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# Simulation analysis of container terminal capacity at multi-terminal Indonesia(MIT)

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**WORLD MARITIME UNIVERSITY**

Shanghai, China

# SIMULATION AND ANALYSIS OF CONTAINER TERMINAL CAPACITY AT MULTI TERMINAL INDONESIA (MTI)

By

**CHANDRA IRAWAN**

**Indonesia**

A research paper submitted to the World Maritime University in partial fulfillment of the requirements for the award of the degree of

**MASTER OF SCIENCE**

**INTERNATIONAL TRANSPORT AND LOGISTICS**

**2013**

# DECLARATION

I certify that all the material in this research paper that is not my own work has been identified, and that no material is included for which a degree has previously been conferred on me.

The contents of this dissertation reflect my own personal views, and are not necessarily endorsed by the University.

…………………….
Chandra Irawan

…………………….

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Last but not least, lovely thanks to my lovely wife, my sons and my parents for their affection and continued support during my precious time of postgraduate study.

The author realizes that this paper is far from perfect. Criticism and suggestions for improvements to the paper is expected. Hopefully this paper can provide benefits.

# ABSTRACT

| | |
|---|---|
| Title of Dissertation | : **Simulation and Analysis of Container Terminal Capacity at Multi Terminal Indonesia (MTI)** |
| Degree | : **Master of Science in International Transport and Logistics** |

Within the development of seaport transportation system, note that the ability of a port plays an important role as a part of integrated global supply chain. As an indivisible share of a port, container terminal has a potential strategic value in the global liner shipping networks as well as a major aspect of the competitiveness of the port.

The main objective of this research is to investigate the proper capacity of the container terminal and to suggest the appropriate development in the near future in order to give a high level of service to customers. For this objective, computerized simulation model is develop to identify proper berth capacity and verified with actual data of terminal operation records as well as traditional method to identify proper yard are also develop.

Additionally, to find out the shortage or surplus capacity of the terminal, a forecasting method is conducted to determine future demand of container throughput within the terminal.

The concluding chapters examine the results of the proper container terminal capacity, and discuss the potential development of terminal due to shortage capacity. Recommendations are made in regard to management of terminal concerning the results of the study as well as the need for further investigation in the subject.

**KEYWORDS**: proper container terminal capacity, simulation model, traditional method, berth capacity, yard capacity, forecasting method, shortage capacity.

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| | |
|---|---|
| ARMA | Auto-Regressive Moving Average |
| BOR | Berth Occupancy Ratio |
| CY | Container Yard |
| CTOS | Container Terminal Operation System |
| CFS | Container Freight Station |
| DEA | Data Envelopment Analysis |
| GDP | Gross Domestic Product |
| GDRP | Gross Domestic Regional Product |
| GT | Gross Tonnage |
| GC | Gantry Crane |
| HT | Head Truck and Chassis |
| ISPS Code | International Ship and Port Facility Security Code |
| LOA | Length Overall |
| LPC | Lift per Call |
| MTI | Multi Terminal Indonesia |
| MAD | Mean Absolute Deviation |
| MSE | Mean Square Error |
| ODCY | Off Dock Container Yard |
| PCTC | Proper Container Terminal Capacity |
| QC | Quay Crane |
| QCSP | Quay Crane Scheduling Problem |
| RMG | Rail Mounted Gantry |
| RTG | Rubber Tire Gantry |
| SMS | Short Message Service |
| THC | Terminal Handling Charge |
| YC | Yard Crane |

# Chapter 1

# INTRODUCTION

## 1.1. Background

Within the international trade most goods carried by sea, this is because the freight by sea are less costly and greater carrying capacity compared to other modes of transport. During this time, seaport is more popular as the node distribution of goods to support the transports, industries and trades. Recently, development in trade has driven the rapid growth of throughput in various ports. Port as the node distribution of goods in the economy has the potential strategic value to be more developed. Accessibility of container port is a potential as well as an opportunities in the containers transportation within the global liner shipping networks. It is also a major aspect of the competitiveness of the port.

Compared with traditional port operations, containerization has greatly improved port production performance because of two reasons. To reap economies of scale and of scope, liner shipping companies and container ports are respectively willing to deploy dedicated container ships and efficient container handling systems (Cullinane, Song and Wang, 2005).

World container traffic has steadily risen over the past few years and it forecasted to remain grow in the next future as shown in figure 1.1. The growth will affected the container terminals activities, the terminals should consider to increase their capacity in term of facilities, equipments, technology as well as terminal policy in order to be competitive. The container ship are increasing steadily in term of carrying capacity, carriers has been focusing on bigger ships to achieve the economies of scale and lower cost which could be seen in figure 1.2.

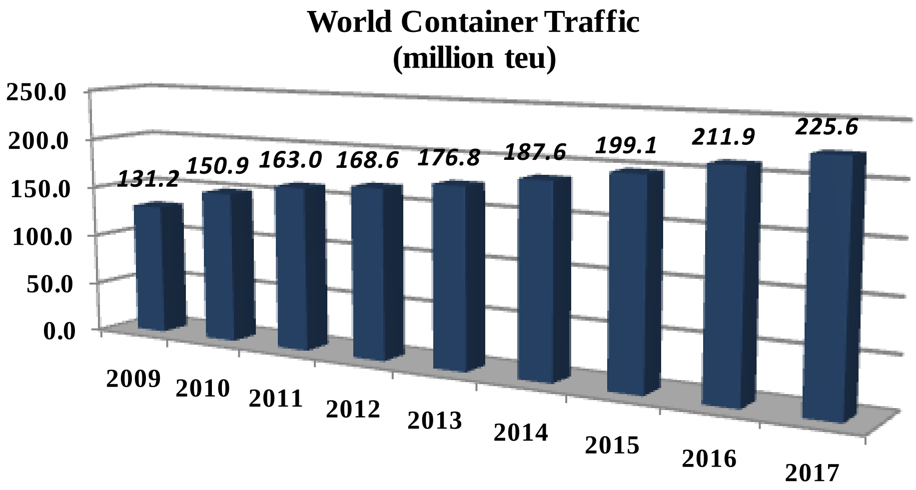


Figure 1.1 - Forecast Development of World Container Traffic

Source: Drewry Shipping Consultant, *Container Market Review and Forecaster Quarter 3* (2012)

Figure 1.2 - Containership Fleet Development

Source: Drewry Shipping Consultant, *Container Market Review and Forecaster Quarter 3* (2012)

This paper will discuss the proper capacity of the container terminal in regard to improve operation process with high level of service to customers.

## 1.2. Research Problem

The container terminals objective is to provide a good service to customers with a sufficient terminal capacity as well as terminal operations efficiency where loading and discharging containers could be done in minimum time. The service is limited by the container terminal capacity such as number of the berths, length of the quay, number and type of container handling equipments as well as the capacity of the container yard. The management of the terminal should provide a sufficient number of facilities and equipments with a sufficient utilization in order to achieve appropriate capacity within container terminal. From the terminal point a view, the main objective is to optimize the utilization of their facilities. However, from the customers point a view the high utilization means high of waiting time for them to get the service consequently lowering its service level.

## 1.3. Research Objectives

The purpose of this paper is to investigate the proper capacity of the container terminal and to suggest the appropriate development in order to give a high level of service to customers.

## 1.4. Problem Limitation

There are several limitations occurred in conducting this research. Firstly, the object of the research is container terminal of Multi Terminal Indonesia (MTI) located in Jakarta. Secondly, within the study the scope of container handling activities are quay side operations and yard operations without includes the gate operation. Thirdly, the simulation is only use to calculate proper berth capacity, while proper yard capacity will be calculated by traditional method. Finally, the data used to calculate proper capacity of berth and yard are base on the data in year 2012 which collected from MTI, furthermore, data for forecasting ocean going container are base on data in year 2002 to 2012 which collected from MTI and Indonesia Statistical Centre Bureau of Jakarta, while for forecasting inter-island container are based on data in year 2011 to 2012 due to the inter-island service started from the end of year 2010.

## 1.5. Thesis Structure

The thesis will be organized as follows:

Chapter 1 INTRODUCTION

Start with an overview of the study. This chapter explains the background of the research, problem formulation and limitation as well as the objective of the research.

Chapter 2 LITERATURE REVIEW & CONCEPTUAL FRAMEWORK

This chapter discusses some literatures and findings related to the topic research. A conceptual framework will be developed in accordance with the literatures. Furthermore, it will explain the methodology used within this research.

Chapter 3 DATA COLLECTION

Data required is the most important item in this study. The chapter starts with data collected from the terminal, BPS-Statistics of DKI Jakarta province and other sources, it presents from general and specific data which will be required for the research.

Chapter 4 CONTAINER THROUGHPUT FORECAST

The demand of container throughput for the next five years will be calculated with different forecasting techniques by comparing the mean square error (MSE) value. This chapter presents the method used for forecasting the container throughput at the terminal including the variables.

Chapter 5 SIMULATION MODEL AND ANALYSIS

The simulation and analysis play a central part of the study. The chapter presents the method use for simulation of the Proper Container Terminal Capacity (PCTC) at the terminal as well as the analysis of the data collected.

Chapter 6 CONCLUSION AND RECOMMENDATION

Finally, conclusions and recommendations based on the analysis of the research will be presented.

# Chapter 2

# LITERATURE REVIEW & CONCEPTUAL FRAMEWORK

This chapter will present some academic literatures related to the research of container terminal operation and performance. The variables and methods form literatures will be used to calculate as well as to support the decision making within this study.

## 2.1. Container Terminal Operations

The principles of operation in container terminals are similar even though considerably differ in size and geometric layout. Berthing area for ship operation equipped with ship to shore gantry cranes for loading and unloading. Container yard for stacking containers usually divided into a number of blocks for import and export. There are also areas for empty containers as well as special container like reefer containers, which supply with electrical for temperature control or to stack hazardous goods. Hinterland operation for truck and train operation area links the terminal to outside transportation systems. Ircha (2012) considered the gate complex, workshop, control tower, administrative offices and other service facilities must then be located so that good flow patterns are established and to allow efficient and reliable control procedures. Aisle ways and roadways of suitable widths are set out to allow the free and uninterrupted movement of equipment and vehicles. Non-essential facilities, such as a container freight station (CFS), should be located away from the terminal itself, and maintenance workshops should not be located within the operational area. Figure 2.1 shows the typical of operations within the container terminal and figure 2.2 provides a graphical representation of the typical container terminal system.

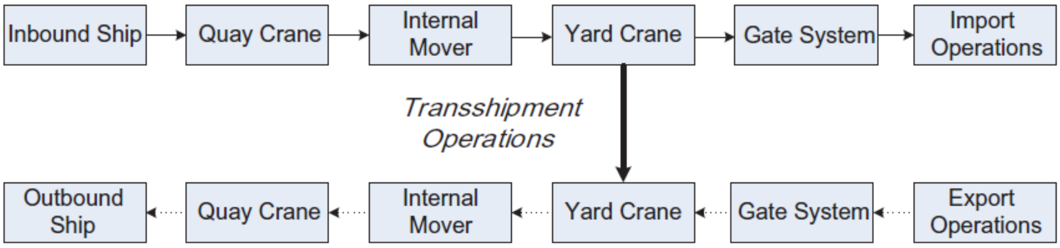


Figure 2.1 - Typical Operations in a Maritime Terminal.

Source: Song, Cherrett and Guan (2012).

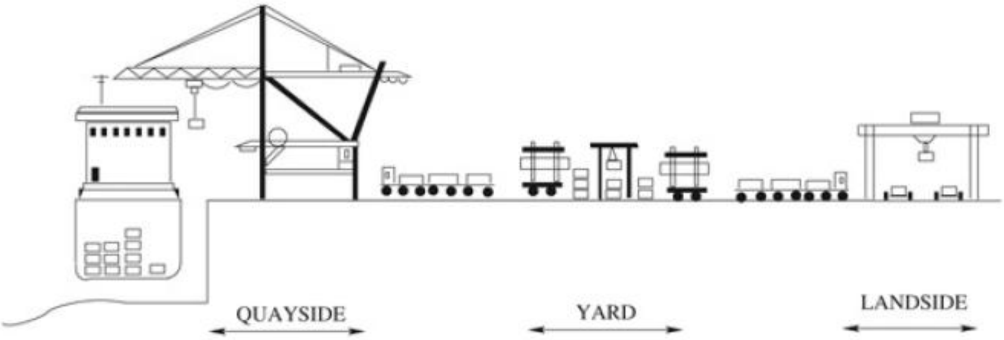


Figure 2.2 - A Typical Container Terminal System.

Source: Monaco, Moccia and Sammarra (2009) in Munisamy and Singh (2011).

Murty et al (2005) mentioned that the functions of a container terminal, a container terminal serves as an interface between ocean and land transportation. Its main functions are to receive outbound containers from shippers for loading onto vessels and to unload inbound containers from vessels for picking up by consignees; and temporary storage of containers between ocean passage and land transportation. Figure 2.3 shows important relations of the strategic planning and the operations planning at the seaside area, the yard, and the landside area.

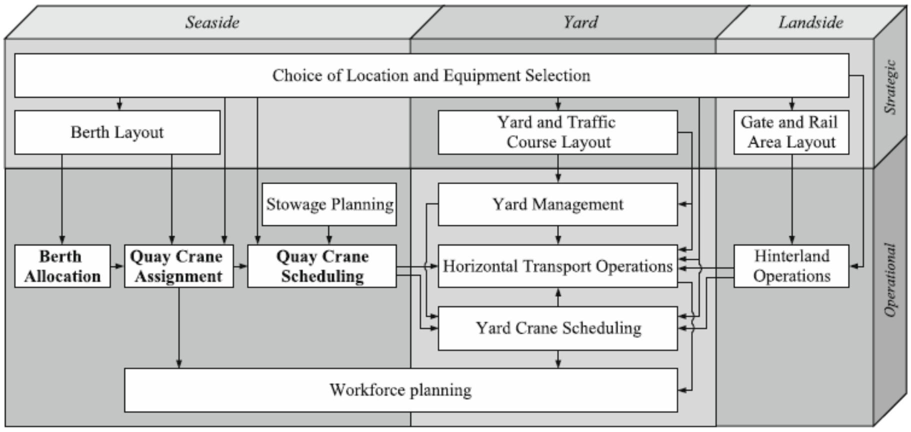


Figure 2.3 - Planning Problems in Container Terminals.

Source: Bierwirth and Meisel (2010).

Munisamy and Singh (2011) studied a benchmarking analysis based on the non-parametric Data Envelopment Analysis (DEA) technique to evaluate the operating efficiency and generate efficiency ranking of 69 major Asian container ports, while Hung, Lu and Wang (2010) has explored the operating efficiency, the scale efficiency targets, and the variability of DEA efficiency estimates of Asian container ports. Wu and Goh (2010) conducted the study of container port efficiency in emerging and more advanced markets Using the DEA-CCR, DEA-BCC, and A&P models to measure the efficiency of ports in developing countries. Imai, Nishimura and Papadimitriou (2013) conducted the research of Marine container terminal configurations for efficient handling of mega-containerships. The other literature regarding the aspect of container terminals competition and efficiency can be found e.g., in Cullinane et al. (2006); Flitsch (2012); Kaselimi et al. (2011); Lam and Yap (2006); Liu (2010); Yeo, Roe and Dinwoodie (2008, 2011).

