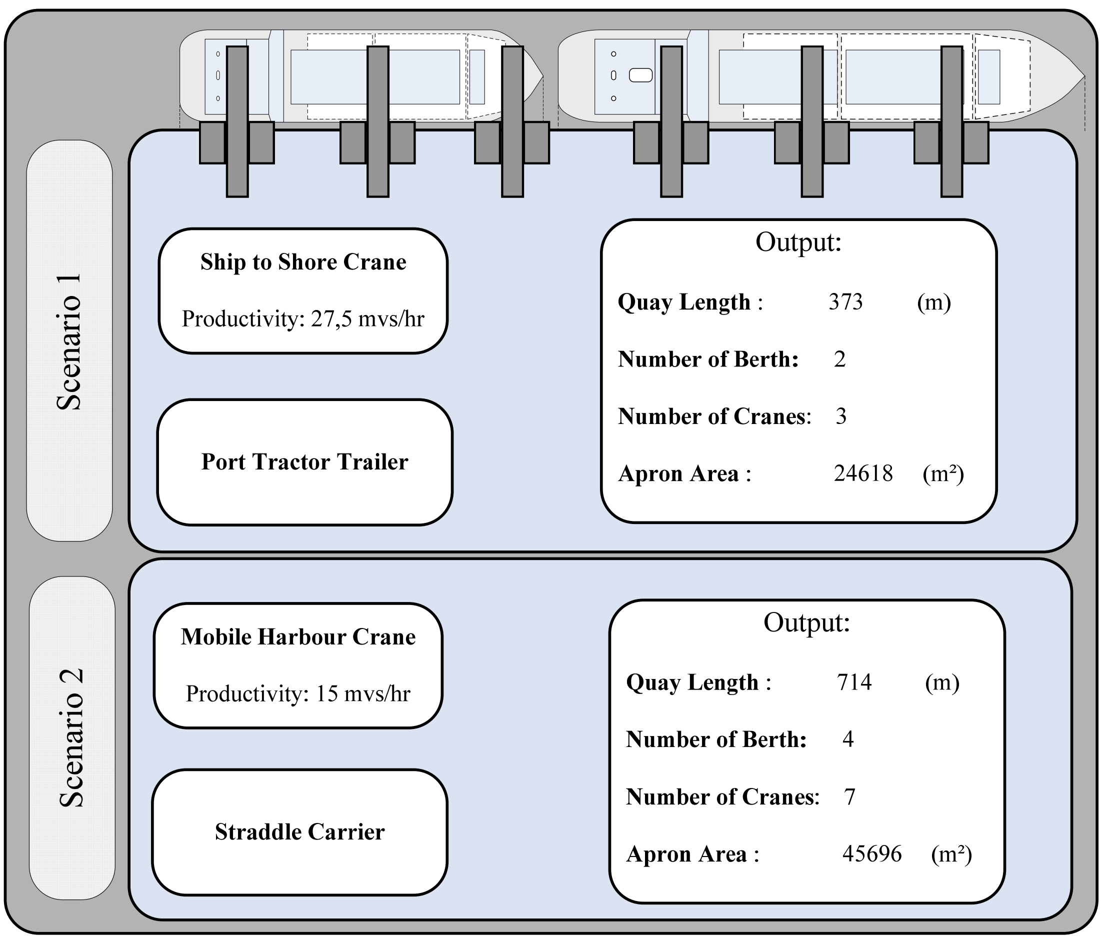


Figure 6-3: Overview of waterside concept in phase 1

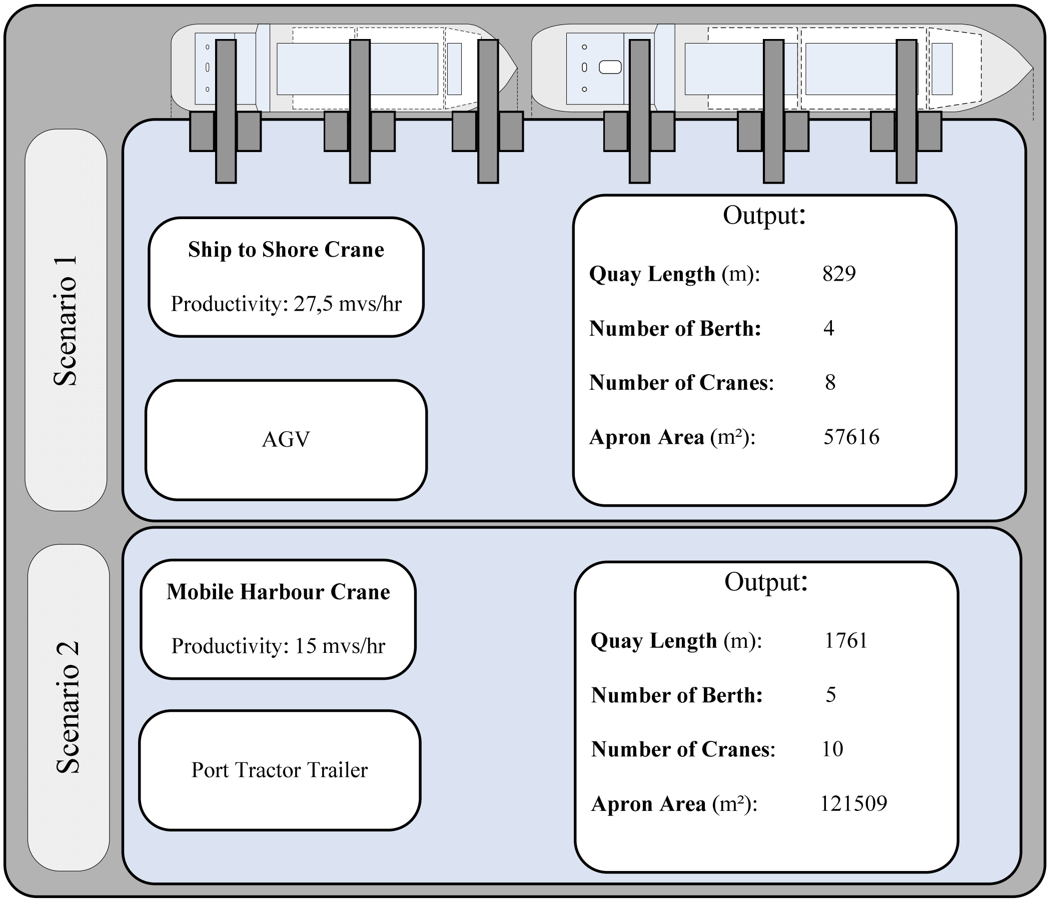


Figure 6-4: Overview of waterside concept in phase 2

The comparison demonstrates the higher berth productivity of a ship to shore gantry crane, compared to mobile harbour cranes. A smaller number of cranes, results in a much smaller quay length and apron area.

Note that, Table 6-4 shows higher value for quay occupancy in the first scenario than in the second scenario in the two phases. In fact, higher quay occupancy indicates optimal use of the quay length and quay cranes. Therefore, decreasing the quay occupancy in second scenario results in increased quay length and number of the handling equipment units.

6.3.2 Landside

On design of the landside area, the first and second scenarios of each phase concern changes in storage yard equipment and dwell time. Comparisons of output for different scenarios are given in Figures 6-5 and 6-6. The figures indicate the results of the tool in respect to the mentioned concepts in Table 6-4. The result of the tool consists of number of TEU ground slots, number of stacks and total stack area. The required hinterland area is mentioned in the output box in lower end of the diagrams.