The terminal management should consider their performance in an objective way. Contu, Febbraro and Sacco (2011) used a model for the performance evaluation of container terminals by describing the import cycles of the terminal. Henesey (2004) argued that modeling and simulating decision making processes, based upon agents, can provide alternative solutions to improving container terminal performance. Lun et al. (2011) found that a direct relationship between firm performance and business risk-taking does not exist. Hence, the “return and risk” argument concerning investment decisions does not apply in the container terminal industry. Sharma and Yu (2009) used DEA as a multi-factor productivity measurement model to measure the efficiency and set benchmarks for the inefficient terminals to improve efficiency. Irawan (2009) study the effect of use of technology for data sharing, relationship with shipping lines and value added service on port/terminal performance with service quality as mediating variable.

### 2.1.1. Quay Side Operations

On the quayside, containers are transported between ship and shore and container quay cranes mobile cranes and ship shore gantries are the main equipments used for ship loading and unloading (Munisamy and Singh 2011). The berth operation concerns the arrival pattern of the vessels and the allocation of berth and quay crane availability to service the vessels. The relationship between berth and quay can be seen in figure 2.4. The key concern of the berthing operation is the total port time or turn-around time of vessels. The ship operation consist of the unloading and loading containers onboard the vessel and it handled by quay cranes. According to Bierwirth and Meisel (2010) tasks to be scheduled on a quay crane (QC) describe the granularity in which the workload of a vessel is considered in a quay crane scheduling problem (QCSP) model. Tasks can be defined on the basis of bay areas or single bays (Figure 2.5a), or on the basis of container stacks, container groups, or individual containers (Figure 2.5b). In Figure 2.6, a ship berthing process contains several periods, whereas the turnaround time of ships experiences all periods (Chang et al., 2010).

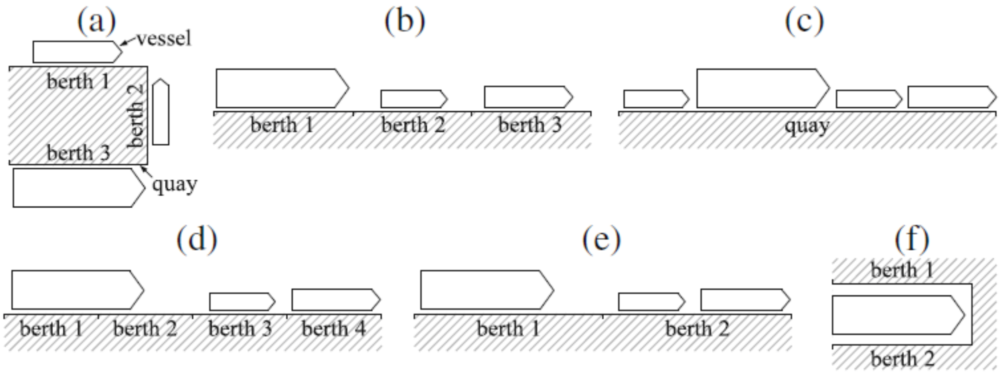


Figure 2.4 - Berth and Quay Relationship

Source: Bierwirth and Meisel (2010).

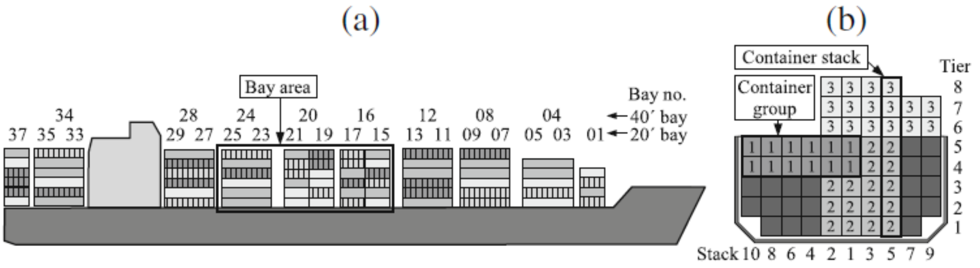


Figure 2.5 - Storage Location Structure of a Vessel (a) and a Cross-Sectional View of a Bay (b).

Source: Bierwirth and Meisel (2010).

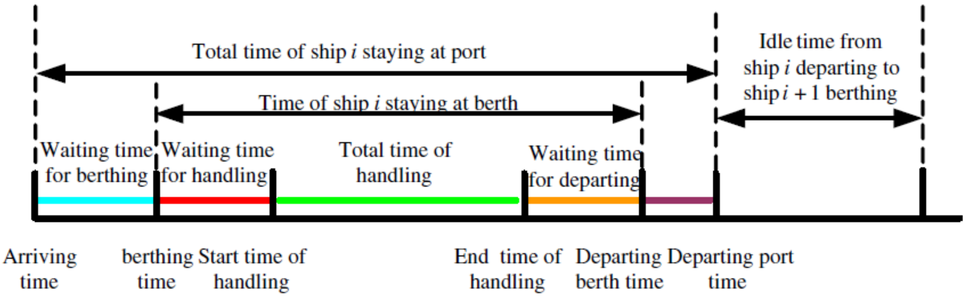


Figure 2.6 - Periods of Ship Berthing Process.

Source: Chang et al. (2010).

Some 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 (Mohseni, 2011):

$$\text{Total service time (hour/vessel)} = \text{(Un)loading time} + \text{(Un)mooring time} \tag{2.1}$$

The following formula can be used to determine the (Un)loading time (Thorsen, 2010 in Mohseni, 2011):

$$\text{(Un)loading time} = \frac{\mathrm{S_p}}{\mathrm{N_c} \times Q_{cr} \times W_{ct}} \tag{2.2}$$

Where:

$\mathrm{S_p}$ : Parcel Size (TEU)

$\mathrm{N_c}$ : 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

Bierwirth and Meisel (2010) stated that one issue of seaside operations planning is the assignment of quay space and service time to vessels that have to be unloaded and loaded at a terminal. This problem is commonly referred to as the berth allocation problem (BAP). Some literatures on the berth allocation and quay crane assignment in container terminal can be found e.g., in Ak (2008); Arango et al.(2011); Giallombardo et al. (2010); Gkolias (2007); Imai et al. (2005, 2007, 2008); Imai, Nishimura and Papadimitriou (2003); Legato, Trunfio and Meisel (2012); Liang, Huang and Yang (2009); Meisel and Bierwirth (2011); Tavakkoli-Moghaddam et al. (2009); Yang, Wang and Li (2012); Zhihong and Na (2011).

### 2.1.2. Yard Operations

On the yard side, containers are transferred to land transport modes or are arranged to be loaded on to other ships. There are two types of activities which occur in the yard area: stacking of container and horizontal transport (Munisamy and Singh 2011). The yard operation involves transfer containers from quay cranes to the container yard and vice versa, temporary storage of containers, transfer containers to other blocks within the terminal. Murty et al (2005) explained that the storage yard in a terminal is usually divided into rectangular regions called storage blocks or blocks. A typical block has seven rows (or lanes) of spaces, six of which are used for storing containers in stacks or columns, and the seventh reserved for truck passing. Each row typically consists of over twenty 20-ft container stacks stored lengthwise end to end. For storing a 40-ft container stack, two 20-ft stack spaces are used.

In the container terminal, the yard area, as a large component of it, provides many functions within the system. These functions include the container unloading/loading operations for storage, transshipment operations, or turnaround. Hence, any type of container flow will be served in the yard (Zhao, 2011) as shown in figure 2.7. Figure 2.8 shows a typical partial container yard layout of a container terminal: the yard is divided into multiple blocks called yard blocks; each yard block consists of a contiguous stretch of slots (40–60 slots); and each slot has several rows (6–8 rows). Each ground slot, denoted as a rectangle in the diagram, can store 5–7 containers. In most container terminals, zones are normally formed by grouping adjacent yard blocks together so as to simplify the control of yard crane movements and to reduce the amount of time in which the yard cranes occupy truck travelling lanes (Ng and Mak, 2005).

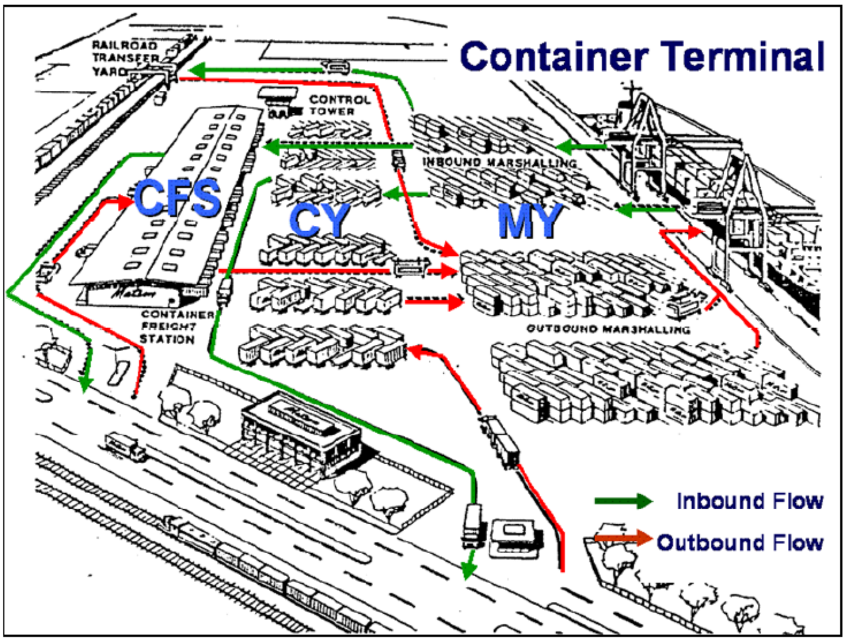


Figure 2.7 - A Typical Yard Allocation.

Source: Ting in Zhao (2011).

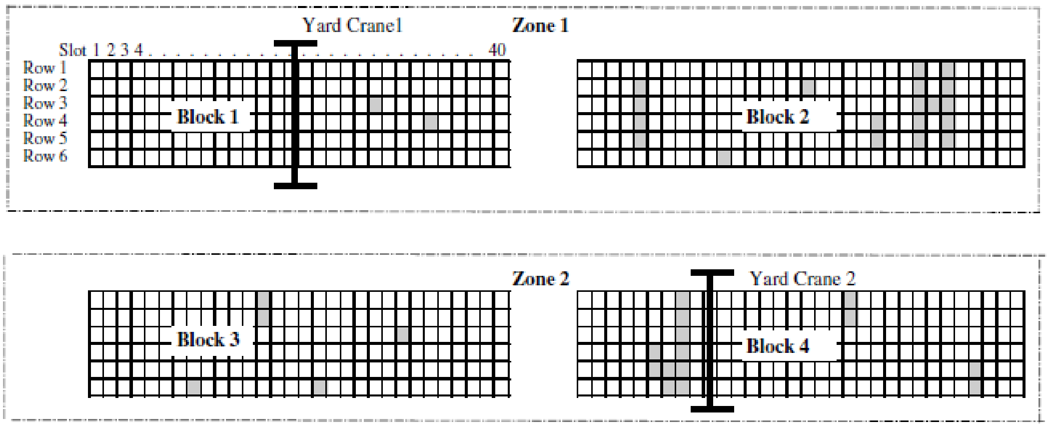


Figure 2.8 - Typical Container Yard Layout of a Container Terminal.

Source: Ng and Mak (2005).

A complex system of container terminals represents the dynamic interactions between the various handling, transportation, and storage units. Yard allocation planning is a daily operational problem, good planning in yard operation will cause a shorten port stay of vessels due to the time for finding the location of containers will reduce. A good selection of a type as well as optimal number of equipments needed within the yard. Lee et al. (2009) stated that yard truck scheduling and storage allocation problems are well-known intractable problems in container terminal operation. Zhao and Goodchild (2010) mentioned that each block within the container yard consists of many parallel bays; each bay is composed of several stacks; and each stack stores several containers. The truck lane occupies the space beside the block and serves as the truck transfer area as shown in figure 2.9.

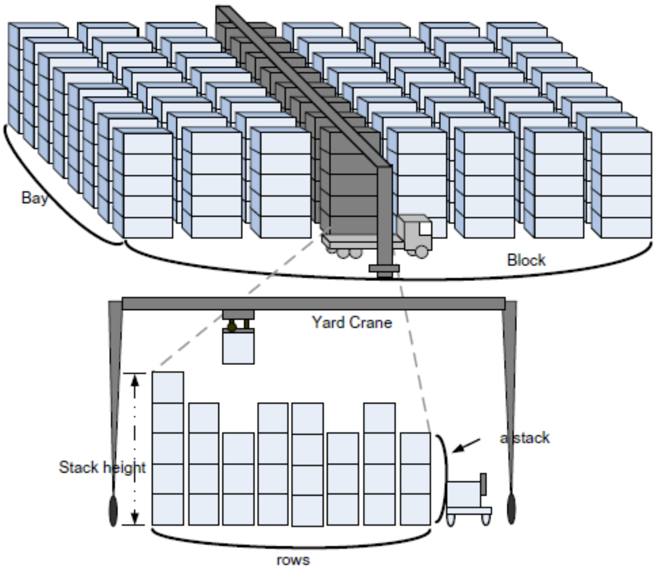


Figure 2.9 - Container Block, Bay Configuration and Yard Crane Positioning.

Source: Zhao and Goodchild (2010).

Many studies have been conducted to investigate the container yard. Zeng and Hsu (2008) presented a mathematical model for container routing in the mesh yard layout. Petering (2009) investigated how the width of the storage blocks in a terminal's container yard affects the overall, long-run performance of a seaport container terminal as measured in terms of GCR (average quay crane work rate). The concept of reservation space was introduced by Woo and Kim (2011) which is being used in practice, for locating the containers of the same group close to each other. This strategy of space allocation is for speeding up the loading operation for outbound containers. Saurí and Martín (2011) analyzed the performance of different storage strategies aiming to reduce the number of unproductive moves in the import container storage area.

### 2.1.3. Receipt and Delivery Operations

The receipt/delivery operation performs the interface function between sea and land transport. The land transport is divided into two modes: rail and truck. Rail loading and unloading operations are similar to the quayside vessel operations. Intra-terminal vehicles are move alongside rail tracks. Top loaders/reach stackers, or RTG, or RMG will undertake load and unload operation. On the other hand, receipt/delivery operation for trucks is different. Trucks arriving at the gate have to undertake documentation processing and equipment inspection. Therefore, inbound trucks in most cases form a queue at the gate complex entrance waiting to be processed. Then instructions are given to pickup or deliver containers in the yard (Guan, 2009). The landside or gate operation deals with external customers. There are two activities within this side, receipt for import containers and delivery for export containers to be loaded onboard. With so many trucks operating, the roads in the terminal may get congested. Congestion slows the trucks from carrying out their operation of transporting containers from one location to another. This has an undesirable effect on truck utilization and, more importantly, on the time taken to process the vessels. Hence, another important measure of performance is congestion on the roads in the terminal, which must be minimized (Murty et al, 2005). Kiani, Sarayeh and Nooramin (2010) found that flatten the gate activity to an efficient level so as to reduce the trucks' queuing time.

Currently, terminals have limited knowledge of the truck arrival sequence. Figure 2.10 provides an example of available truck information if a truck appointment system is utilized, and appointments are met. Trucks 1 and 2 will arrive within time window A, prior to trucks 3, 4, and 5 which will arrive within time window B, but the exact order of truck arrivals within time window A or B is unknown. This illustrates that truck information could be available in terms of truck groups. If much narrower appointment time windows are adopted, or the terminal tracks the real-time location of each truck and can estimate arrival times, a more complete truck arrival sequence will become available (Zhao and Goodchild, 2010).

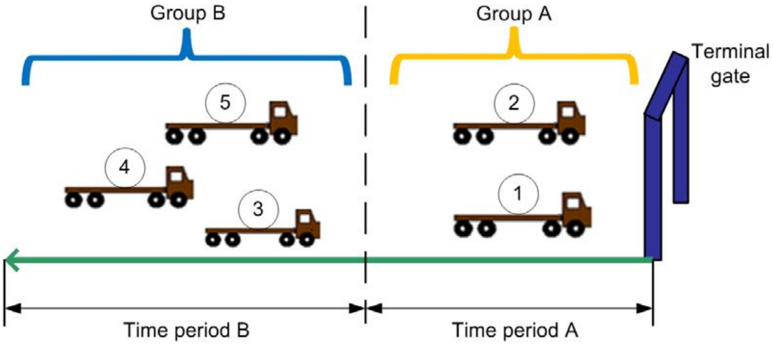


Figure 2.10 - An illustration of Truck Information Availability at Terminals with a Truck Appointment System.

Source: Zhao and Goodchild (2010).

To provided evidences that there is a relationship between truck traffic at the gates and the apron container's volume at a marine container terminal, Moini (2010) established the connection by developing two approaches: analytical and simulation techniques. Chen, Govindan and Yang (2013) addressed the effects of the time window control program on truck arrivals and the truck queuing behavior at gate, and try to develop it as a method to alleviate the gate congestion in container terminals.

## 2.2. Container Terminal Capacity

To meet growing demand, ports need to enhance capacity. Pure physical expansion is constrained by a limited supply of available land, especially for urban center ports, and escalating environmental concerns. In this context, expanding port capacity by improving the productivity of terminal facilities appears to be the only viable solution. How to improve productivity sufficiently to accommodate a large portion of the anticipated increase in container traffic, however, presents a particular challenge to terminal operators and port authorities (Le-Griffin and Murphy, 2006). Yeo (2010) analyzed factors affecting the competitiveness of Asian container terminals by including quantitative as well as qualitative factors such as operating capacity, convenient facilities, electronic documents handling capacity and connectivity to hinterland, He found that the container terminal's facilities are positively associated with the port performance.

Lee and Kim (2010) proposed four optimization models to determine the block size at a container terminal, according to the following objective functions and constraints: minimizing the weighted expected YC cycle time for various operations subject to the minimum block storage capacity provided, maximizing the storage capacity subject to the maximum expected cycle time of a YC, minimizing the weighted expected truck waiting time for various operations subject to the minimum block storage capacity provided, and maximizing the storage capacity subject to the maximum expected truck waiting time.

Petering (2011) argue that the issue of yard capacity presents a trade-off between congestion and traveling distance. In terms of congestion, a larger storage yard is better because the same amount of cargo is spread out over a larger area, reducing the likelihood of yard crane and yard truck working in close proximity.

According to Moon (2012) the definition of Proper Container Terminal Capacity (PCTC) is handling capacity to cope with incoming cargoes with no congestion which leads to the port with competitive edge. The characteristics of each terminal such as ship's arrival and service time distribution and crane allocation should be included in the calculation of a proper throughput. Generally well-known PCTC calculation method by UNCTAD: berth throughput capacity and yard capacity. PCTC is calculated by comparing berth capacity with yard capacity, i.e. whichever is lower is considered as PCTC (figure 2.11).

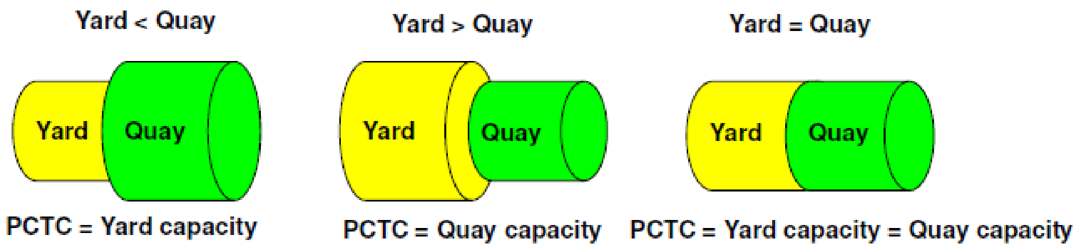


Figure 2.11 - Proper Container Throughput Capacity (PCTC).

Source: Moon (2012).

There are two ways in order to calculating a proper throughput of the terminal, traditional method and simulation method. The traditional method for calculating proper berth throughput could use the formulas (Moon, 2012).

Berth throughput = Number of crane x Work hours per year x Work hour ratio of crane x Work efficiency of crane x Unit conversion factor x Overstow factor (2.3)

In which:

Work hours per year = work days a year x work hours a day

Crane work hour ratio = berth occupancy x ship transfer ratio x crane operation ratio

Crane work efficiency = crane design capacity x crane work loss adj. factor x interference factor

Unit conversion factor = 1.6 (VAN/TEU ratio)

Dally (1983) which cited in Moon (2012) propose equation to calculate the proper throughput capacity of a container yard as follow:

$$Cc = (Tgs \times H \times U \times K) / (DT \times PF) \tag{2.4}$$

Where Cc denotes container yard throughput (per annum); Tgs denotes total ground slot; H denotes average stacking height; U denotes ratio of land utilization; DT denotes dwell time of containers; PF denotes peak factor; K denotes operating days of yard.

In another literature, to calculate storage yard capacity of a container terminal Merckx (2005) propose mathematical framework as follows:

$$\begin{aligned}&\text{Storage Yard Capacity}_{\text{Total}}\ (\text{TEU})\\&\quad = \text{Store}_{\text{Full}} + \text{Store}_{\text{Empty}} + \text{Store}_{\text{Reefer}} + \text{Store}_{\text{Hazardous}}\end{aligned} \tag{2.5}$$

For each yard (FCL & LCL, empty, reefer and hazardous goods):

$$\text{Storage Capacity (TEU)} = \text{Number of ground slots (TGS)} \times \text{Stacking Height (TEU/TGS)} \tag{2.6}$$

Whereby:

$$\text{Number of ground slots (TGS)} = \text{Slot Density (TGS/ha)} \times \text{Yard Area (ha)} \tag{2.7}$$

Resulting in:

$$\begin{aligned}&\text{Storage Capacity(TEU)}\\&\quad = \text{SlotDensity(TGS/ha)} \times \text{YardArea(ha)}\\&\quad \times \text{StackingHeight(TEU/TGS}*)\end{aligned} \tag{2.8}$$

$$\begin{aligned}&\text{Storage Yard Capacity}\left(\frac{\text{TEU}}{\text{pa}}\right)\\&\quad = \text{Storage Capacity(TEU)} \times \frac{\text{365days/pa}}{\text{MeanDwellTime(days)} \times \text{Peakingfactor}}\end{aligned} \tag{2.9}$$

Chen and Chen (2010) used Hoffman (1985) formula to built up a forecast container yard area model with TEU area, average container dwelling time and a safety factor. The formula is showed as following:

$$\text{CY} = [(C \times A \times T)/(360 \times R)] \times (1 + F) \tag{2.10}$$

Where CY denotes requirement of container yard; $C$ denotes annual containers handled, TEUs/year; $A$ denotes average area per TEU, m2/TEU; $T$ denotes average container dwell time in the container yard, in days; $R$ denotes lane and aisle area utility rate; R = 85% in most cases; $F$ denotes safety factor, %.

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 equation 2.1 (Ligteringen, 2007 which cited by Mohseni, 2011).

$$f = \frac{N_{20} + 2N_{40}}{N_{tot}} \tag{2.11}$$

In which:

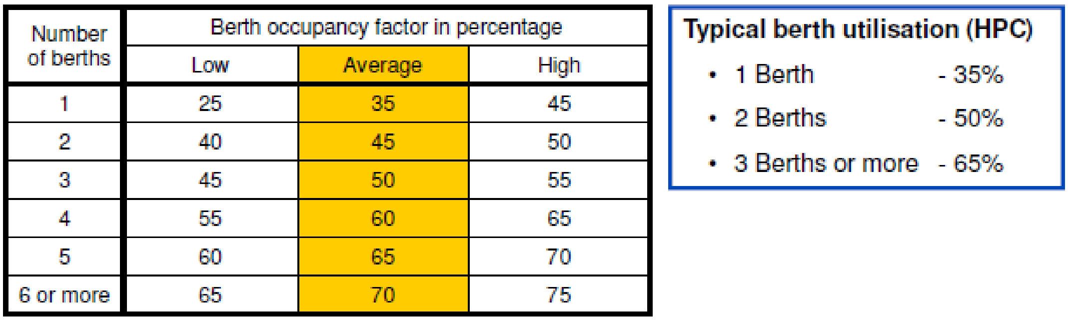
20 $N$ = number of twenty foot equivalent units (TEU`s)

40 $N$ = number of forty foot equivalent units (FEU`s)

*tot* $N$ = sum of containers

Moon (2012) proposed the average berth occupancy ratio (BOR) in major European ports according to Dragovic (2005) and Hamburg Port Consultant (HPC) as shown in table 2.1.

Table 2.1 - Average BOR in Major European Ports



| Number of berths | Berth occupancy factor in percentage | | |
|---|---|---|---|
| | Low | Average | High |
| 1 | 25 | 35 | 45 |
| 2 | 40 | 45 | 50 |
| 3 | 45 | 50 | 55 |
| 4 | 55 | 60 | 65 |
| 5 | 60 | 65 | 70 |
| 6 or more | 65 | 70 | 75 |

**Typical berth utilisation (HPC)**

| | |
|---|---|
| • 1 Berth | - 35% |
| • 2 Berths | - 50% |
| • 3 Berths or more | - 65% |

Source: Moon (2012).

## 2.3. Forecasting Techniques

To design a new container terminal as well as develop an existing terminal start with forecast the container flow. A traffic forecast is an attempt to predict the level of future traffic in a rational and scientifically founded manner, with a view to anticipate optimally during the planning stage of the investment projects, the needs for the potential infrastructure (Dufour, Steane and Wong, 2009).

All forecast analyses should satisfy three simple criteria: they should be relevant to the decision for which they are required; they should be rational in the sense that the conclusion should be based upon a consistent line of argument; and they should be based upon research at a significant level of detail (Stopford, 2009).

Stopford (2009) describes the four most popular forecasting techniques as follows:

1) *Opinion surveys* ask people ‘in the know’ what they expect to happen. Lots of shipping people do this informally, but there are structured methodologies such as the Delphi technique or opinion surveys. This technique is particularly useful for picking up emerging trends that are obvious to specialists but are not apparent from past data. The approach can be formal, using a panel, or informal.
    a) Delphi technique is discussion session in which group of experts make a consensus forecast.
    b) Opinion surveys conducted by send questionnaire to selection of experts and analyze results.
2) *Trend analysis* identifies trends and cycles in past data series (time series). The naive forecast extrapolates recent trends into the future, a quick approach because there are no tricky exogenous variables to forecast, but it gives no indication of when or why the trend may change. More sophisticated trend analysis analyses the underlying trends, cycles and the unexplained residuals. With one grand gesture the trends and cycles tell us what will happen, but the forecaster still has to decide whether past trends will change.
    a) Naive is a simple rule e.g. ‘no change’, or ‘if earnings are more than twice OPEX they will fall’.
    b) Trend extrapolation is the simplest time series technique, fit a trend using one of several methodologies and extrapolate forward.
    c) Smoothing is a smooth out fluctuations to obtain average change, and project this; Decomposition model is split out trend, seasonality, cyclicality and random fluctuations, and project each separately.
    d) Filters forecasts are expressed as a linear combination of past actual values and/or errors.

e) Auto-Regressive Moving Average (ARMA) is Forecasts expressed as a linear combination of past actual values; Box–Jenkins model is a variant of the ARMA model, with rules to deal with the problem of stability.

3) *Mathematical models* go a step further and explain trends by quantifying the relationships with other explanatory variables. For example, how much does the oil trade grow if world industrial production increases? By estimating equations which quantify relationships like this we can build a model to predict the oil trade.

   a) Single regression estimated equation with one explanatory variable to predict target variable. The equation can be shown as:

   $$Y_t = a + bX_t + e_t \tag{2.12}$$

   In this equation, which represents a straight line, '$a$' and '$b$' are parameters (i.e. constants) and $e$ is the error term. The parameter '$a$' shows the value of *Y* when *X* is zero (i.e. where the line cuts the vertical axis), the parameter *b* measures the slope of the line (i.e. the change in *Y* for each unit change in *X*), and *e* is the difference between the actual value and the value indicated by the estimated line.

   b) Multiple regression estimated equation with more than one independent variable to predict target variable. The equation can be shown as:

   $$Y_t = a + b_1X_{1t} + b_2X_{2t} \tag{2.13}$$

   Similar to the single regression analysis the parameter 'a' illustrates the value of Y when X1 and X2 is zero and b1 and b2 indicate the degree of contribution to Y for every change in X.

   c) Econometric models are system of regression equations to predict target variable; Supply–demand models estimate supply and demand from their component parts and predict change in balance.

   d) Sensitivity analysis is a model to examine the sensitivity of the forecast to different assumptions.

4) *Probability analysis* uses a completely different approach. Instead of predicting what will happen, probability analysis estimates the chance of a particular outcome occurring. For example, probability analysis might tell the decision-maker that there is a 20% chance that freight rates will be $20,000 per day next year. This approach only works if you can find a way of calculating probability in numeric terms.

   a) Monte Carlo is probability analysis used to calculate the likelihood of a particular outcome occurring.