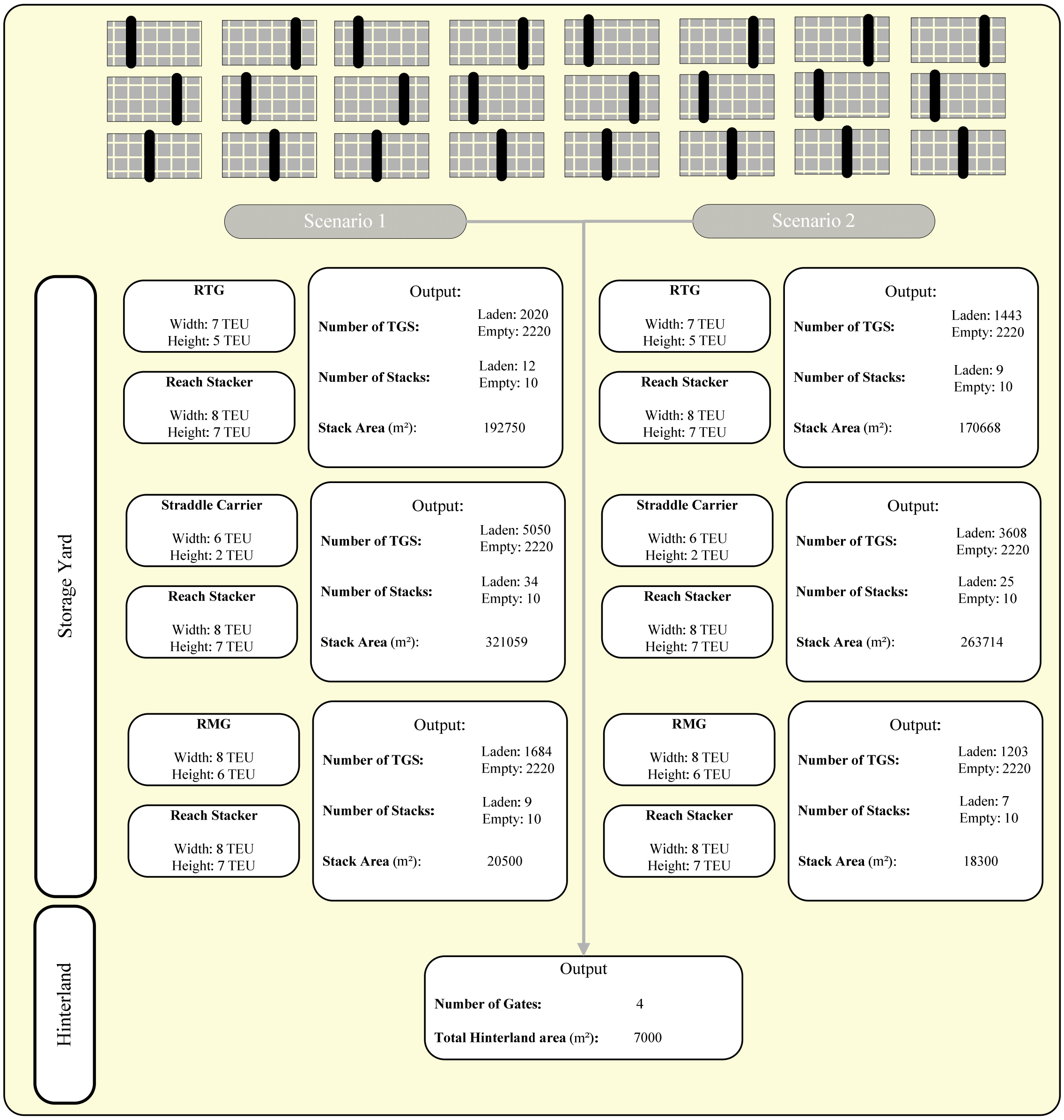


Figure 6-5: Overview of storage yard concept in phase 1

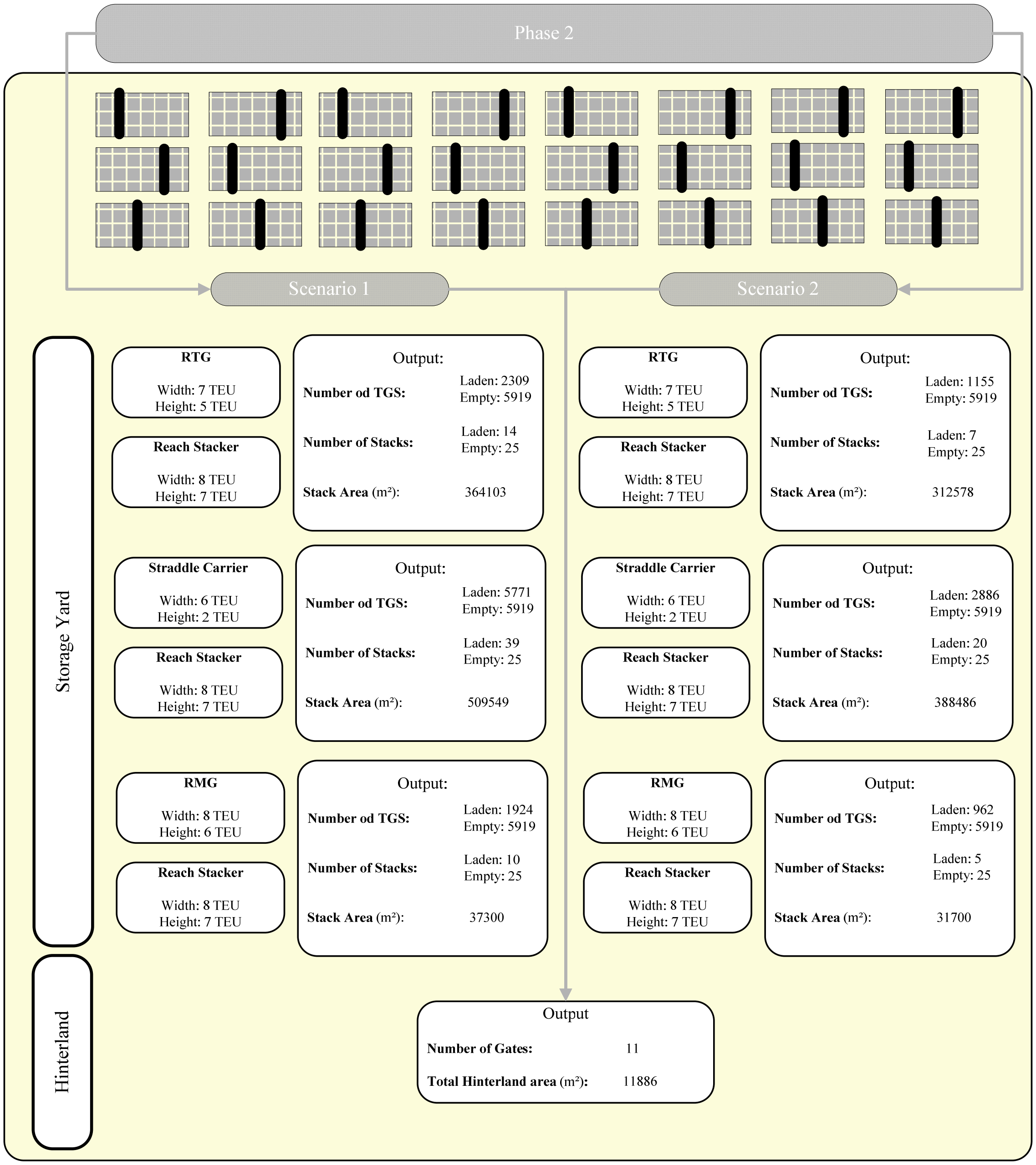


Figure 6-6: Overview of storage yard concept in phase 2

For similar throughput and equipment the two scenarios (Figures 6-5 and 6-6) show that longer dwell times of laden containers in scenario one causes laden containers to take up more space of the storage yard when compared to the second scenario. Therefore the required storage capacity is increased in scenario one.

Figures 6-7 and 6-8 summarize the results of the tool for the required total terminal area corresponding to the variable quay side and landside equipment. Selection of a favorable concept for the terminal is based on the total allocated area by the local/port authorities, which are both a financial and a political decision. The tool output sheets can be found on appendix III.

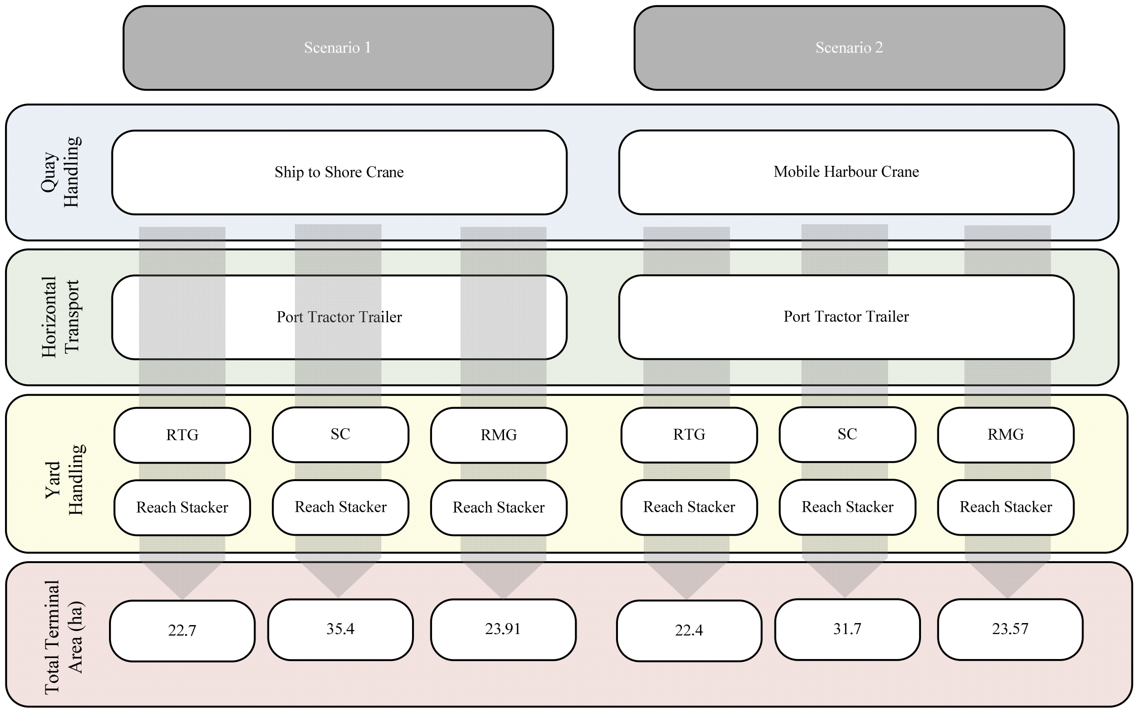


Figure 6-7: Required total terminal area in phase 1

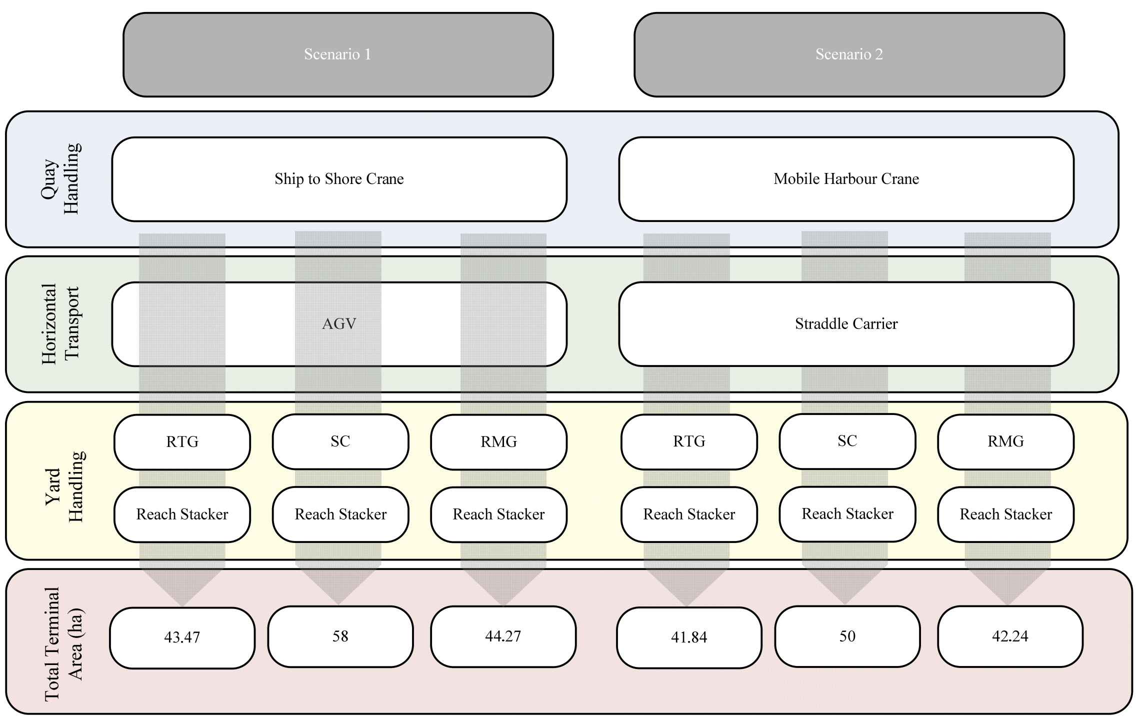


Figure 6-8: Overview of waterside concept in phase 2

6.4 Recommendations

- Based on the aforementioned results, different equipment combinations can be selected for further development in the Angola container terminal. Key issues in the selection of the equipments are budget price, terminal throughput and the size of the area that can be allocated by the port authority.

  It is recommended that for selection of the most favourable handling equipment combination, a multi criteria analysis (MCA) is conducted. This is elaborated in section 7.2.