Qun (2012) explained time series methods are extrapolation methods use only past values of the time series variable to forecast future values and several extrapolation methods are frequently used, including moving-average methods and exponential smoothing methods. The type of time series methods as follows:

1) Moving Average Model

   The simplest and one of the most frequently used extrapolation methods is the method of moving average. To implement the moving average method, we first choose a span, the number of terms in each moving average. If we choose a span of 3 weeks, then the forecast of next week's value is the average of the previous 3 weeks.

$$f = Average\ of\ the\ last\ N\ observations. \text{ or}$$

$$f = Average\ of\ y_{t-1}, y_{t-2}, K\ y_{t-N} \tag{2.14}$$

   Where N is a given parameter called the span.

   For weeks 1-3, we have not yet observed three weeks of data, so we cannot develop a moving average forecast of sales for these weeks, for weeks 4, 5, 6 the moving average forecast based on the average of the first three observations.

2) Weight Moving Average Model

   In moving average method described before, each of the observations used to calculate the forecast value is weighted equally. In this weight moving average model consider more weight on the observations to forecast future, the weights must sum to 1.

$$Ft4 = (weigth1 * a1) + (weigth2 * a2) + (weigth3 * a3) \qquad (2.15)$$

3) Exponential Smoothing Model

The one main criticism of the moving averages method is that it puts equal weight on each value in a typical moving average. Exponential smoothing is a method that addresses this criticism. It bases it forecasts on a weighted average of past observations, with more weight on the more recent observations. Simple exponential smoothing is appropriate when there is no trend or seasonality. Every exponential model has at least one smoothing constant, which is always a number between 0 and 1.

$$Ft = \alpha A_{t-1} + (1 - \alpha)F_{t-1} \qquad (2.16)$$

Where:

| | |
|---|---|
| Ft | : forecast value for the coming t time period |
| Ft-1 | : forecast value in 1 past time period |
| At-1 | : actual occurrence in the past t time period |
| α | : alpha smoothing constant (0~1) |

4) Trend Prediction Model

The procedures in trend prediction model are creating a scatter plot, inserting trend lines and prediction.

The principle of choosing the best forecasting methods is “forecast error”, the best one is to find the forecast error as small as possible (Qun, 2012). There are many measures of forecast error such as mean absolute deviation (MAD) and mean square error (MSE). MAD is the average of the absolute values of these errors, the formula is:

$$MAD = \frac{\sum |y_i - \bar{y}_i|}{n} \tag{2.17}$$

MSE measures the average squared difference between the estimator and the parameter, a somewhat reasonable measure of performance for an estimator, the formula is:

$$MSE = \sum_i \frac{(y_i - \bar{y}_i)^2}{n} \tag{2.18}$$

## 2.4. Simulation Model

Simulation is a tool that allows the users to make any changes in the program without changing the real system or building any physical system. Usually, a simulation model is a computer model that duplicates a real process or situation. According to Moon (2012) simulation is a broad collection of methods and applications to mimic the behavior of real systems, usually on a computer with appropriate software, it also the imitation of some real thing, state of affairs, or process. Simulation can be used to show the eventual real effects of alternative conditions and courses of action. Key issues in simulation are acquisition of valid source information about the referent, selection of key characteristics and behaviors, the use of simplifying approximations and assumptions within the simulation, fidelity and validity of the simulation outcomes. The process of the simulation could be seen in figure 2.12.

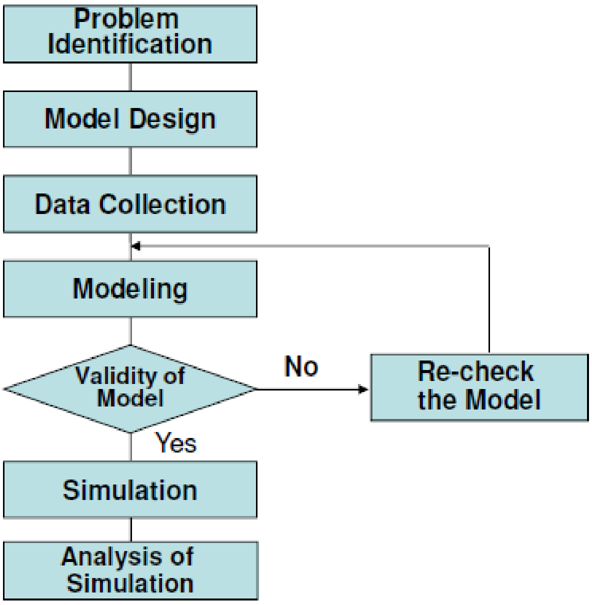


Figure 2.12 - Simulation Process.

Source: Moon (2012).

The purpose of simulation in container terminal is to be able to allocate the resources usefully and to make all the entities having interoperability and stand work in single as well. Also it will help the container terminal manager to see what could be the best possible ways to use resources effectively, to make sure that the ship is served with in desire time, to save cost and make some good profit (Bakht and Ahmad, 2008). Valencia (2006) mentioned that the purpose of a simulation model is to observe the behavior of a model and use the results in a practical way. A simulation model may also be described as a discrete system, in which the state variables change instantaneously at separate points in time or a continuous system in which the state variables change continuously with respect to time.

The simulation model of a container terminal can be used to analysis the capacity of existing terminals or new terminals. There are many different simulation models were used to investigate the performance of container terminals, several studies developed simulation models e.g., Shabayek and Yeung (2002) employed the ***Witness program*** to analyze the performance of Hong Kong's Kwai Chung container, Moon (2012); Na and Shinozuka (2009); Park and Dragović (2009); Tahar and

Hussain (2000) used the ***Arena software*** to determine systems performance of container terminal, Zeng and Yang (2009) used ***Visual Basic*** as integration environment and ***Arena7.0*** is used as simulation plat- form, Sun et al. (2012) introduced a general simulation platform, named ***MicroPort***, for container terminals, Li and Li (2010) simulate the container terminal handling and scheduling system on an advanced dynamic simulation platform ***AnyLogic 6.5.0.*** based on ***Java*** and the ***Eclipse*** framework, Zhao, Lau and Lam (2002) built a simulation model of a queuing system using ***ServiceModel***, Dougherty (2010) evaluated the roadside impacts of the two most common operational strategies (a gate appointment system and extended gate hours) using ***dynamic Microsimulation***, Hartmann, Pohlmann, and Schönknecht (2011) used a model coded in the simulation framework ***Flexsim***.

### 2.5. Conceptual Framework

Container terminal is a complex system. There are three sub systems within the container terminal such as Quay side operations, yard operations and receipt and delivery operations. In order to evaluate the proper container terminal capacity (PCTC) this research develop independently both a quay performance analysis model and a CY performance analysis model, and then combined these models into an integrative simulation model.

Firstly, the simulation model for quay performance analysis is to be made based on real data of ship's arrival time interval, lift per call (LPC) per ship, the number of assigned quay cranes. The actual throughput also applied to the simulation model. The outputs of the quay simulation model are average berth occupancy, average services time, average ratio of ship's waiting time, the number of crane per ship and the throughput per berth.

Secondly, using the traditional model for calculate CY performance. This calculation is made by considering the dwell time of containers, stacking height, TGS, peaking factor, and separation factor. Then by comparing the berth performance with CY performance will get the proper capacity of the terminal.

The next step analysis is to forecast the future demand of the container throughput using forecasting model. Then by comparing the throughput forecast with proper capacity of the terminal will get the shortage or surplus capacity within the terminal. To facilitate the understanding of this study figure 2.13 shows a proposed conceptual framework.

The conceptual framework was developed in order to answer the following questions:

1) What will be the demand of MTI container terminal for the next five years?

2) What is the annual proper throughput of berth (handling volume)?

3) What is the annual proper throughput of yard (handling volume)?

4) What is the annual proper throughput for the terminal by comparing berth throughput with yard throughput?

5) How many shortage or surplus capacities within the terminal by comparing throughput forecast with proper throughput of terminal?

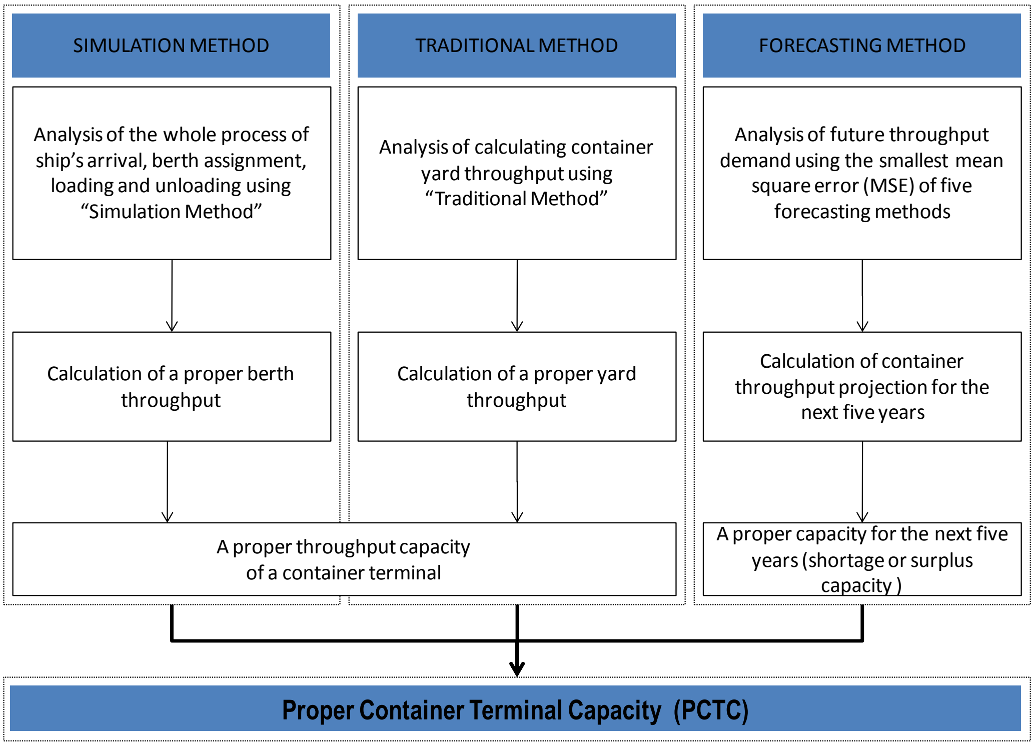


Figure 2.13 - Conceptual Framework

Source: Author

## 2.6. Usage of Methodology in this Thesis

Container terminals modeling has been essential in many applications such as terminal planning; determining and evaluating terminal facilities, equipments and storage space needed; analyzing containers flow; scheduling the terminal resources. According to study from literatures, there are two ways in order to calculating a proper throughput of the terminal, traditional method and simulation method.

The main objective of this study is to investigate the proper capacity of container terminal. To do this can follow the established methodology of Park and Dragović (2009) and Moon (2012). The methodology involves simulation model using ARENA software as a platform to building and testing the simulation modules. The proper container terminal capacity (PCTC) is calculated by developing a quay performance analysis model. The first step in berth simulation is to analyze arrival pattern, lift per call (LCP) which is the number of movements (loading and unloading) that each calling ship handles and crane productivity which is the time taken to handle one container at each crane in the container terminal.

The proper yard throughput will be calculated using traditional methods in equation 2.4 proposed by Dally (1983) which cited in Moon (2012):

$$\mathrm{Cc} = (\mathrm{Tgs\,x\,H\,x\,U\,x\,K}) / (\mathrm{DT\,x\,PF})$$

By comparing berth capacity with yard capacity, i.e. whichever is lower is considered as proper throughput of the terminal.

Furthermore, in order to know the demand of Container in the next five years, the forecasting model will be select by comparing the values of mean square error (MSE) from two or more statistical models as a measure of how well they explain a given set of observations. For multiple regression model, gross domestic regional product (GDRP) and total value of export and import of Jakarta province will be used as independent variables while container throughput as dependant variable.

# Chapter 3

# DATA COLLECTION

The data within this research were collected from field observation and from sample data in MTI container terminal kind of terminal facilities and equipments information, ship arrival, service time, number of container loading/unloading for each vessel, number of facility and equipment used to serve a vessel, etc. Data of gross domestic regional product (GDRP) and total value of export and import of Jakarta province were collected from Indonesia Statistical Center Bureau of Jakarta.

## 3.1. Multi Terminal Indonesia (MTI) Overview

Multi Terminal Indonesia (MTI) is a subsidiary company of Indonesia Port Corporation which engaged in three business segments which are Multi Purpose Terminal, Container Terminal and Freight Forwarding, located in Tanjung Priok, Jakarta which is the largest seaport in Indonesia. The Company is a spin off from Terminal Business Division (DUT) under Tanjung Priok Port Branch. MTI which was established on 15 February 2002 is intended to optimize the business potentials and to strengthen the competitive advantages as the provider of port services. MTI is 99% owned by Indonesia Port Corporation and 1% by Koperasi Pegawai Maritim (Kopegmar). After being part of the PT. Multi Terminal Indonesia, Container Terminal developed into an international container terminal to serve the loading and unloading of ocean going container. However in the end of year 2010 the container terminal split into two services, dedicated for ocean going services and dedicated for inter-island services.

The operation activities in the container terminal have been supported by information technology such as Container Terminal Operation System (CTOS) application, temporary storage on-line system and wireless system. Moreover, to providing convenience to customers the container terminal also provides container tracking information via short message service (SMS) which contains information about the location of containers, handling cost estimation and berthing schedule information. Meanwhile, to provide security and safety of the ship and goods, the terminal has been equipped with a ship security system and port facilities according to the requirements of international standard i.e. the International Ship and Port Facility Security Code (ISPS Code).

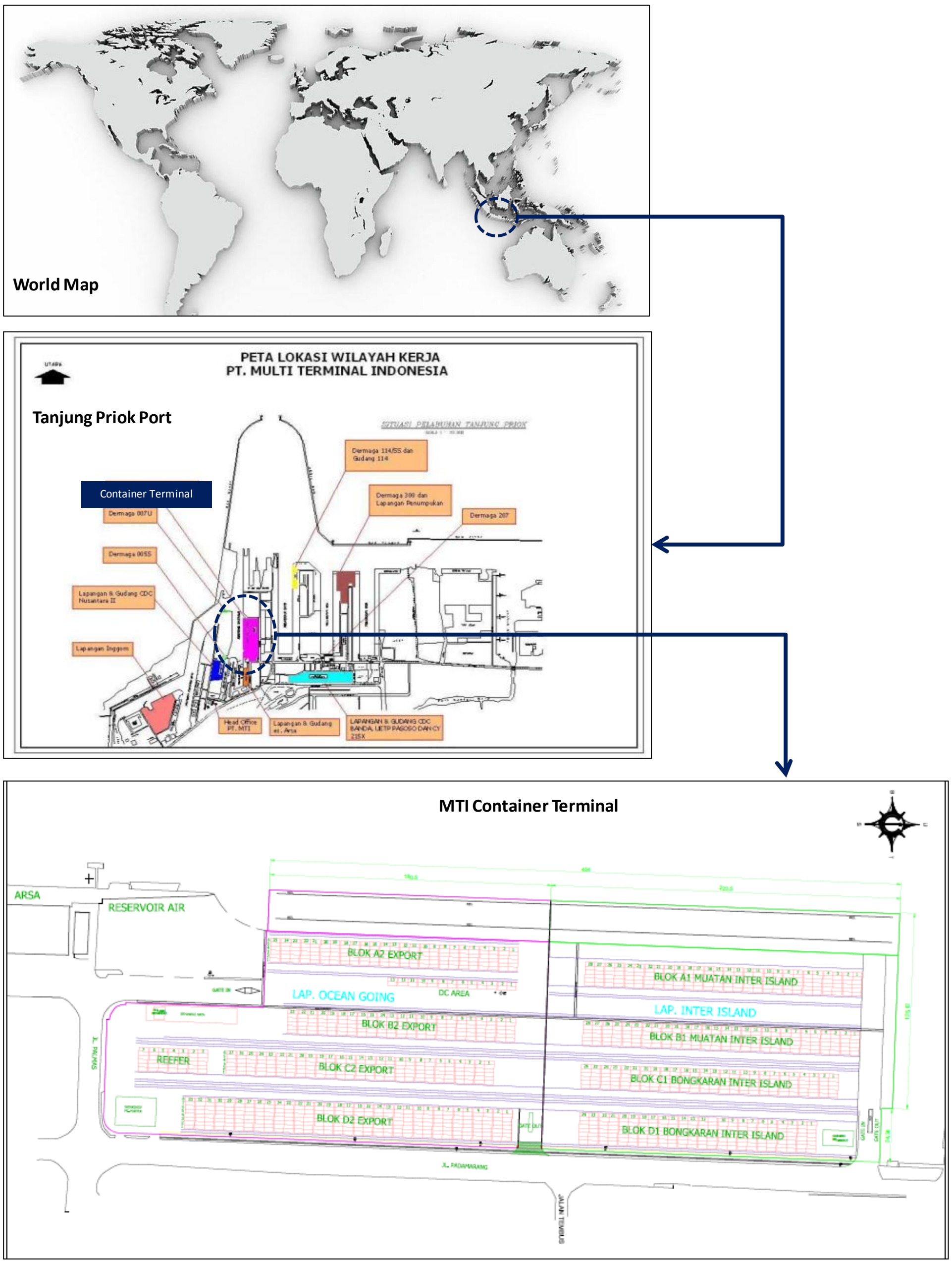


Figure 3.1 - MTI Container Terminal Layout

Source: MTI

### 3.1.1. Terminal Facilities and Equipments

MTI provides facilities and equipments of container terminal handling in order to serve loading and unloading activities ocean going and inter-island container which presented in table 3.1 and 3.2.

Table 3.1 - MTI Container Terminal Berth Facilities

| No. | Facilities | Remaks |
|---|---|---|
| 1 | Berth | Length 404 M |
| 2 | Draft | -10 M LWS |
| 3 | Container Yard | 6 Ha |
| 4 | Holding Capacity | 9,097 Teus |
| 5 | Reefer Plug | 104 Unit |
| 6 | BCH | 26 |

Source: MTI

Table 3.2 - MTI Container Terminal Equipment Facilities

| No. | Facilities | Capacity | Unit |
|---|---|---|---|
| 1 | Gantry Crane | 35 | 4 |
| 2 | Rubber Tired Gantry | 35 | 11 |
| 3 | Side Loader | 15 | 1 |
| 4 | Top Loader | 35 | 1 |
| 5 | Reach Stacker | 35 | 1 |
| 6 | Head Truck | 40 | 16 |
| 7 | Chassis | 40 | 16 |
| 8 | Weight Bridge | 60 | 4 |
| 9 | Behandle Warehouse | 200 m2 | 1 |

Source: MTI

### 3.1.2. Ship Calls and Container Throughput

Ship calls at MTI container terminal tended to decrease from year 2002 to 2012 for ocean going vessels which shows in figure 3.2. On the other side the data of inter-island container vessels started from year 2011 to 2012 due to it was operated in the end of year 2010, the historical data shows in figure 3.3.

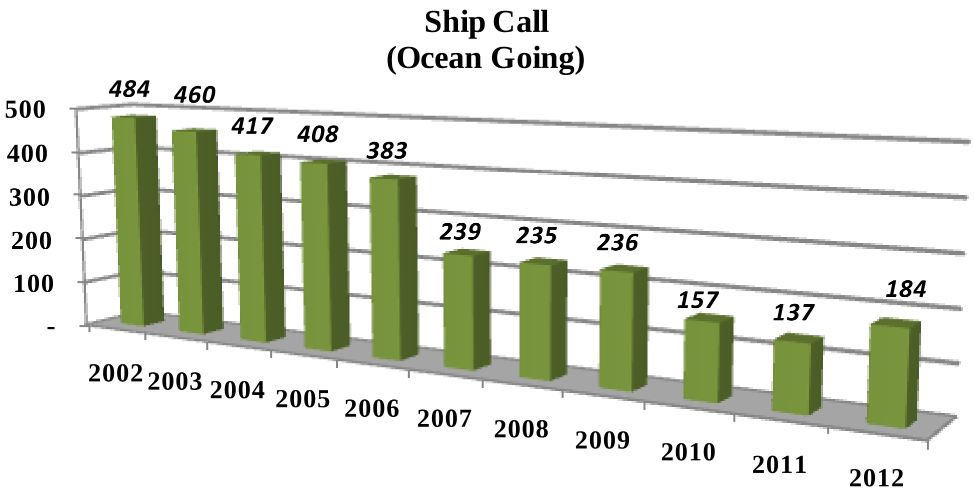


Figure 3.2 - Ship Calls of Ocean Going Vessel from year 2002 to 2012 at MTI

Source: MTI

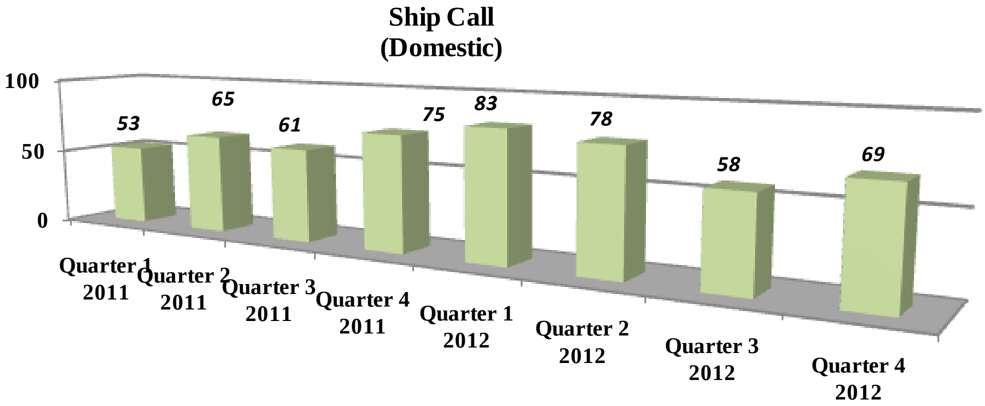


Figure 3.3 - Ship Calls of Inter-Island Vessel from year 2011 to 2012 at MTI

Source: MTI

The container throughput of MTI container terminal tended to fluctuate for ocean going service as well as inter-island. The detail charts could be seen in figure 3.4 and figure 3.5.

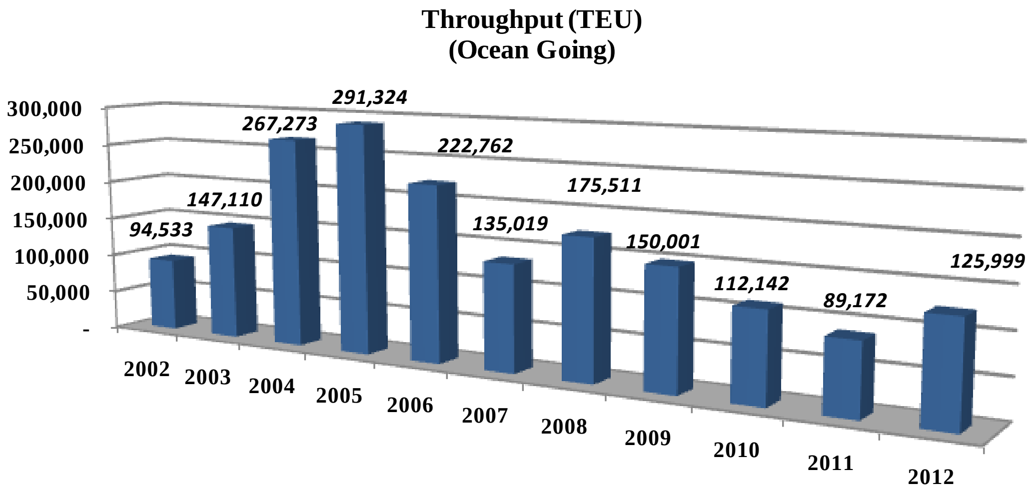


Figure 3.4 - Throughput in TEU of Ocean Going from year 2002 to 2012 at MTI

Source: MTI

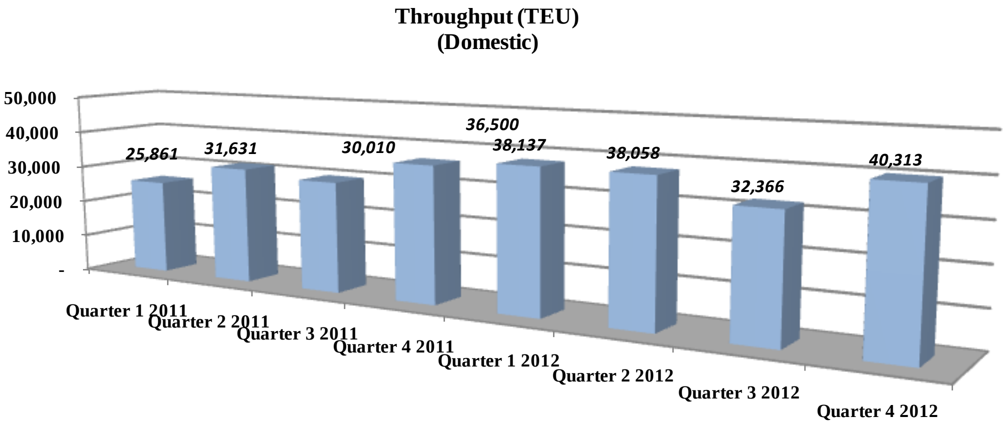


Figure 3.5 - Throughput in TEU of Inter-Island from year 2011 to 2012 at MTI

Source: MTI

### 3.1.3. Container Handling Process

Within the terminal, the activities of container handling consist of loading and unloading operation. The process could be seen in figure 3.6.

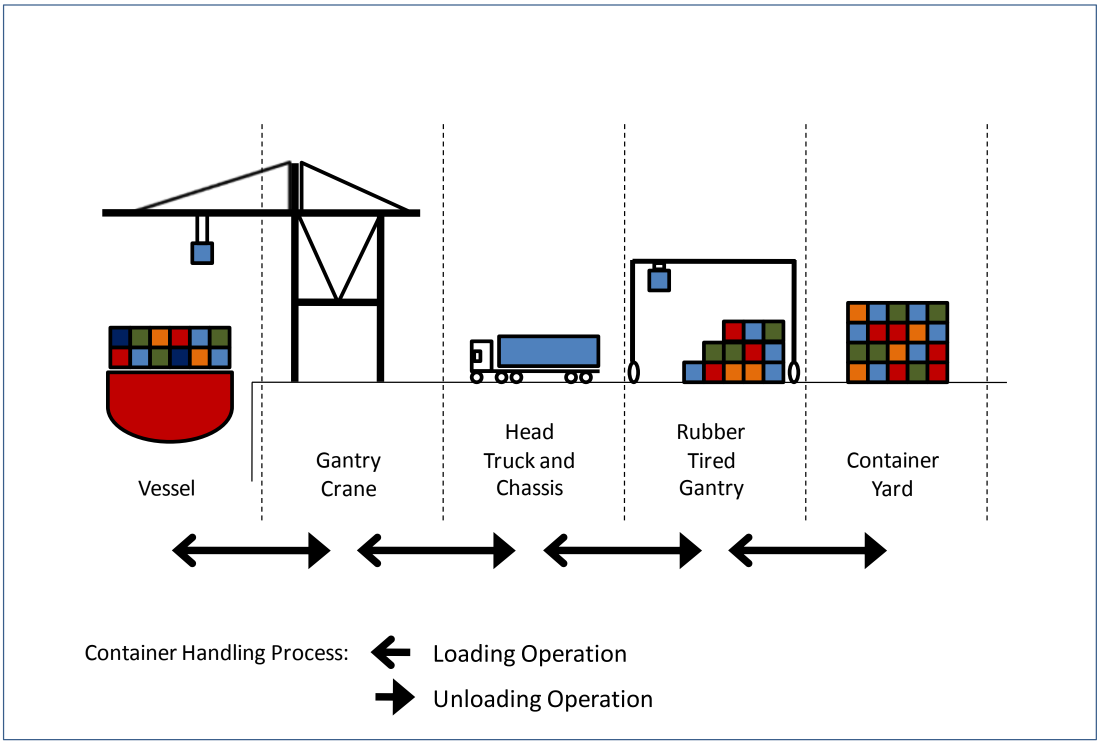


Figure 3.6 - Loading and Unloading Operation Process at MTI Container Terminal

Source: Author

The unloading operation process could be explained as follows:

a. All the equipments needed for unloading and loading operation are prepared while waiting for the vessel to be berthed and ready to be discharged.

b. The gantry crane (GC) unloaded container from the vessel put onto the head truck and chassis (HT) which already standby under the GC.

c. The container will be transferred to the container yard (CY) to be stacked.

d. At container yard, the container will be lifted off from the chassis to be stacked for temporary storage.

On the other side, the loading operation process is same as the unloading operation process but it is done in reverse order.

### 3.1.4. Operational Data

Operational data required in this study are inter-arrival times among vessels which call to unloading and loading containers at MTI container terminal. Lift per call (LCP) which is the number of movements (loading and unloading) that each calling ship handles at berth. The data used are from January 2012 to December 2012, the rule for the number of bins is $(2*n)^{1/3}$ where n denotes the number of observations. For ocean going service the data is 185, then $(2*185)^{1/3} = 7.18$. We round up to 8 to get 8 bins. For inter-island service the data is 289, then $(2*289)^{1/3} = 8.33$. We round up to 9 to get 9 bins. To get the bin width, take the largest data minus smallest divide by number of bins. For example, the largest and smallest of ship inter-arrival data are 307.5 and 0, the interval is (307.5 – 0)/8 = 38.44. The distribution data presents in table 3.3; 3.4; 3.5 and 3.6 while the histogram presents in figure 3.7; 3.8; 3.9 and 3.10.