- In this study, reefers containers are not taken into account. For further study, the detailed reefers data has to be provided for the yard calculation.

- To select the suitable concept, financial evaluation has to be done with higher accuracy. For example, the required budget price for the straddle carrier and ship to shore crane concept is less than the automated rail mounted gantry cranes and ship to shore crane concept. However, the automation system decreases the number of labours and it results in a lower operation cost compared to other concept. Usually in developing countries, such as Angola, the cost of labour is less when compared to developed countries. Therefore, the concept of the straddle carrier may be a better solution.

7 CONCLUSIONS AND RECOMMENDATIONS

7.1 Conclusions

- The aim of this study was to provide Royal Haskoning Maritime Division with a model to support container-terminal designers in calculating the required total area for a new container terminal. The model is developed to assist the designer in assessing various design scenarios. The scenarios can differ in terms of land allocation to different parts of the terminal, and selection of a proper combination of handling equipments both on the waterside and the landside.

- The package is developed as a set of Excel worksheets as this platform is accessible, user-friendliness and flexible.

- The developed tool is not case-specific and without any limitation, multiple users (designers) may contribute. In addition, a user with some basic knowledge on factors and handling equipments may successfully apply the tool.

- The presented package was verified against two different cases. The cases have been successfully designed by Royal Haskoning Maritime Division. The validation showed a relatively accurate comparison between the results of the tool and the designed values. The model is also applied to the design of a container terminal in Angola. Some general conclusions can be drawn from the validation cases and case study:

    - Quay length and apron area are very sensitive to gantry crane productivity, number of calls, maritime vessel size, working hours and berth occupancy.
    - Stack yard area is sensitive to type of handling equipment and storage yard occupancy.
    - Hinterland area is sensitive to number of gates, landside breakdown flow, number of personnel and size of the buildings.
    - The abovementioned points support the need for such a tool in order to carry out a sensitivity analysis any to achieve a clear overview of the alternative concepts.

7.2 Recommendations

- In this model, rough information for vessel arrival and dwell time are used as input. It is recommended to better investigate the impacts of vessel arrival "pattern" and dwell time "distribution" on the design of container terminal elements such as handling equipments, storage yard capacity and total required terminal area.

- In this model, a rule of thumb is used to calculate the number of quay cranes. In fact, the number of quay cranes can have strong impact on total service time and quay length. Therefore, it is recommended to use a "Quay Crane Assignment" to find maximum number of quay cranes allowed to serve a vessel simultaneously. For further details the reader may refer to Frank Meisel (2009).

- It is recommended to use Multi-Criteria Analysis (MCA) to select the appropriate terminal handling combination. The MCA may provide a more accurate result with a limited amount of data. The main criteria for this comparison may matched:

    - Quay productivity
    - Investment costs
    - Running cost

  The basic assumption of the multi-criteria analysis is that, not all the criteria have similar importance. Therefore, the user assigns weights to each criterion. Each concept is awarded a score based on the mentioned criteria. Eventually, based on the awarded score the favourable concept is selected for further development.

- In this package, only rough cost estimation of container terminal is used. For a more detailed study, it is recommended to use more sophisticated methods to calculate the running and civil-works costs.

APPENDIX I: TABLES QUEUING THEORY

o Waiting-time factor, Average waiting time of ships M/E2/n. (In Units of Average Service Time)

Random Arrivals

	Number of berthing Points														
Utilization	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
30	0,32	0,08	0,03	0,02	0,01	0	0	0	0	0	0	0	0	0	0
31	0,34	0,09	0,03	0,02	0,01	0	0	0	0	0	0	0	0	0	0
32	0,35	0,09	0,03	0,02	0,01	0	0	0	0	0	0	0	0	0	0
33	0,36	0,09	0,04	0,02	0,01	0	0	0	0	0	0	0	0	0	0
34	0,37	0,1	0,04	0,02	0,01	0	0	0	0	0	0	0	0	0	0
35	0,39	0,11	0,04	0,02	0,01	0,01	0	0	0	0	0	0	0	0	0
40	0,48	0,14	0,06	0,03	0,02	0,01	0,01	0	0	0	0	0	0	0	0
41	0,5	0,15	0,06	0,03	0,02	0,01	0,01	0	0	0	0	0	0	0	0
42	0,52	0,16	0,06	0,04	0,02	0,02	0,01	0	0	0	0	0	0	0	0
43	0,54	0,16	0,07	0,04	0,03	0,02	0,01	0	0	0	0	0	0	0	0
44	0,56	0,17	0,07	0,04	0,03	0,02	0,01	0	0	0	0	0	0	0	0
45	0,59	0,18	0,08	0,04	0,03	0,02	0,01	0,01	0	0	0	0	0	0	0
46	0,61	0,19	0,08	0,05	0,03	0,02	0,02	0,01	0,01	0	0	0	0	0	0
47	0,64	0,2	0,09	0,05	0,03	0,02	0,02	0,01	0,01	0	0	0	0	0	0
48	0,66	0,21	0,09	0,05	0,04	0,03	0,02	0,01	0,01	0	0	0	0	0	0
49	0,69	0,23	0,1	0,06	0,04	0,03	0,02	0,01	0,01	0,01	0	0	0	0	0
50	0,72	0,24	0,11	0,06	0,04	0,03	0,02	0,01	0,01	0,01	0	0	0	0	0
51	0,74	0,25	0,12	0,07	0,04	0,03	0,02	0,02	0,01	0,01	0,01	0	0	0	0
52	0,78	0,26	0,13	0,07	0,05	0,03	0,02	0,02	0,01	0,01	0,01	0	0	0	0
53	0,81	0,28	0,13	0,08	0,05	0,04	0,03	0,02	0,01	0,01	0,01	0,01	0	0	0
54	0,84	0,29	0,14	0,08	0,05	0,04	0,03	0,02	0,01	0,01	0,01	0,01	0	0	0
55	0,88	0,31	0,15	0,09	0,06	0,04	0,03	0,02	0,02	0,01	0,01	0,01	0	0	0
56	0,91	0,33	0,16	0,1	0,06	0,05	0,03	0,02	0,02	0,01	0,01	0,01	0,01	0	0
57	0,95	0,35	0,17	0,11	0,07	0,05	0,04	0,03	0,02	0,02	0,01	0,01	0,01	0	0
58	1	0,37	0,18	0,11	0,07	0,05	0,04	0,03	0,02	0,02	0,01	0,01	0,01	0,01	0
59	1,04	0,39	0,19	0,12	0,08	0,06	0,05	0,03	0,02	0,02	0,02	0,01	0,01	0,01	0
60	1,08	0,42	0,2	0,13	0,08	0,06	0,05	0,04	0,03	0,02	0,02	0,01	0,01	0,01	0,01
61	1,13	0,44	0,22	0,14	0,09	0,07	0,06	0,04	0,03	0,02	0,02	0,02	0,01	0,01	0,01
62	1,18	0,47	0,23	0,15	0,14	0,07	0,06	0,04	0,03	0,03	0,02	0,02	0,01	0,01	0,01
63	1,23	0,49	0,25	0,16	0,11	0,08	0,07	0,05	0,03	0,03	0,02	0,02	0,02	0,01	0,01
64	1,29	0,51	0,27	0,17	0,12	0,09	0,07	0,05	0,04	0,03	0,03	0,02	0,02	0,01	0,01
65	1,34	0,53	0,29	0,19	0,12	0,1	0,07	0,05	0,04	0,04	0,03	0,02	0,02	0,02	0,01
66	1,4	0,6	0,31	0,2	0,13	0,11	0,08	0,06	0,05	0,04	0,03	0,03	0,02	0,02	0,02
67	1,48	0,63	0,33	0,22	0,14	0,12	0,09	0,06	0,05	0,04	0,04	0,03	0,02	0,02	0,02
68	1,55	0,66	0,36	0,23	0,16	0,13	0,09	0,07	0,06	0,05	0,04	0,03	0,03	0,02	0,02
69	1,62	0,7	0,38	0,25	0,17	0,14	0,1	0,08	0,06	0,05	0,04	0,03	0,03	0,03	0,02

70	1,7	0,72	0,42	0,27	0,19	0,15	0,11	0,09	0,07	0,06	0,05	0,04	0,03	0,03	0,03
71	1,8	0,78	0,44	0,29	0,2	0,17	0,12	0,1	0,08	0,07	0,06	0,04	0,04	0,03	0,03
72	1,9	0,83	0,48	0,31	0,22	0,17	0,13	0,11	0,08	0,07	0,06	0,04	0,04	0,04	0,03
73	1,99	0,87	0,51	0,34	0,24	0,18	0,14	0,12	0,09	0,08	0,07	0,05	0,05	0,04	0,04
74	2,08	0,93	0,54	0,36	0,26	0,2	0,16	0,13	0,1	0,09	0,08	0,05	0,05	0,05	0,04
75	2,2	1	0,59	0,39	0,28	0,22	0,17	0,14	0,11	0,1	0,09	0,06	0,06	0,05	0,05
76	2,31	1,08	0,63	0,42	0,3	0,24	0,19	0,15	0,13	0,11	0,09	0,07	0,07	0,06	0,06
77	2,46	1,16	0,68	0,45	0,33	0,26	0,21	0,17	0,14	0,12	0,11	0,09	0,08	0,07	0,07
78	2,59	1,23	0,73	0,49	0,36	0,28	0,23	0,19	0,16	0,13	0,12	0,1	0,09	0,08	0,07
79	2,75	1,3	0,79	0,53	0,4	0,31	0,25	0,21	0,17	15	0,13	0,11	0,1	0,09	0,08
80	2,95	1,4	0,84	0,57	0,43	0,34	0,27	0,22	0,19	0,17	0,15	0,13	0,11	0,1	0,09
81	3,17	1,5	0,92	0,63	0,47	0,38	0,3	0,24	0,21	0,19	0,16	0,14	0,12	0,11	0,1
82	3,45	1,7	0,98	0,68	0,52	0,42	0,34	0,27	0,23	0,21	0,18	0,16	0,14	0,12	0,11
83	3,75	1,85	1,08	0,74	0,57	0,47	0,38	0,31	0,26	0,23	0,2	0,18	0,15	0,14	0,13
84	4,1	1,9	1,16	0,81	0,64	0,5	0,42	0,34	0,29	0,26	0,22	0,2	0,17	0,16	0,15
85	4,4	2,05	1,28	0,9	0,7	0,56	0,46	0,38	0,32	0,29	0,25	0,22	0,19	0,18	0,16
86	4,75	2,2	1,4	0,98	0,76	0,61	0,51	0,42	0,36	0,32	0,28	0,25	0,22	0,2	0,18
87	5,2	2,4	1,52	1,07	0,84	0,67	0,56	0,47	0,4	0,35	0,31	0,28	0,25	0,23	0,2
88	5,6	2,6	1,68	1,16	0,92	0,75	0,63	0,52	0,45	0,39	0,35	0,31	0,28	0,26	0,24
89	6,1	2,85	1,83	1,29	1,01	0,83	0,7	0,58	0,5	0,44	0,4	0,36	0,32	0,29	0,27
90	6,6	3,2	2	1,43	1,12	0,92	0,76	0,64	0,56	0,49	0,44	0,4	0,36	0,33	0,3

o Appropriate Number of Lanes at the Gate

Arrival Rate (λ)	Service time (1/μ)	Number of lanes
1	1	2
	1.5	3
	2	4
	3	6
	4	8
	5	9
1.5	1	3
	1.5	5
	2	7
	3	9
	4	11
	5	15
2	1	5
	1.5	6
	2	8
	3	11
	4	14
	5	17
2.5	1	6
	1.5	7
	2	8
	3	11
	4	15
	5	18
3	1	6
	1.5	8
	2	10
	3	14
	4	18
	5	21
3.5	1	6
	1.5	8
	2	11
	3	15
	4	20
	5	24

APPENDIX II: THE USER TOOL MANUAL

The presented package is standardized and user-friendly tool that is accessible to Royal Haskoning container terminal designers. The present package aims to provide an easy model for engineers to prepare a concept of a terminal layout and estimate the required total area for a new container terminal. It assists the engineers in selection of cargo handling equipment. By using different equipment for different throughput magnitude, the total area for container terminal will be calculated. Figure 1 shows the structure of the container terminal design tool.