Table 3.3 - Distribution of Inter-arrival Times of Ocean Going Vessels at MTI 2012

| Bin | Interval (hours) | Frequency | Cumulative % |
|---|---|---|---|
| 1 | 0 - 38.44 | 86 | 46.49% |
| 2 | 38.44 - 76.88 | 69 | 83.78% |
| 3 | 76.88 - 115.31 | 26 | 97.84% |
| 4 | 115.31 - 153.75 | 3 | 99.46% |
| 5 | 153.75 - 192.19 | 0 | 99.46% |
| 6 | 192.19 - 230.63 | 0 | 99.46% |
| 7 | 230.63 - 269.06 | 0 | 99.46% |
| 8 | 269.06 > | 1 | 100.00% |
| | Number of observations | 185 | |

Source: Author calculation

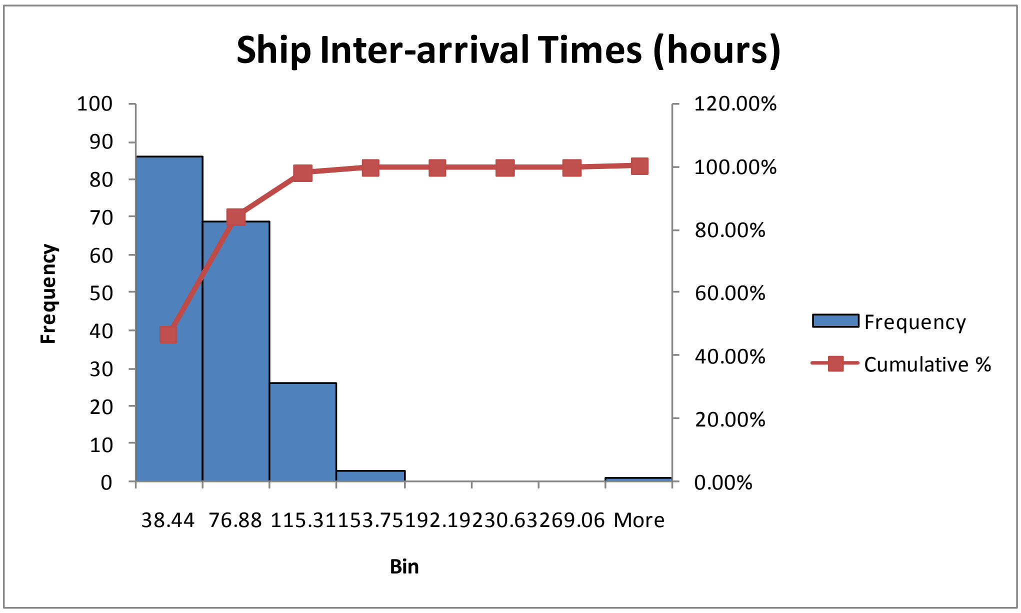


Figure 3.7 - Histogram of Ship Inter-arrival Times of Ocean Going Vessels

Source: Author calculation

Table 3.4 - Distribution of Inter-arrival Times of Inter-Island Vessels at MTI 2012

| Bin | Interval (hours) | | | Frequency | Cumulative % |
|---|---|---|---|---|---|
| 1 | 0 | - | 13.09 | 65 | 22.49% |
| 2 | 13.09 | - | 26.19 | 84 | 51.56% |
| 3 | 26.19 | - | 39.28 | 66 | 74.39% |
| 4 | 39.28 | - | 52.37 | 29 | 84.43% |
| 5 | 52.37 | - | 65.46 | 24 | 92.73% |
| 6 | 65.46 | - | 78.56 | 8 | 95.50% |
| 7 | 78.56 | - | 91.65 | 9 | 98.62% |
| 8 | 91.65 | - | 104.74 | 3 | 99.65% |
| 9 | 104.74 | > | | 1 | 100.00% |
| Number of observations | | | | 289 | |

Source: Author calculation

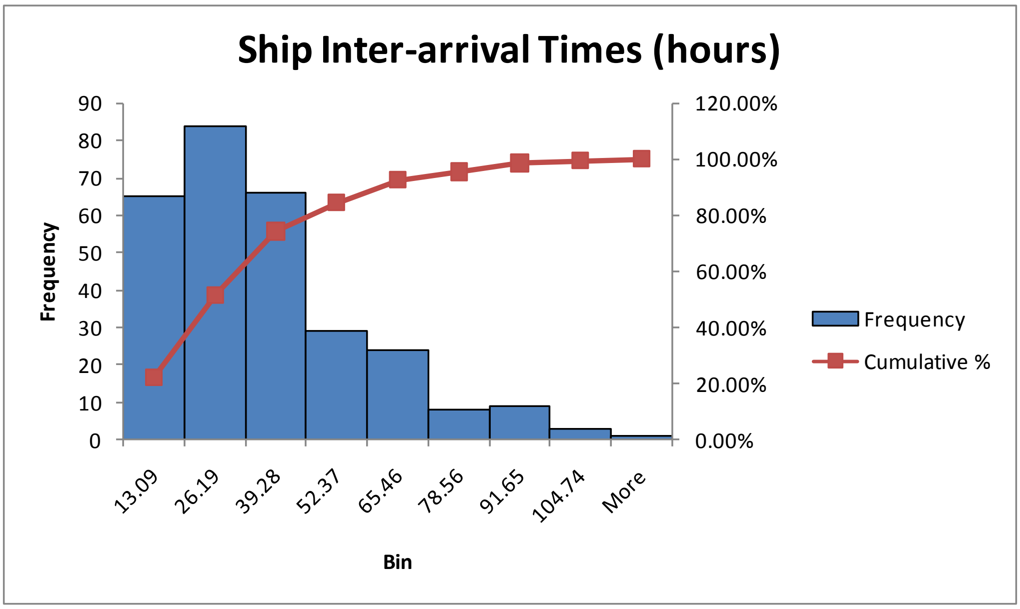


Figure 3.8 - Histogram of Ship Inter-arrival Times of Inter-Island Vessels

Source: Author calculation

Table 3.5 - Distribution of Lift per Call of Ocean Going Vessels at MTI 2012

| Bin | Interval (containers) | | | Frequency | Cumulative % |
|---|---|---|---|---|---|
| 1 | 4 | - | 177 | 65 | 35.14% |
| 2 | 177 | - | 351 | 18 | 44.86% |
| 3 | 351 | - | 524 | 6 | 48.11% |
| 4 | 524 | - | 697 | 15 | 56.22% |
| 5 | 697 | - | 870 | 27 | 70.81% |
| 6 | 870 | - | 1044 | 31 | 87.57% |
| 7 | 1044 | - | 1217 | 13 | 94.59% |
| 8 | 1217 | > | | 10 | 100.00% |
| | Number of observations | | | 185 | |

Source: Author calculation

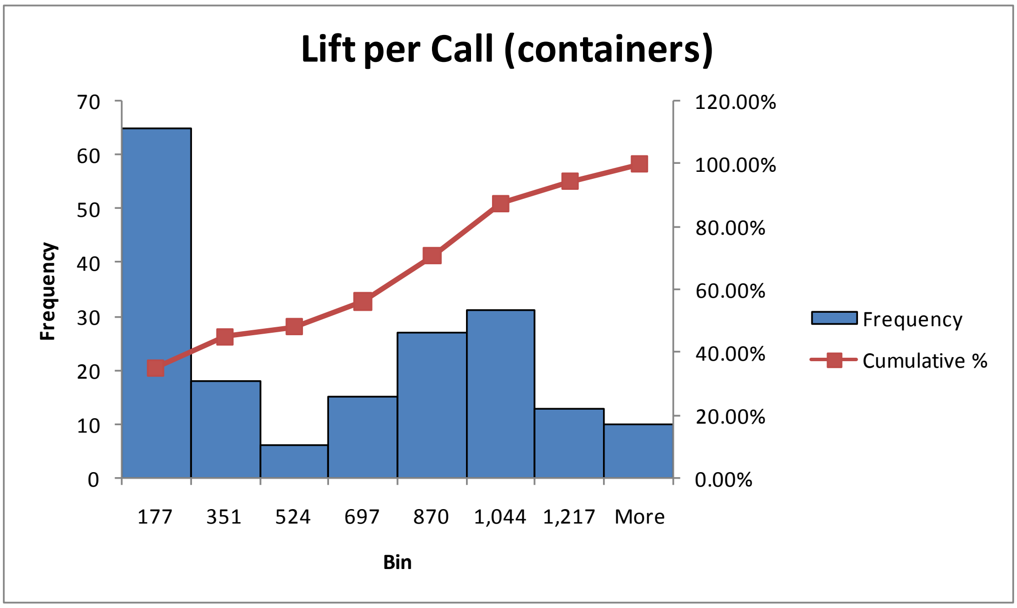


Figure 3.9 - Histogram of Lift per Call of Ocean Going Vessels

Source: Author calculation

Table 3.6 - Distribution of Lift per Call of Inter-Island Vessels at MTI 2012

| Bin | Interval (containers) | | | Frequency | Cumulative % |
|---|---|---|---|---|---|
| 1 | 20 | - | 170 | 38 | 13.15% |
| 2 | 170 | - | 321 | 82 | 41.52% |
| 3 | 321 | - | 471 | 57 | 61.25% |
| 4 | 471 | - | 621 | 56 | 80.62% |
| 5 | 621 | - | 772 | 23 | 88.58% |
| 6 | 772 | - | 922 | 10 | 92.04% |
| 7 | 922 | - | 1072 | 13 | 96.54% |
| 8 | 1072 | - | 1223 | 8 | 99.31% |
| 9 | 1223 | > | | 2 | 100.00% |
| | Number of observations | | | 289 | |

Source: Author calculation

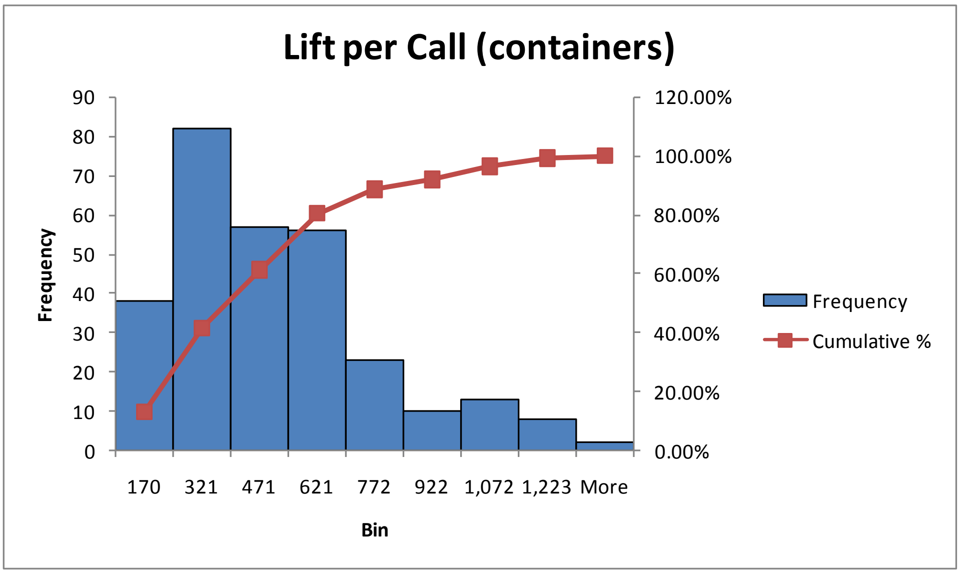


Figure 3.10 - Histogram of Lift per Call of Inter-Island Vessels

Source: Author calculation

The other operational data presents in this study is the length overall (LOA) and size in gross tonnage (GT) of the vessels which calling at MTI container terminal. The distribution data of LOA presents in table 3.7 and 3.8 and the histogram presents in figure 3.11and 3.12 while the distribution of GT presents in table 3.9 and 3.10 and the histogram presents in figure 3.13 and 3.14.

Table 3.7 - Distribution of LOA Ocean Going Vessels at MTI 2012

| Bin | Interval of LoA (m) | Frequency | Cumulative % |
|---|---|---|---|
| 1 | 73.00 - 85.28 | 1 | 0.54% |
| 2 | 85.28 - 97.57 | 7 | 4.32% |
| 3 | 97.57 - 109.85 | 4 | 6.49% |
| 4 | 109.85 - 122.13 | 11 | 12.43% |
| 5 | 122.13 - 134.41 | 36 | 31.89% |
| 6 | 134.41 - 146.70 | 99 | 85.41% |
| 7 | 146.70 - 158.98 | 24 | 98.38% |
| 8 | 158.98 > | 3 | 100.00% |
| | Number of observations | 185 | |

Source: Author calculation

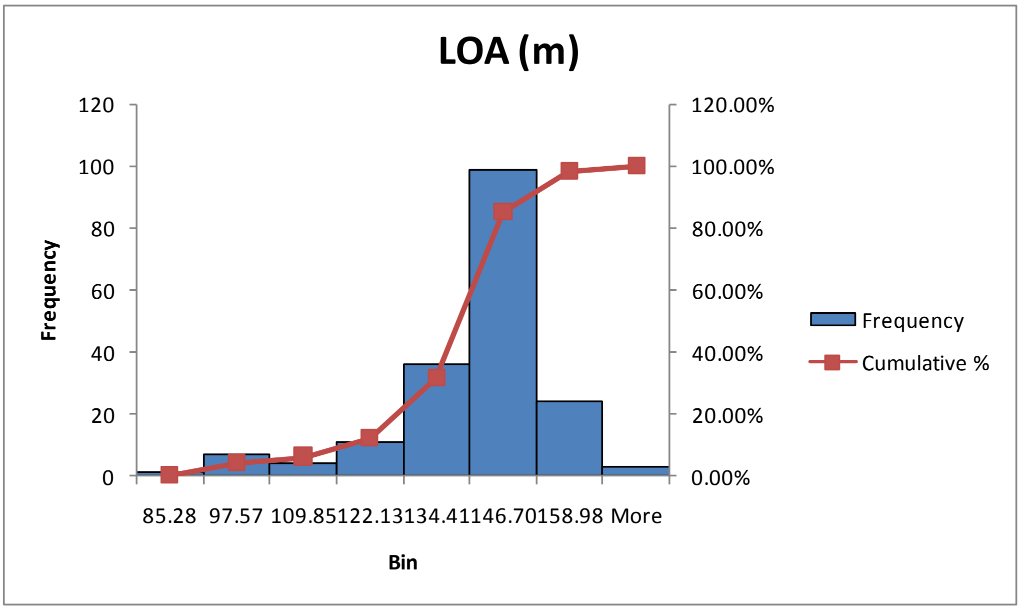


Figure 3.11 - Histogram of LOA of Ocean Going Vessels

Source: Author calculation

Table 3.8 - Distribution of LOA Inter-Island Vessels at MTI 2012

| Bin | Interval of LoA (m) | Frequency | Cumulative % |
|---|---|---|---|
| 1 | 72.00 - 80.61 | 21 | 7.27% |
| 2 | 80.61 - 89.22 | 0 | 7.27% |
| 3 | 89.22 - 97.83 | 62 | 28.72% |
| 4 | 97.83 - 106.44 | 5 | 30.45% |
| 5 | 106.44 - 115.06 | 33 | 41.87% |
| 6 | 115.06 - 123.67 | 28 | 51.56% |
| 7 | 123.67 - 132.28 | 59 | 71.97% |
| 8 | 132.28 - 140.89 | 14 | 76.82% |
| 9 | 140.89 > | 67 | 100.00% |
| Number of observations | | 289 | |