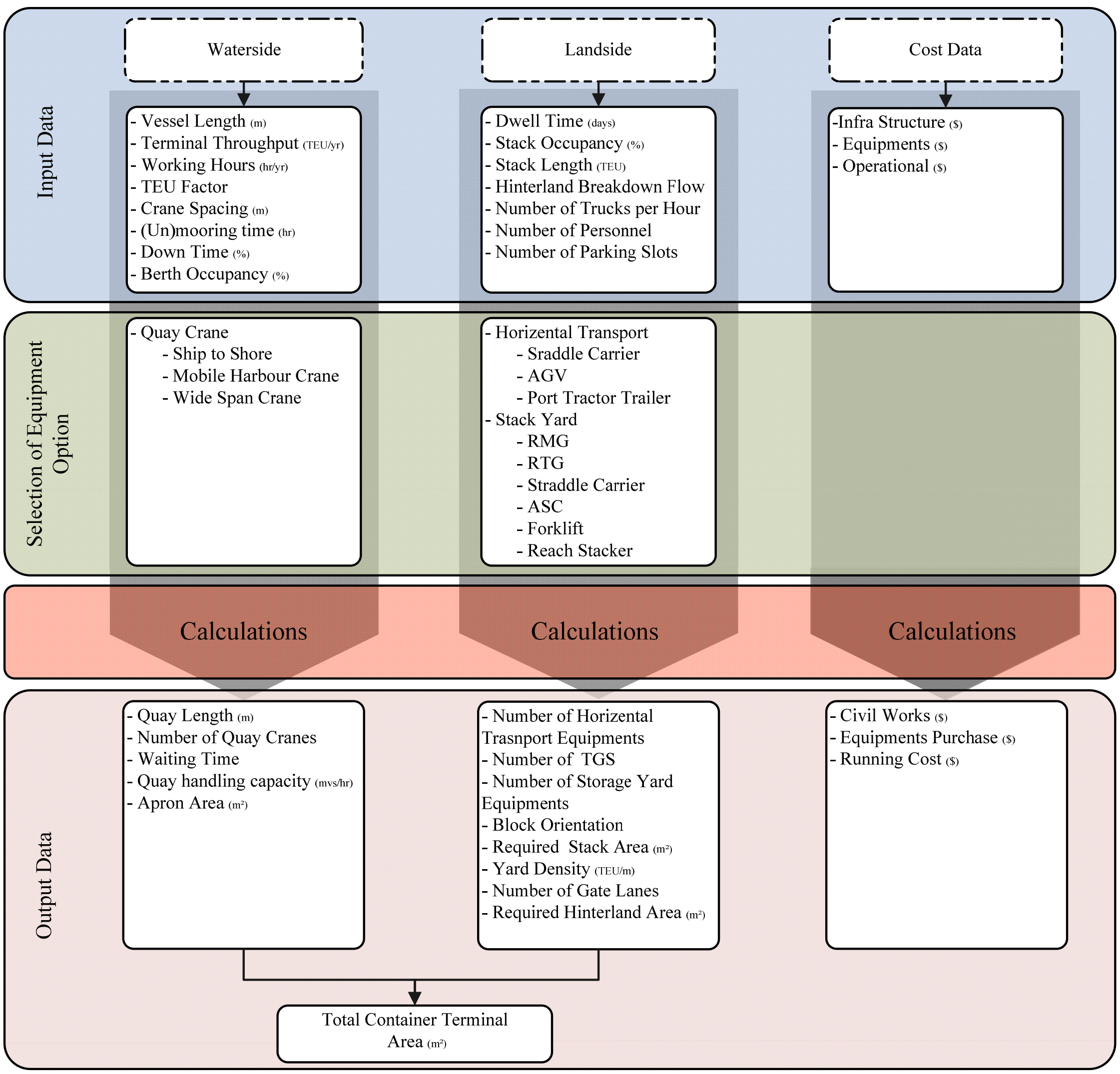


Figure 1: Structure of the container terminal design tool

1. Overview of the model worksheets

In this section, an overview of all sheets in the model is indicated (Figure 2). In the presented package, the total number of worksheets is 21. However, not all of them are used at the same time. The input data determines the required worksheets. All benchmarks in those sheets are defined as variable values and if the users do not want to use them, they can be replaced by new data.

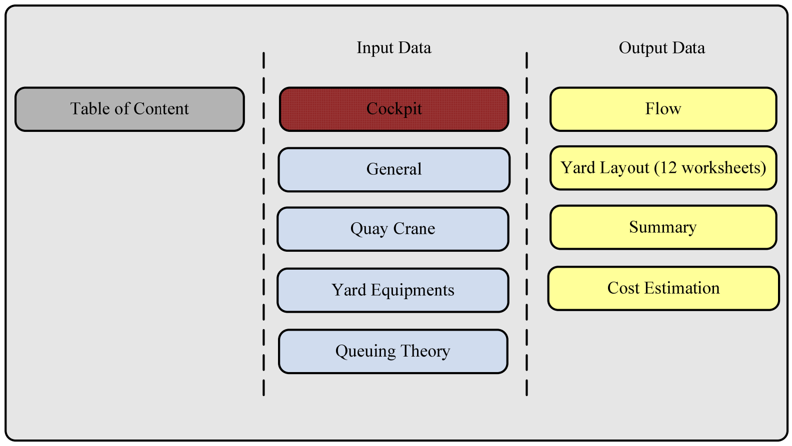


Figure 2: an overview of the model worksheets

Figure 2 shows that there are two main categories of worksheets, the input and output sheets. These two categories have their own color (Yellow and Blue) to show the function of the worksheets (Figure 2). The only exception in the input category is the cockpit (Red).

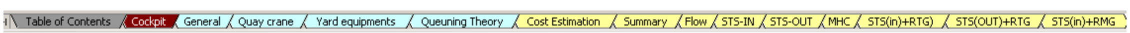


Figure 3: the color of model tabs

1.1. Input sheets

Cockpit Sheet is the most important sheet of the model. Cockpit is a popular name used of Royal Haskoning Maritime Divison for main worksheet. It is divided into two main parts, “Input Data” and “Output Data”. Each part is separated into waterside and landside. The most basic information that mentioned in figure 3 is entered into the “Input Data” part. After the basic inputs have been entered, the model calculates the requested output data (Figure 1). The results can be found in the “Output Data” section in the cockpit. The cells where input is required are yellow.

General Sheet is separated into two parts. The first part indicates the basic dimensions of the terminal buildings and apron area. In the second part, the unit rates of civil-work items and running costs are presented. The cells where input is required are green.

Quay Crane and Yard Equipments Sheets present the basic primary benchmarks used in the package. All benchmarks are defined as default variables. These values can be replaced by user-defined values. The cells where input is required are green.

Queuing Theory Sheet is used to calculate the waiting time the combination M/E2/n is used, meaning that service rate and arrival rate are respectively assumed to be the negative exponential distributed and Erlang-2 distributed with n service points (berths). In addition, a queuing theory is used to calculate the number of lanes at gate area. These tables are given in the queuing theory sheet.

1.2. Output sheets

Flow Sheet shows the containers flow through a terminal. It shows the annual volume of containers that import/export over the quay wall and leave from the hinterland and vice versa, meaning that how the annual flow of containers is separated into vessels, road and rails.

Cost Estimation sheet is divided into the required investment costs for civil-works, equipment purchases and running costs. Eventually, the total terminal cost is determined at the end of the sheet.

Summary Sheet combines initial outputs such as quay length, number of equipment and total terminal area on one sheet.

Yard Layout Sheets present a top-view and a cross-section of the terminal, based on the output quantities of the summary sheet.

1.3. How to use the model

As mentioned before, cockpit is the main sheet of the model. In this sheet, in first step, number of vessels and the method to input throughput data are selected from drop-down menus (Figure 4). In the present package, there are two methods for input the throughput data. In one method, the input is defined as the total number of TEU loading and unloading over the quay wall. In the second one, the throughput magnitude is defined in terms of annual number of calls and the volume of containers loading and unloading per call. Depending on choices user made, proper table to input the throughput data will appear (Figure 5).

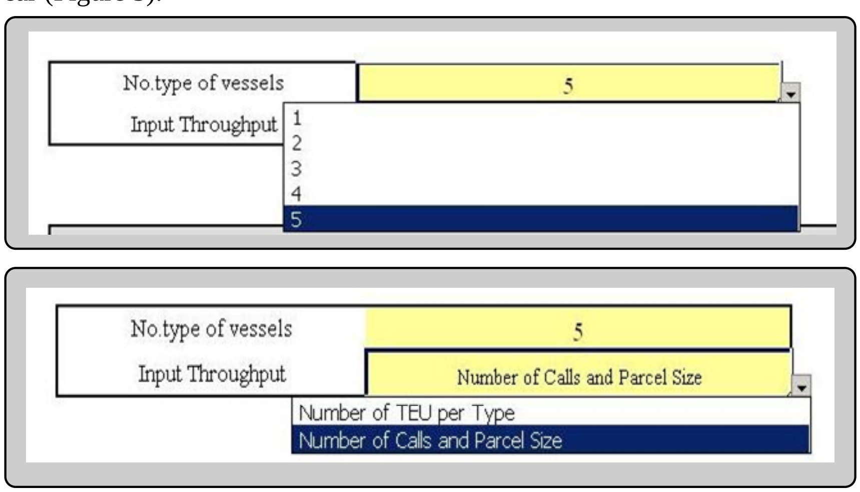


Figure 4: number of vessels and input throughput drop-down menus

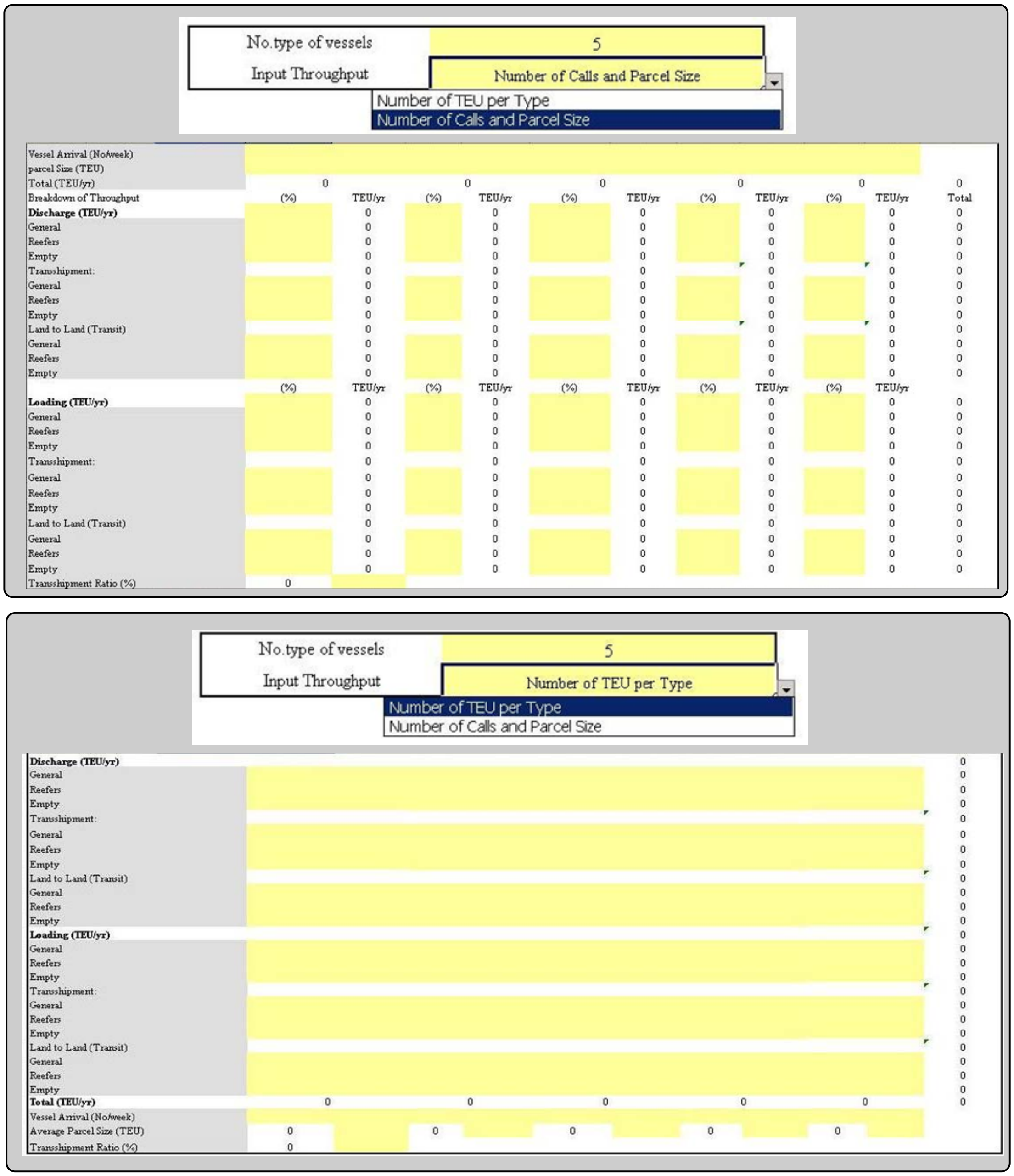


Figure 5: throughput data section

In second step, the requested factors to calculate the port requirements that are mentioned in Figure 1 are entered into yellow cells in next tables. Some of the yellow cells in those tables such as “Crane Productivity”, “Dwell time” and “Utilization” contain drop-down menus (Figure 6). It helps the user to limit the possibilities and enter the right data in the right cell.

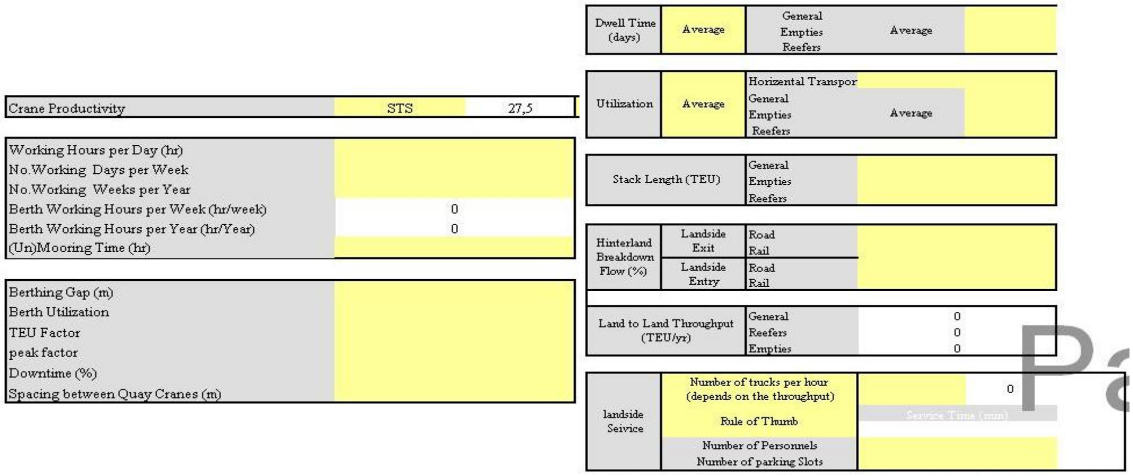


Figure 6: required factors to calculate the quay length, storage yard and hinterland dimensions

Output

The input data is used to calculate the port requirements mentioned in Figure 1 and the results are presented in "Output Data" section. In the first table of this section, the waterside outputs such as required quay length, number of berths and number of quay cranes can be found (figure 7).

Output Data

	Type 1	Type 2	Type 3
Berth Use (vessel Length+Spacing)	0	0	0
Crane Effectivity	0	0	0
(Un)loading Time (hr)	0	0	0
Total Service Time (hr/vsl)	0	0	0
Berth Service Time (hr/week)	0	0	0
Berth Requirement (hr.m/week)	0	0	0
Quay Length (m)	0		
No. Berth	0		
Waiting Time in Units of Service Time	0		
Number of Quay Cranes	0		
Quay Productivity (mvs/hr)	0		

Figure 7: waterside output data

In "Apron" table, three yellow cells contain drop-down menus as shown in Figure 8 that the user can choose traffic lane location, different types of quay cranes and horizontal equipments. After selection of proper choice from drop-down menus, the total required apron area is calculated.

In the next step, in order to determine the required terminal area, the type of storage yard crane can be chosen from drop-down menus in "Selection Yard Equipment" table (Figure 9).

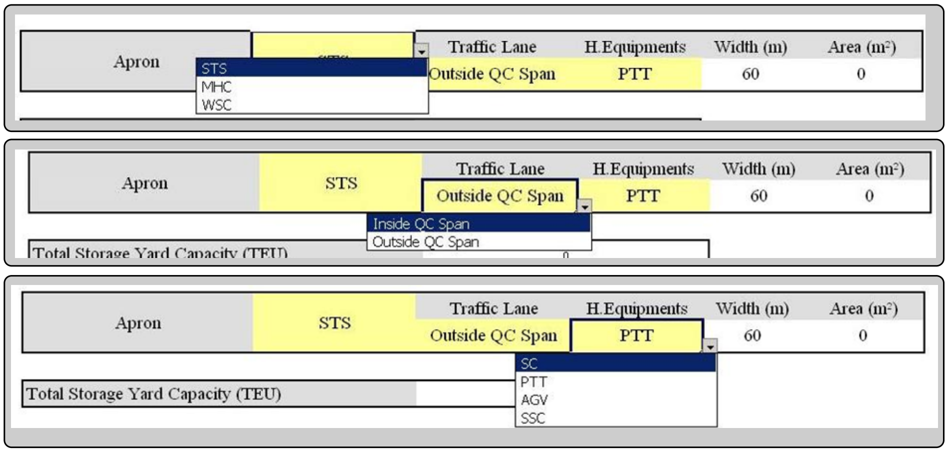


Figure 8: "Apron" table

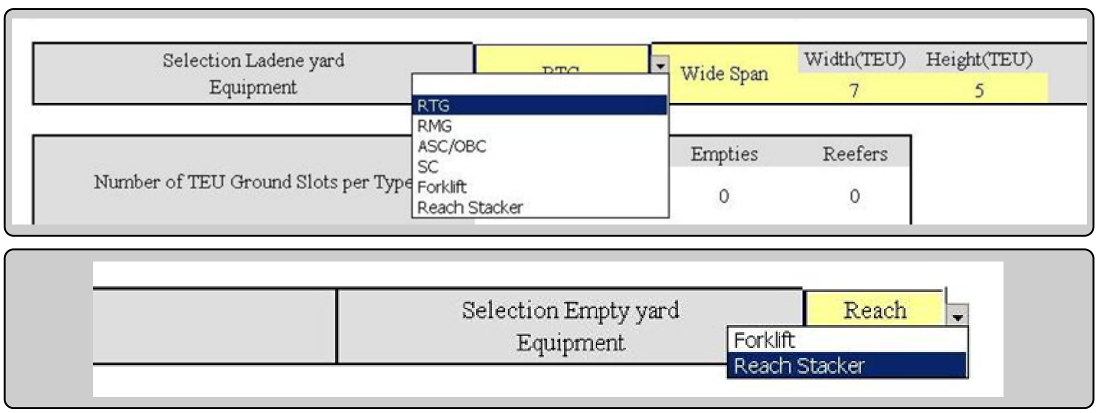


Figure 9: "Selection Yard Equipment" table

Eventually, landside outputs such as number of TGS, Stacks, the required storage yard and hinterland areas are presented in next tables the sheet. In some cases, the required area for terminal buildings and gates areas are assumed as parentage of the total area. In these cases, the user can enter the proper value for hinterland areas into yellow cells in "Total Hinterland Area" table. The model uses these values to calculate the total terminal area instead of the calculated results for total hinterland area (figure 8).