Source: Author calculation

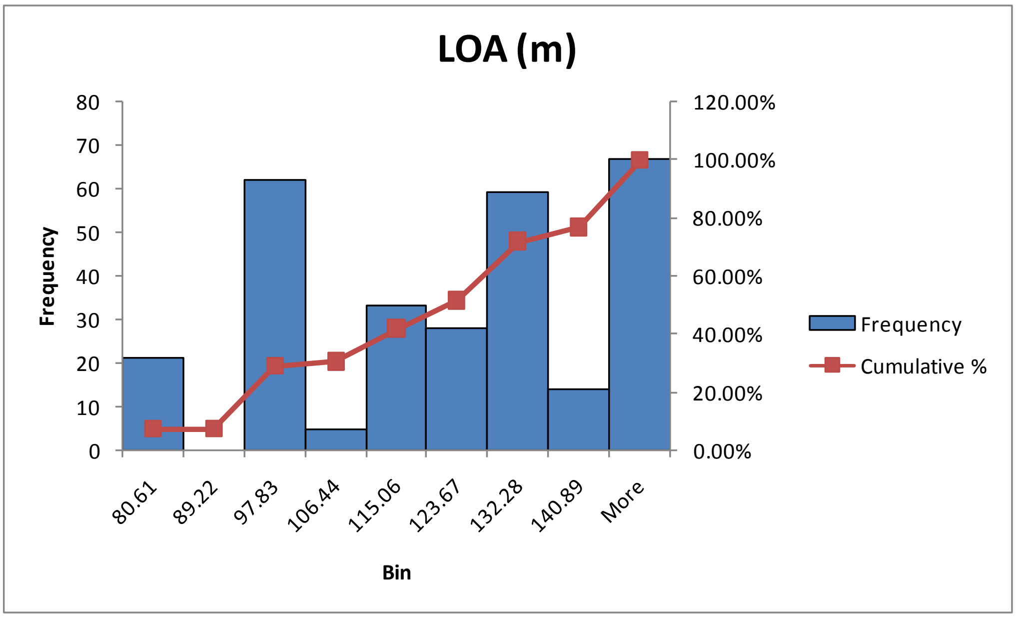


Figure 3.12 - Histogram of LOA of Inter-Island Vessels

Source: Author calculation

Table 3.9 - Distribution of GT Ocean Going Vessels at MTI 2012

| Bin | Interval of size (GT) | Frequency | Cumulative % |
|---|---|---|---|
| 1 | 2,163 - 3,834 | 5 | 2.70% |
| 2 | 3,834 - 5,506 | 12 | 9.19% |
| 3 | 5,506 - 7,177 | 29 | 24.86% |
| 4 | 7,177 - 8,848 | 1 | 25.41% |
| 5 | 8,848 - 10,519 | 42 | 48.11% |
| 6 | 10,519 - 12,191 | 93 | 98.38% |
| 7 | 12,191 - 13,862 | 0 | 98.38% |
| 8 | 13,862 > | 3 | 100.00% |
| Number of observations | | 185 | |

Source: Author calculation

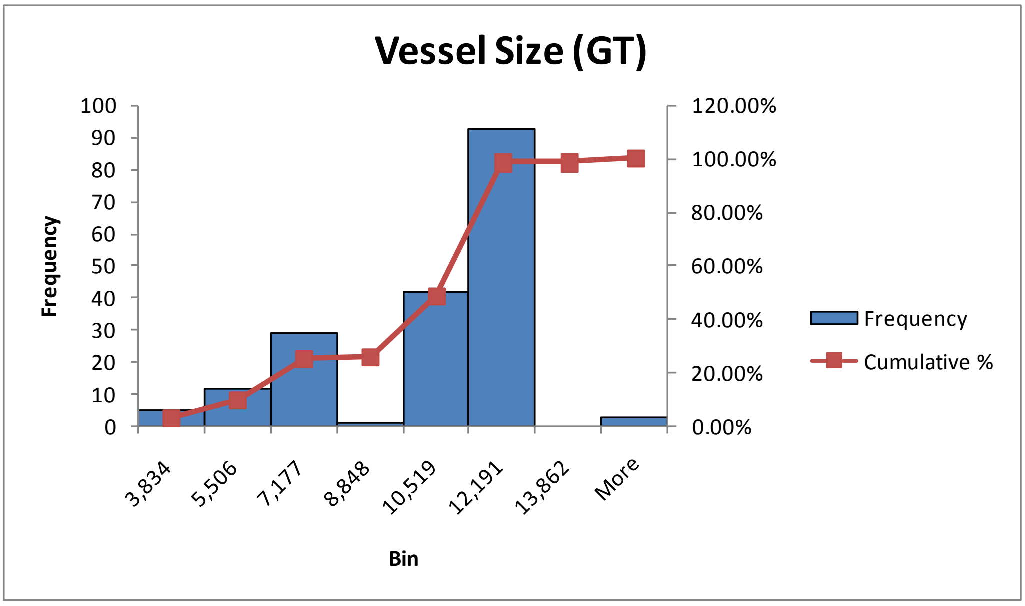


Figure 3.13 - Histogram of GT of Ocean Going Vessels

Source: Author calculation

Table 3.10 - Distribution of GT Inter-Island Vessels at MTI 2012

| Bin | Interval of size (GT) | | | Frequency | Cumulative % |
|---|---|---|---|---|---|
| 1 | 1,790 | - | 2,901 | 21 | 7.27% |
| 2 | 2,901 | - | 4,012 | 42 | 21.80% |
| 3 | 4,012 | - | 5,123 | 47 | 38.06% |
| 4 | 5,123 | - | 6,234 | 61 | 59.17% |
| 5 | 6,234 | - | 7,344 | 24 | 67.47% |
| 6 | 7,344 | - | 8,455 | 0 | 67.47% |
| 7 | 8,455 | - | 9,566 | 28 | 77.16% |
| 8 | 9,566 | - | 10,677 | 30 | 87.54% |
| 9 | 10,677 | > | | 36 | 100.00% |
| | Number of observations | | | 289 | |

Source: Author calculation

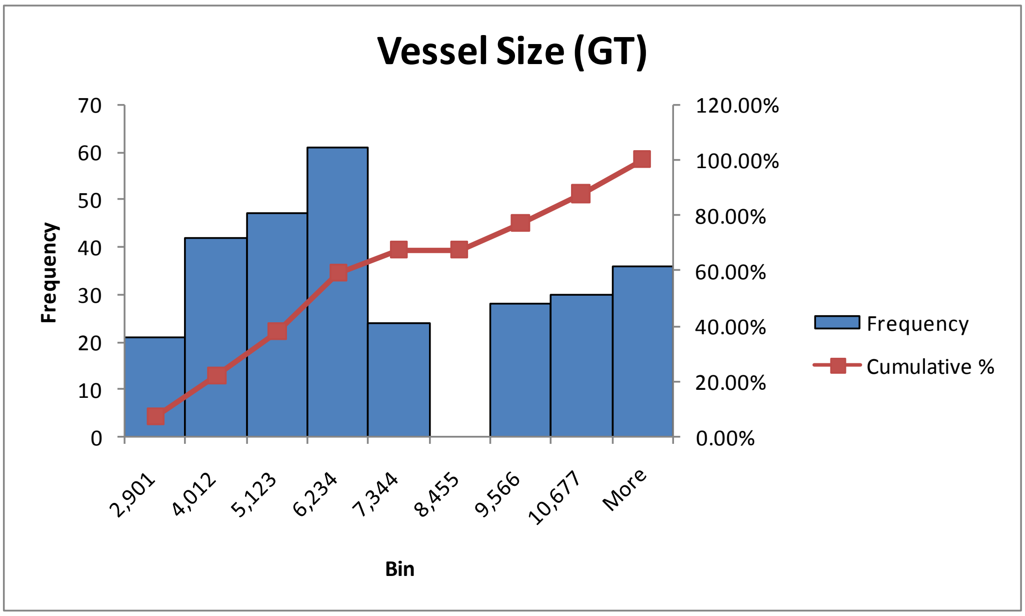


Figure 3.14 - Histogram of GT of Inter-Island Vessels

Source: Author calculation

## 3.2. Hinterland Overview

A hinterland is the inland area from where a port produces the majority of its businesses. Concretely, the catchment area of a port is the scatter of inland points of cargo origin/destination generating the traffic flows passing through a specific port. In abstract terms, the traditional concept of hinter-land conceives it as the area whose contour is a continuous line bounding the port economic influence on shore (Ferrari; Parola and Gattorna, 2011).

Primarily, maritime logistics is the concept of physical, economic/strategic or organizational/relational integration and comprises planning, design, execution and management of material and information flows alongside the maritime supply chain from ship to port to the hinterland and vice versa (Flitsch, 2012).

MTI container terminal located within the Port of Tanjung Priok Jakarta which is the capital and largest city of Indonesia also known as the Special Capital Region of Jakarta (DKI Jakarta). Tanjung Priok Port is the busiest port in Indonesia. The hinterland area is around the Jakarta situated in Java Island which is surrounded by West Java province in east side and Banten Province in west side.

Jakarta city was established over 460 year ago, in 1527‘s. During its history it was not even called Jakarta but born the name given it by the Dutch and administrators who settled there: “Gemeente en Stadgemeente Batavia“ or simply “Batavia“. Since Japanese occupation in World War II, it was called “Jakarta Toku-betsushi“. Following the struggle for independence in 1949 is finally taken on its current and popular name, Jakarta Metropolitan City.

Based on its geographic position, Province of DKI Jakarta has boundaries: on the north stretches a coast from West to East along the ±35 km of the estuary of the 9 rivers and 2 channels, border on the Java Sea, while to the south and eastern is bordering with West Java Province, on the west is bounded by Province of Banten (BPS-Statistics of DKI Jakarta province).

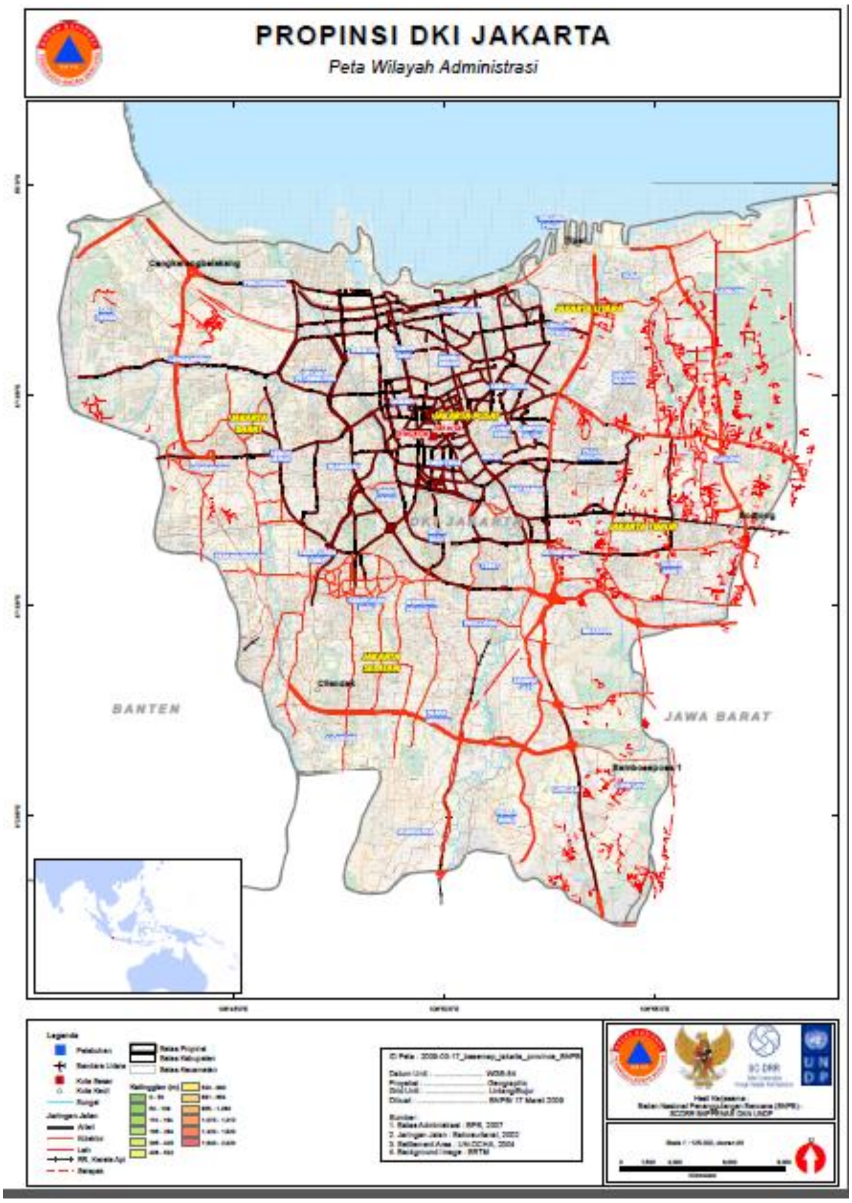


Figure 3.15 - Administrative Area of Jakarta Province

Source: http://geospasial.bnpb.go.id/2009/05/12/provinsi-dki-jakarta/

### 3.2.1. Gross Domestic Regional Product (GDRP)

The countries that trade more than others generally have bigger economies (GDP), but trade volumes are also a matter of supply and demand (Stopford, 2009). The Gross Domestic Product (GDP) of the hinterland reflects the port throughput (Dorsser, Wolters and Wee, 2012). The economic growth in Jakarta reflects by the growth of Gross Domestic Regional Product (GDRP) of Jakarta which presented in table 3.11.

Table 3.11 - Gross Domestic Regional Product of Jakarta from the year 2002 to 2012

| Year | GDRP (million IDR) |
|---|---:|
| 2002 | 299,967,605 |
| 2003 | 334,331,300 |
| 2004 | 375,561,523 |
| 2005 | 433,860,253 |
| 2006 | 501,771,731 |
| 2007 | 566,449,360 |
| 2008 | 677,044,743 |
| 2009 | 757,696,594 |
| 2010 | 862,089,737 |
| 2011 | 982,540,044 |
| 2012 | 1,103,737,600 |

Source: BPS-Statistics of DKI Jakarta province

### 3.2.2. Export and Import value of Jakarta

As a capital city of Indonesia, Jakarta is the province that has contributed the most in terms of exports and imports. According to data from Indonesia Statistical Centre Bureau of Jakarta province, the value of export and import of Jakarta province from year 2002 to 2012 is shown in table 3.12.