In the lower part of the cockpit worksheet, by clicking on the "Shape" button a top-view and a cross-section of the terminal, based on the output quantities are presented (figure 9). In addition, all outputs can be found in the "Summary" sheet (Figure 10).

As mentioned in section 1.2, the container flows through a terminal and cost estimation can be found in the "Flow" and "Cost Estimation" sheets (Figure 11).

	General	Empties	Reefers
Number of TEU Ground Slots per Type	0	0	0

Laden Stack Configuration		
	Width (TEU)	7
	Height (TEU)	5

	Genral	Empties	Reefers
Number of Stacks per Type	0	0	0

	RTG	Reach Stacker
Number of Storage Yard Equipments	0	0

	General	Reefers	Empties
Stack Width (m)	38,7	42,0	47,1
Stack Length (m)	32,7	32,7	32,7
Stack Height (m)	12,5	12,5	17,5
Stack Orientation to the Quay		Parallel	

	General	Reefers	Empties	Total
Stack Area (m²)	0	0	0	0
Total Stack Area (ha)	0			
Yard Density (TEU/m)	#DIV/0!			

Hinterland			General	Reefers	Empty	Total per Mode	Total
Throughput (TEU/yr)	Landside Exit	Road	0	0	0	0	0
		Rail	0	0	0	0	
	Landside Entry	Road	0	0	0	0	0
		Rail	0	0	0	0	

Terminal Gate			
	Number of Gates	0	
	Gate Area (m²)	Rigid Vehicles	0
	Parking Area (m²)	210	
	Gate Receiption Building Area (m²)	64	
	Total Gate Area (m²)	274	

Workshop and Stores (m²)	506
Offices (m²)	0

	(m²)	(ha)	(m²)	(ha)
Total Hinterland Area	780	0,1		

	(m²)	(ha)
Total Terminal Area	780	0,1

Shape

Figure 8: landside outputs tables

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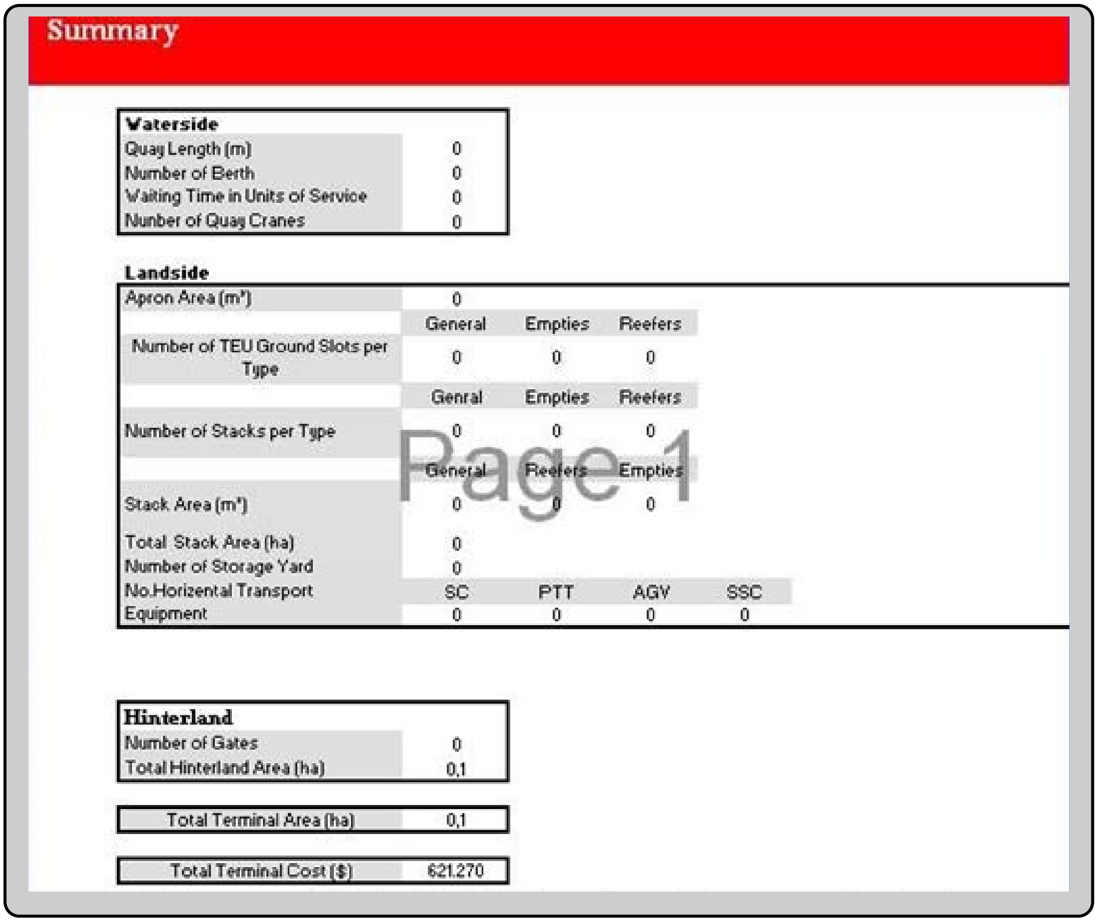

Summary

Waterside	
Quay Length (m)	0
Number of Berth	0
Waiting Time in Units of Service	0
Nunber of Quay Cranes	0

Landside

Apron Area (m²)	0			
	General	Empties	Reefers	
Number of TEU Ground Slots per Type	0	0	0	
	Genral	Empties	Reefers	
Number of Stacks per Type	0	0	0	
	General	Reefers	Empties	
Stack Area (m²)	0	0	0	
Total Stack Area (ha)	0			
Number of Storage Yard	0			
No.Horizental Transport	SC	PTT	AGV	SSC
Equipment	0	0	0	0

Page 1

Hinterland	
Number of Gates	0
Total Hinterland Area (ha)	0,1

Total Terminal Area (ha)	0,1
Total Terminal Cost ($)	621.270

Figure 10: summary worksheet

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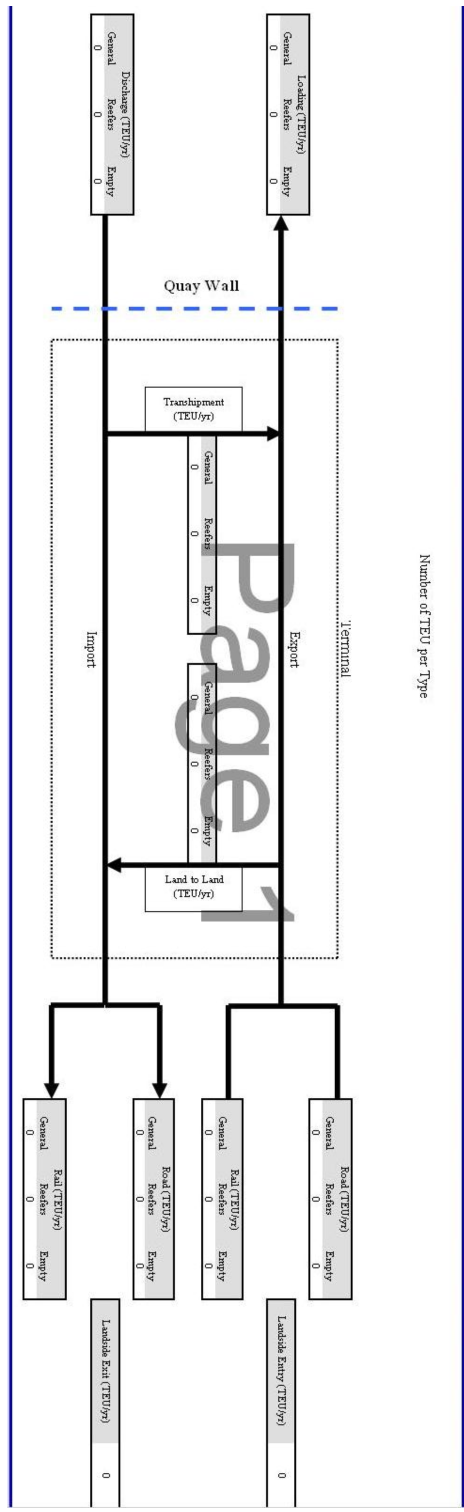

Figure 10: flow diagram

APPENDIX III: THE RESULTS OF THE MODEL

Phase 1, scenario 1

Input Data	Type 1	Type 2	Type 3	Total
Vessel Length (m)	250	134	110	
Vessel Width (m)				
Crane per Vessel	3	2	2	
Discharge (TEU/yr)				180000
General	180000			180000
Reefers				0
Empty				0
Transshipment:				45000
General	45000			45000
Reefers				0
Empty				0
Land to Land (Transit)				0
General				0
Reefers				0
Empty				0
Loading (TEU/yr)				180000
General	22500			22500
Reefers				0
Empty	157500			157500
Transshipment:				45000
General	45000			45000
Reefers				0
Empty				0
Land to Land (Transit)				0
General				0
Reefers				0
Empty				0
Total (TEU/yr)	450000	0	0	450000
Vessel Arrival (No/week)	3	8	12	
Average Parcel Size (TEU)	2885 1500	0 300	0 150	
Transshipment Ratio (%)	20			

Crane Productivity	STS	27,5	STS	27,5	STS	27,5

Working Hours per Day (hr)	24
No.Working Days per Week	7
No.Working Weeks per Year	52
Berth Working Hours per Week (hr/week)	160
Berth Working Hours per Year (hr/Year)	8320
(Un)Mooring Time (hr)	3

Berthing Gap (m)	25
Berth Utilization	75
TEU Factor	1,2
peak factor	1,2
Downtime (%)	5
Spacing between Quay Cranes (m)	100

	Cranes	Factor
Crane Usage Factor	1	1,00
	2	0,90
	3	0,80
	4	0,75
	5	0,70
	6	0,65

Working Hours per Day (hr)	12
No.Working Days per Week	6
No.Working Weeks per Year	52
Landside Working Hours per Week (hr/week)	72
Landside Working Hours per Year (hr/Year)	3744

Dwell Time (days)	Average	General Empties Reefers	Average	7 15

Utilization	Average	Horizental Transpo	60	
		General Empties Reefers	Average	60 50

Stack Length (TEU)	General	25
	Empties	30
	Reefers	

Hinterland Breakdown Flow (%)	Landside Exit	Road	100
		Rail	0
	Landside Entry	Road	100
		Rail	0

Land to Land Throughput (TEU/yr)	General	0
	Reefers	0
	Empties	0

landside Seivice	Number of trucks per hour (depends on the throughput)		80
	Rule of Thumb	Service Time (min)	
	Number of Personnels	200	
	Number of parking Slots	40	

Output Data

	Type 1	Type 2	Type 3	Total
Berth Use (vessel Length+Spacing)	275	159	135	
Crane Effectivity	0,8	0,9	0,9	
(Un)loading Time (hr)	18	5	3	
Total Service Time (hr/vsl)	21	8	6	
Berth Service Time (hr/week)	63	64	72	
Berth Requirement (hr.m/week)	17325	10176	9720	37221
Quay Length (m)	373			
No. Berth	2			
Waiting Time in Units of Service Time	1,057			
Number of Quay Cranes	3			
Quay Productivity (mvs/hr)	46			

Landside Handling Capacity (mvs/hr)		134
No.Horizental Transport Equipment	SC	17
	PTT	15
	AGV	15
	SSC	15

Horizontal EQ. Traffic Lanes Width (m)	SC	10
	PTT	6
	AGV	7
	SSC	10

Apron	STS	Traffic Lane	H.Equipments	Width (m)	Area (m²)
		Outside QC Span	PTT	66	24618

Total Storage Yard Capacity (TEU)	13827

Selection Ladene yard Equipment	RTG	Wide Span	Width(TEU)	Height(TEU)	Selection Empty yard Equipment	Reach Stacker
			7	5		

Number of TEU Ground Slots per Type	General	Empties	Reefers
	2020	2220	0

Laden Stack Configuration		
	Width (TEU)	7
	Height (TEU)	5

Empty Stack Configuration		
	Vidth (TEU)	8
	Height (TEU)	7

Number of Stacks per Type	Genral	Empties	Reefers
	12	10	0

Number of Storage Yard Equipments	RTG	Reach Stacker
	7	2

	General	Reefers	Empties
Stack Width (m)	38,7	42,0	47,1
Stack Length (m)	190,2	32,7	221,7
Stack Height (m)	12,5	12,5	17,5
Stack Orientation to the Quay		Parallel	

	General	Reefers	Empties	Total
Stack Area (m²)	88329	0	104421	192750
Total Stack Area (ha)	19,3			
Yard Density (TEU/m)	0,11			

Hinterland			General	Reefers	Empty	Total per Mode	Total
Throughput (TEU/yr)	Landside Exit	Road	90000	0	0	90000	90000
		Rail	0	0	0	0	
	Landside Entry	Road	0	0	157500	157500	157500
		Rail	0	0	0	0	

Terminal Gate			
	Number of Gates	4	
	Gate Area (m²)	Rigid Vehicles	1722
	Parking Area (m²)	1330	
	Gate Receiption Building Area (m²)	64	
	Total Gate Area (m²)	3116	

Workshop and Stores (m²)	506
Offices (m²)	3000

Total Hinterland Area	(m²)	(ha)	(m²)	(ha)
	6622	0,7		

Total Terminal Area	(m²)	(ha)
	223990	22,47

Shape

Summary

Waterside	
Quay Length (m)	373
Number of Berth	2
Waiting Time in Units of Service	1,057
Nunber of Quay Cranes	3

Landside

Apron Area (m²)	24618			
	General	Empties	Reefers	
Number of TEU Ground Slots per Type	2020	2220	0	
	Genral	Empties	Reefers	
Number of Stacks per Type	12	10	0	
	General	Reefers	Empties	
Stack Area (m²)	88329	0	104421	
Total Stack Area (ha)	19,3			
Number of Storage Yard	7			
No.Horizental Transport	SC	PTT	AGV	SSC
Equipment	17	15	15	15

Hinterland	
Number of Gates	4
Total Hinterland Area (ha)	0,7

Total Terminal Area (ha)	22,47

Total Terminal Cost ($)	125.767.854

Phase 1, scenario 2

Input Data

	Type 1		Type 2		Type 3		Total
Vessel Length (m)	250		134		110		
Vessel Width (m)							
Crane per Vessel	3		2		2		
Discharge (TEU/yr)							180000
General	180000						180000
Reefers							0
Empty							0
Transshipment:							45000
General	45000						45000
Reefers							0
Empty							0
Land to Land (Transit)							0
General							0
Reefers							0
Empty							0
Loading (TEU/yr)							180000
General	22500						22500
Reefers							0
Empty	157500						157500
Transshipment:							45000
General	45000						45000
Reefers							0
Empty							0
Land to Land (Transit)							0
General							0
Reefers							0
Empty							0
Total (TEU/yr)	450000		0		0		450000
Vessel Arrival (No/week)	3		8		12		
Average Parcel Size (TEU)	2885	1500	0	300	0	150	
Transshipment Ratio (%)	20						

Crane Productivity	MHC	15	MHC	15	MHC	15

Working Hours per Day (hr)	24
No.Working Days per Week	7
No.Working Weeks per Year	52
Berth Working Hours per Week (hr/week)	160
Berth Working Hours per Year (hr/Year)	8320
(Un)Mooring Time (hr)	3

Berthing Gap (m)	25
Berth Utilization	60
TEU Factor	1,2
peak factor	1,2
Downtime (%)	5
Spacing between Quay Cranes (m)	100

	Cranes	Factor
Crane Usage Factor	1	1,00
	2	0,90
	3	0,80
	4	0,75
	5	0,70
	6	0,65

Working Hours per Day (hr)	12
No.Working Days per Week	6
No.Working Weeks per Year	52
Landside Working Hours per Week (hr/week)	72
Landside Working Hours per Year (hr/Year)	3744

Utilization	Average	Horizental Transpo		60
		General	Average	60
		Empties		50
		Reefers		

Stack Length (TEU)	General	25
	Empties	30
	Reefers	

Hinterland Breakdown Flow (%)	Landside Exit	Road	100
		Rail	
	Landside Entry	Road	100
		Rail	

Land to Land Throughput (TEU/yr)	General	0
	Reefers	0
	Empties	0

landside Seivice	Number of trucks per hour (depends on the throughput)	80
	Rule of Thumb	Service Time (min)
	Number of Personnels	200
	Number of parking Slots	40

Pa

Output Data

	Type 1	Type 2	Type 3	Total
Berth Use (vessel Length+Spacing)	275	159	135	
Crane Effectivity	0,8	0,9	0,9	
(Un)loading Time (hr)	32	9	5	
Total Service Time (hr/vsl)	35	12	8	
Berth Service Time (hr/week)	105	96	96	
Berth Requirement (hr.m/week)	28875	15264	12960	57099
Quay Length (m)	714			
No. Berth	4			
Waiting Time in Units of Service Time	0,14			
Number of Quay Cranes	7			
Quay Productivity (mvs/hr)	46			

Landside Handling Capacity (mvs/hr)		134
No.Horizental Transport Equipment	SC	39
	PTT	35
	AGV	35
	SSC	35

Horizontal EQ. Traffic Lanes Width (m)	SC	12
	PTT	7
	AGV	8
	SSC	12

Apron	MHC	Traffic Lane	H.Equipments	Width (m)	Area (m²)
			SC	64	45696

Total Storage Yard Capacity (TEU)	12097

Selection Ladene yard Equipment	RTG	Wide Span	Width(TEU)	Height(TEU)	Selection Empty yard Equipment	Reach Stacker
			7	5		

Number of TEU Ground Slots per Type	General	Empties	Reefers
	1443	2220	0

Laden Stack Configuration		
	Width (TEU)	7
	Height (TEU)	5

Empty Stack Configuration		
	Width (TEU)	8
	Height (TEU)	7

Number of Stacks per Type	Genral	Empties	Reefers
	9	10	0

Number of Storage Yard Equipments	RTG	Reach Stacker
	17	3

	General	Reefers	Empties
Stack Width (m)	38,7	42,0	47,1
Stack Length (m)	190,2	32,7	221,7
Stack Height (m)	12,5	12,5	17,5
Stack Orientation to the Quay		Parallel	

	General	Reefers	Empties	Total
Stack Area (m²)	66247	0	104421	170668
Total Stack Area (ha)	17,1			
Yard Density (TEU/m)	0,11			

Hinterland			General	Reefers	Empty	Total per Mode	Total
Throughput (TEU/yr)	Landside Exit	Road	90000	0	0	90000	90000
		Rail	0	0	0	0	
	Landside Entry	Road	0	0	157500	157500	157500
		Rail	0	0	0	0	

Terminal Gate			
	Number of Gates	4	
	Gate Area (m²)	Rigid Vehicles	1722
	Parking Area (m²)	1330	
	Gate Receiption Building Area	64	
	Total Gate Area (m²)	3116	

Workshop and Stores (m²)	506

Offices (m²)	3000

Total Hinterland Area	(m²)	(ha)	(m²)	(ha)
	6622	0,7		

Total Terminal Area	(m²)	(ha)
	222986	22,37

Summary

Waterside	
Quay Length (m)	373
Number of Berth	2
Waiting Time in Units of Service	1,057
Nunber of Quay Cranes	3

Landside

Apron Area (m²)	24618			
	General	Empties	Reefers	
Number of TEU Ground Slots per Type	2020	2220	0	
	Genral	Empties	Reefers	
Number of Stacks per Type	12	10	0	
	General	Reefers	Empties	
Stack Area (m²)	88329	0	104421	
Total Stack Area (ha)	19,3			
Number of Storage Yard	7			
No.Horizental Transport Equipment	SC	PTT	AGV	SSC
	17	15	15	15

Hinterland	
Number of Gates	4
Total Hinterland Area (ha)	0,7

Total Terminal Area (ha)	22,47
Total Terminal Cost ($)	125.767.854

Phase 2, scenario 1

Input Data

	Type 1	Type 2	Type 3	Total
Vessel Length (m)	250	176	134	
Vessel Width (m)				
Crane per Vessel	3	2	2	
Discharge (TEU/yr)				480000
General	480000			480000
Reefers				0
Empty				0
Transshipment:				120000
General	120000			120000
Reefers				0
Empty				0
Land to Land (Transit)				0
General				0
Reefers				0
Empty				0
Loading (TEU/yr)				480000
General	60000			60000
Reefers				0
Empty	420000			420000
Transshipment:				120000
General	120000			120000
Reefers				0
Empty				0
Land to Land (Transit)				0
General				0
Reefers				0
Empty				0
Total (TEU/yr)	1200000	0	0	1200000
Vessel Arrival (No/week)	6	8	12	
Average Parcel Size (TEU)	3847 1700	0 750	0 300	
Transshipment Ratio (%)	20			

Crane Productivity	STS	27,5	STS	27,5	STS	27,5

Working Hours per Day (hr)	24
No.Working Days per Week	7
No.Working Weeks per Year	52
Berth Working Hours per Week (hr/week)	160
Berth Working Hours per Year (hr/Year)	8320
(Un)Mooring Time (hr)	3

Berthing Gap (m)	25
Berth Utilization	70
TEU Factor	1,2
peak factor	1,2
Downtime (%)	5
Spacing between Quay Cranes (m)	100

	Cranes	Factor
Crane Usage Factor	1	1,00
	2	0,90
	3	0,80
	4	0,75
	5	0,70
	6	0,65

Working Hours per Day (hr)	12
No.Working Days per Week	6
No.Working Weeks per Year	52
Landside Working Hours per Week (hr/week)	72
Landside Working Hours per Year (hr/Year)	3744

Dwell Time (days)	Average	General	Average	4
		Empties		15
		Reefers		

Utilization	Average	Horizental Transpo		60
		General	Average	80
		Empties		50
		Reefers		

Stack Length (TEU)	General	25
	Empties	30
	Reefers	

Hinterland Breakdown Flow (%)	Landside Exit	Road	100
		Rail	
	Landside Entry	Road	100
		Rail	

Land to Land Throughput (TEU/yr)	General	0
	Reefers	0
	Empties	0

landside Seivice	Number of trucks per hour (depends on the throughput)	212
	Rule of Thumb	Service Time (min)
	Number of Personnels	350
	Number of parking Slots	40

Output Data

	Type 1	Type 2	Type 3	Total
Berth Use (vessel Length+Spacing)	275	201	159	
Crane Effectivity	0,8	0,9	0,9	
(Un)loading Time (hr)	20	12	5	
Total Service Time (hr/vsl)	23	15	8	
Berth Service Time (hr/week)	138	120	96	
Berth Requirement (hr.m/week)	37950	24120	15264	77334
Quay Length (m)	829			
No. Berth	4			
Waiting Time in Units of Service Time	0,32			
Number of Quay Cranes	8			
Quay Productivity (mvs/hr)	121			

Landside Handling Capacity (mvs/hr)		357
No.Horizental Transport Equipment	SC	44
	PTT	40
	AGV	40
	SSC	40

Horizontal EQ. Traffic Lanes Width (m)	SC	13
	PTT	8
	AGV	9
	SSC	14

Apron	STS	Traffic Lane	H.Equipments	Width (m)	Area (m²)
		Outside QC Span	AGV	69,5	57616

Total Storage Yard Capacity (TEU)	29947

Selection Ladene yard Equipment	RMG	Selection Empty yard Equipment	Reach Stacker

Number of TEU Ground Slots per Type	General	Empties	Reefers
	1924	5919	0

Laden Stack Configuration		
	Width (TEU)	8
	Height (TEU)	6

Empty Stack Configuration		
	Width (TEU)	8
	Height (TEU)	7

Number of Stacks per Type	Genral	Empties	Reefers
	10	25	0

Number of Storage Yard Equipments	RMG	Reach Stacker
	24	4

	General	Reefers	Empties
Stack Width (m)	58,7	62,0	47,1
Stack Length (m)	190,2	32,7	221,7
Stack Height (m)	15,0	15,0	17,5
Stack Orientation to the Quay		Perpendicular	

	General	Reefers	Empties	Total
Stack Area (m²)	111648	0	261052	372700
Total Stack Area (ha)	37,3			
Yard Density (TEU/m)	0,13			

Hinterland			General	Reefers	Empty	Total per Mode	Total
Throughput (TEU/yr)	Landside Exit	Road	240000	0	0	240000	240000
		Rail	0	0	0	0	
	Landside Entry	Road	0	0	420000	420000	420000
		Rail	0	0	0	0	

Terminal Gate			
	Number of Gates	11	
	Gate Area (m²)	Rigid Vehicles	4736
	Parking Area (m²)	1330	
	Gate Receiption Building Area	64	
	Total Gate Area (m²)	6130	

Workshop and Stores (m²)	506
Offices (m²)	5250

Total Hinterland Area	(m²)	(ha)	(m²)	(ha)
	11886	1,2		

Total Terminal Area	(m²)	(ha)
	442201,5	44,27

Shape

Summary

Waterside	
Quay Length (m)	829
Number of Berth	4
Waiting Time in Units of Service	0,32
Nunber of Quay Cranes	8

Landside

Apron Area (m²)	57615,5			
	General	Empties	Reefers	
Number of TEU Ground Slots per Type	1924	5919	0	
	Genral	Empties	Reefers	
Number of Stacks per Type	10	25	0	
	General	Reefers	Empties	
Stack Area (m²)	111648	0	261052	
Total Stack Area (ha)	37,3			
Number of Storage Yard	24			
No.Horizental Transport Equipment	SC	PTT	AGV	SSC
	44	40	40	40

Hinterland	
Number of Gates	11
Total Hinterland Area (ha)	1,2

Total Terminal Area (ha)	44,27

Total Terminal Cost ($)	338.075.828

Phase 2, scenario 2

Input Data

	Type 1		Type 2		Type 3		Total
Vessel Length (m)	250		176		134		
Vessel Width (m)							
Crane per Vessel	3		2		2		
Discharge (TEU/yr)							480000
General	480000						480000
Reefers							0
Empty							0
Transshipment:							120000
General	120000						120000
Reefers							0
Empty							0
Land to Land (Transit)							0
General							0
Reefers							0
Empty							0
Loading (TEU/yr)							480000
General	60000						60000
Reefers							0
Empty	420000						420000
Transshipment:							120000
General	120000						120000
Reefers							0
Empty							0
Land to Land (Transit)							0
General							0
Reefers							0
Empty							0
Total (TEU/yr)	1200000		0		0		1200000
Vessel Arrival (No/week)	6		8		12		
Average Parcel Size (TEU)	3847	1700	0	750	0	300	
Transshipment Ratio (%)	20						

Crane Productivity	MHC	15	MHC	15	MHC	15

Working Hours per Day (hr)	24
No.Working Days per Week	7
No.Working Weeks per Year	52
Berth Working Hours per Week (hr/week)	160
Berth Working Hours per Year (hr/Year)	8320
(Un)Mooring Time (hr)	3

Berthing Gap (m)	25
Berth Utilization	55
TEU Factor	1,2
peak factor	1,2
Downtime (%)	5
Spacing between Quay Cranes (m)	100

	Cranes	Factor
Crane Usage Factor	1	1,00
	2	0,90
	3	0,80
	4	0,75
	5	0,70
	6	0,65

Working Hours per Day (hr)	12
No.Working Days per Week	6
No.Working Weeks per Year	52
Landside Working Hours per Week (hr/week)	72
Landside Working Hours per Year (hr/Year)	3744

Dwell Time (days)	Average	General	Average	2
		Empties		15
		Reefers		

Utilization	Average	Horizental Transpo	60	
		General	Average	80
		Empties		50
		Reefers		

Stack Length (TEU)	General	25
	Empties	30
	Reefers	

Hinterland Breakdown Flow (%)	Landside Exit	Road	100
		Rail	
	Landside Entry	Road	100
		Rail	

Land to Land Throughput (TEU/yr)	General	0
	Reefers	0
	Empties	0

landside Seivice	Number of trucks per hour (depends on the throughput)	212
	Rule of Thumb	Service Time (min)
	Number of Personnels	350
	Number of parking Slots	40

Output Data

	Type 1	Type 2	Type 3	Total
Berth Use (vessel Length+Spacing)	275	201	159	
Crane Effectivity	0,8	0,9	0,9	
(Un)loading Time (hr)	37	22	9	
Total Service Time (hr/vsl)	40	25	12	
Berth Service Time (hr/week)	240	200	144	
Berth Requirement (hr.m/week)	66000	40200	22896	129096
Quay Length (m)	1761			
No. Berth	8			
Waiting Time in Units of Service Time	0,021			
Number of Quay Cranes	17			
Quay Productivity (mvs/hr)	121			

Landside Handling Capacity (mvs/hr)		357
No.Horizental Transport Equipment	SC	94
	PTT	85
	AGV	85
	SSC	85

Horizontal EQ. Traffic Lanes Width (m)	SC	14
	PTT	9
	AGV	10
	SSC	15

Apron	MHC	Traffic Lane	H.Equipments	Width (m)	Area (m²)
			PTT	53	93333

Total Storage Yard Capacity (TEU)	25331

Selection Ladene yard Equipment	RTG	Wide Span	Width(TEU)	Height(TEU)	Selection Empty yard Equipment	Reach Stacker
			7	5		

Number of TEU Ground Slots per Type	General	Empties	Reefers
	1155	5919	0

Laden Stack Configuration		
	Width (TEU)	7
	Height (TEU)	5

Empty Stack Configuration		
	Width (TEU)	8
	Height (TEU)	7

Number of Stacks per Type	Genral	Empties	Reefers
	7	25	0

Number of Storage Yard Equipments	RTG	Reach Stacker
	40	7

	General	Reefers	Empties
Stack Width (m)	38,7	42,0	47,1
Stack Length (m)	190,2	32,7	221,7
Stack Height (m)	12,5	12,5	17,5
Stack Orientation to the Quay		Parallel	

	General	Reefers	Empties	Total
Stack Area (m²)	51526	0	261052	312578
Total Stack Area (ha)	31,3			
Yard Density (TEU/m)	0,12			

Hinterland			General	Reefers	Empty	Total per Mode	Total
Throughput (TEU/yr)	Landside Exit	Road	240000	0	0	240000	240000
		Rail	0	0	0	0	
	Landside Entry	Road	0	0	420000	420000	420000
		Rail	0	0	0	0	

Terminal Gate			
	Number of Gates	11	
	Gate Area (m²)	Rigid Vehicles	4736
	Parking Area (m²)	1330	
	Gate Receiption Building Area	64	
	Total Gate Area (m²)	6130	

Workshop and Stores (m²)	506

Offices (m²)	5250

Total Hinterland Area	(m²)	(ha)	(m²)	(ha)
	11886	1,2		

Total Terminal Area	(m²)	(ha)
	417797	41,84

Summary

Waterside	
Quay Length (m)	1761
Number of Berth	8
Waiting Time in Units of Service	0,021
Nunber of Quay Cranes	17

Landside

Apron Area (m²)	93333			
	General	Empties	Reefers	
Number of TEU Ground Slots per Type	1155	5919	0	
	Genral	Empties	Reefers	
Number of Stacks per Type	7	25	0	
	General	Reefers	Empties	
Stack Area (m²)	51526	0	261052	
Total Stack Area (ha)	31,3			
Number of Storage Yard	40			
No.Horizental Transport	SC	PTT	AGV	SSC
Equipment	94	85	85	85

Hinterland	
Number of Gates	11
Total Hinterland Area (ha)	1,2

Total Terminal Area (ha)	41,84

Total Terminal Cost ($)	461.525.257

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