Table 3.12 - Trend of Export and Import Value of Jakarta from the year 2002 to 2012

| Year | Export Value (000 US$) | Import Value (000 US$) | Total of Export and Import Value (000 US$) |
|---|---|---|---|
| 2002 | 19,959,587 | 15,189,262 | 35,148,849 |
| 2003 | 20,454,440 | 16,169,568 | 36,624,008 |
| 2004 | 24,501,222 | 23,883,257 | 48,384,479 |
| 2005 | 26,958,167 | 26,827,744 | 53,785,911 |
| 2006 | 29,809,518 | 27,134,810 | 56,944,328 |
| 2007 | 32,186,885 | 34,739,269 | 66,926,154 |
| 2008 | 36,090,170 | 63,312,742 | 99,402,912 |
| 2009 | 32,536,510 | 48,099,308 | 80,635,818 |
| 2010 | 39,648,257 | 70,069,085 | 109,717,342 |
| 2011 | 46,476,171 | 88,874,020 | 135,350,191 |
| 2012 | 48,136,860 | 96,885,200 | 145,022,060 |

Source: BPS-Statistics of DKI Jakarta province

# Chapter 4

# CONTAINER THROUGHPUT FORECAST

The main objective of this chapter is to determine the future demand of container in the next five years and will answer the question number one mentioned in chapter 2 section 2.5. The best forecasting method will be choose by finding the smallest forecast error. In this study, the forecasting of container throughput will be done by comparing the mean square error (MSE) of five forecasting methods as a measure of how well they explain a given set of observations.

1) Single regression method using equation 2.12, where time series will be used as independent variable.

$$Y_t = a + bX_t + e_t$$

2) Polynomial regression method using below equation where time series will be used as independent variable.

$$Y_t = aX^2 + bX + c$$

3) Multiple regression using equation 2.13

$$Y_t = a + b_1X_{1t} + b_2X_{2t}$$

Wherein gross domestic regional product (GDRP) and total value of export and import of Jakarta province will be used as independent variables while container throughput as dependant variable.

4) Moving average method calculated using equation 2.14

$$f = Average\ of\ the\ last\ N\ observations.$$ or

$$f = Average\ of\ y_{t-1}, y_{t-2}, K\ y_{t-N}$$

5) Weight moving average method calculated using equation 2.15

$$Ft4 = (weigth1 * a1) + (weigth2 * a2) + (weigth3 * a3)$$

While the MSE will be calculated using equation 2.18:

$$MSE = \sum_{i} \frac{(y_i - \bar{y}_i)^2}{n}$$

### 4.1. Container Throughput Forecast for Ocean Going Service year 2013-2017

The forecasting equations generated by scattered trend line for forecasting ocean going container throughput using data of container throughput from year 2002 to 2012 as presented in figure 3.4, while the data of GDRP and total value of export and import from year 2002 to 2012 presented in table 3.11 and table 3.12. The scattered trend line is presents in figures 4.1; 4.2 and 4.3.

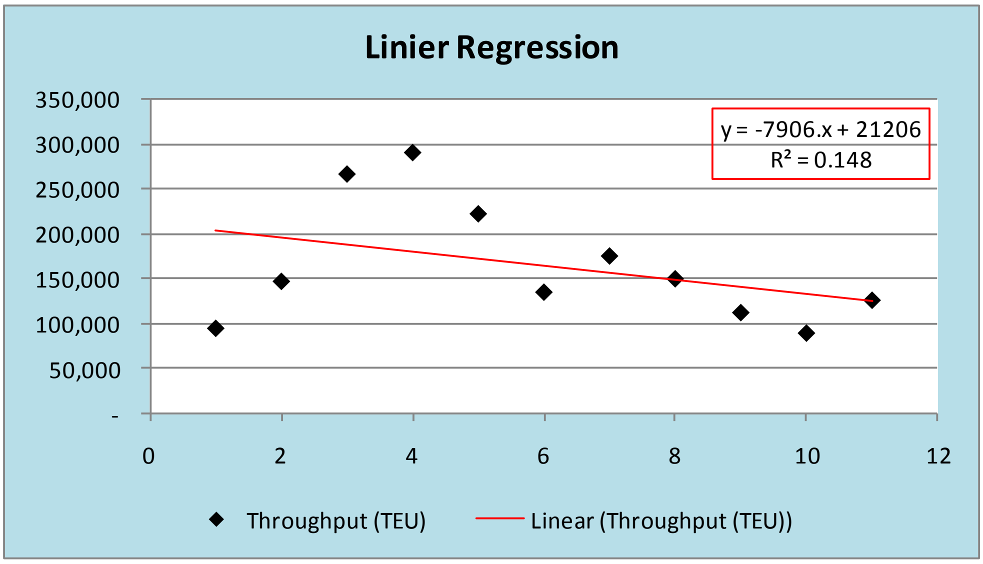


Figure 4.1 - Linier Regression of Ocean Going Container Throughput

Source: Author calculation

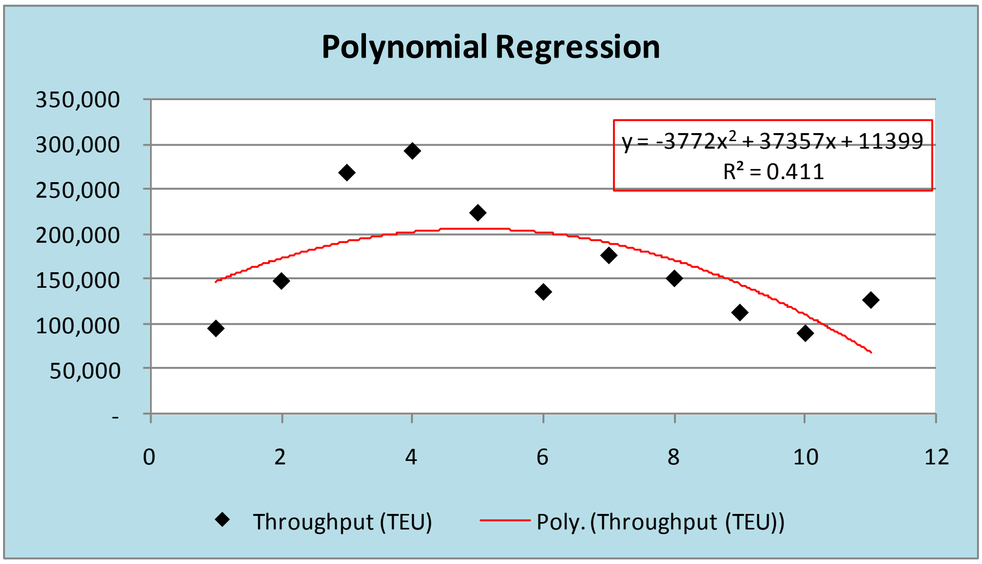


Figure 4.2 - Polynomial Regression of Ocean Going Container Throughput

Source: Author calculation

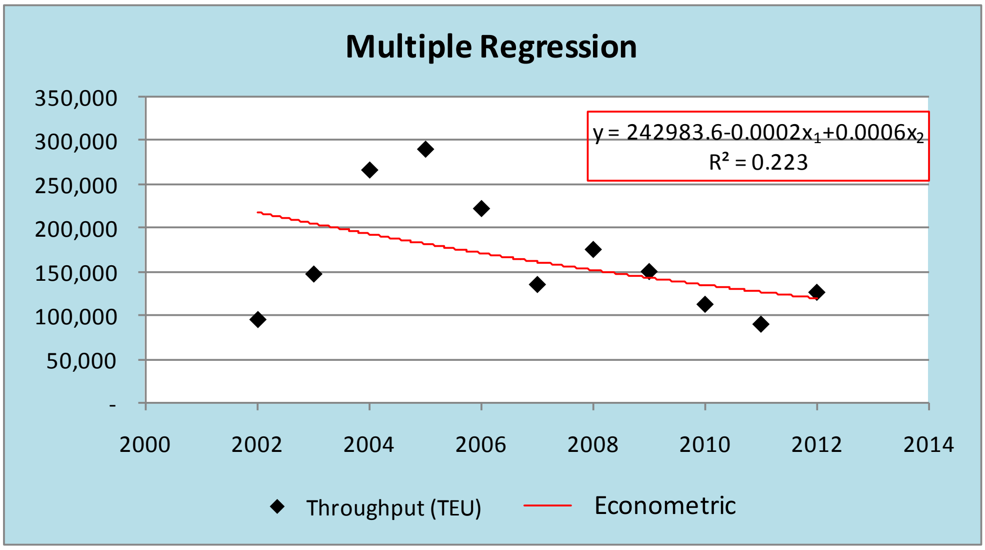


Figure 4.3 - Multiple Regression of Ocean Going Container Throughput

Source: Author calculation

To know the correlation among variables in multiple regression method of GDRP, total value of export and import and container throughput of ocean going service, wherein the independent variable are value of export and import and GDRP and dependant variable is container throughput, the result is the best correlation among variable only shown in correlation of GDRP with total export and import value as presents in table 4.1.

Table 4.1 - Correlation among Variables (Ocean Going)

| | ***Throughput*** | ***GDRP*** | ***Total Exim Value*** |
|---|---|---|---|
| ***Throughput*** | 1 | | |
| ***GDRP*** | -0.467698069 | 1 | |
| ***Total Exim Value*** | -0.445018933 | 0.980657805 | 1 |

Source: Author calculation

The differences among forecasted and actual throughput is illustrated in figure 4.4.

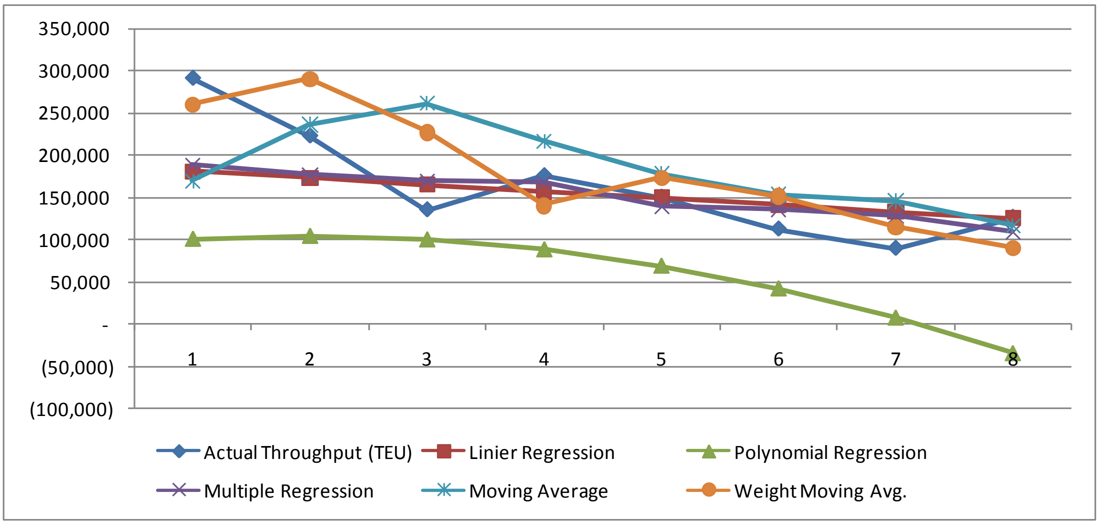


Figure 4.4 - Forecasted and Actual Throughput of Ocean Going Container

Source: Author calculation

From the table 4.2, the result of MSE values of all forecasting methods show that weight moving average is the best methods to forecast the ocean going container throughput since it has the smallest MSE equal to 2,395,915,308.

Table 4.2 - MSE Values (Ocean Going)

| | **Linier Regression** | **Polynomial Regression** | **Multiple Regression** | **Moving Average** | **Weight Moving Average** |
|---|---|---|---|---|---|
| ***MSE*** | **3,587,358,060** | **13,002,998,262** | **3,270,600,846** | **4,767,934,465** | **2,395,915,308** |

Source: Author calculation

The weight1, weight2 and weight3 should be determined in order to get the best value of MSE in weight moving average method, it could be find using solver in Microsoft office excel. The weights obtained from the solver are: weight1 = 0; weight2 = 0.0625381; weight3 = 0.9374629.

For example, the calculation of throughput forecast of ocean going vessels using equation 2.15 in year 2013 will be:

$$\begin{aligned} TEU\ 2013 &= (0 * 112{,}142) + (0.0625381 * 89{,}172) + (0.9374629 * 125{,}999) \\ &= 123{,}696 \end{aligned}$$

The result of forecasting throughput for year 2013 to 2017 is presents in table 4.3.

Table 4.3 - Throughput Forecast of Ocean Going Service at MTI year 2013-2017

| **Year** | **Throughput (TEU)** |
|---|---|
| 2013 | 123,696 |
| 2014 | 123,840 |
| 2015 | 123,831 |
| 2016 | 123,832 |
| 2017 | 123,832 |

Source: Author calculation

## 4.2. Container Throughput Forecast for Inter-Island Service year 2013-2017

In the same way with forecasting ocean going container throughput, the forecasting equations generated by scattered trend line for forecasting inter-island container throughput. The difference is only in the historical data used to forecast, the inter-island forecast using data from year 2011 to 2012 due to it was operated in the end of year 2010, the historical data of quarterly collected in order to get higher frequency of data. The historical data of container throughput used as presented in figure 3.5, while the GDRP and total value of export and import use breakdown data every quarter present in table 4.4 and 4.5. The scattered line is presents in figures 4.5; 4.6 and 4.7.

Table 4.4 - GDRP Quarterly of Jakarta from the year 2011 to 2012

| Year | GDRP (billion IDR) |
|---|---|
| Quarter 1 2011 | 233,104 |
| Quarter 2 2011 | 239,714 |
| Quarter 3 2011 | 251,421 |
| Quarter 4 2011 | 258,301 |
| Quarter 1 2012 | 260,694 |
| Quarter 2 2012 | 269,384 |
| Quarter 3 2012 | 280,033 |
| Quarter 4 2012 | 293,627 |

Source: BPS-Statistics of DKI Jakarta province

Table 4.5 - Export Import Value Quarterly of Jakarta from the year 2011 to 2012

| Year | Export Value (million US$) | Import Value (milion US$) | Total of Export and Import Value (million US$) |
|---|---|---|---|
| Quarter 1 2011 | 10,860 | 20,396 | 31,256 |
| Quarter 2 2011 | 11,347 | 21,559 | 32,906 |
| Quarter 3 2011 | 12,109 | 22,684 | 34,793 |
| Quarter 4 2011 | 12,160 | 24,236 | 36,396 |
| Quarter 1 2012 | 12,029 | 23,355 | 35,384 |
| Quarter 2 2012 | 12,255 | 25,821 | 38,076 |
| Quarter 3 2012 | 11,933 | 23,407 | 35,340 |
| Quarter 4 2012 | 11,917 | 24,343 | 36,261 |

Source: BPS-Statistics of DKI Jakarta province

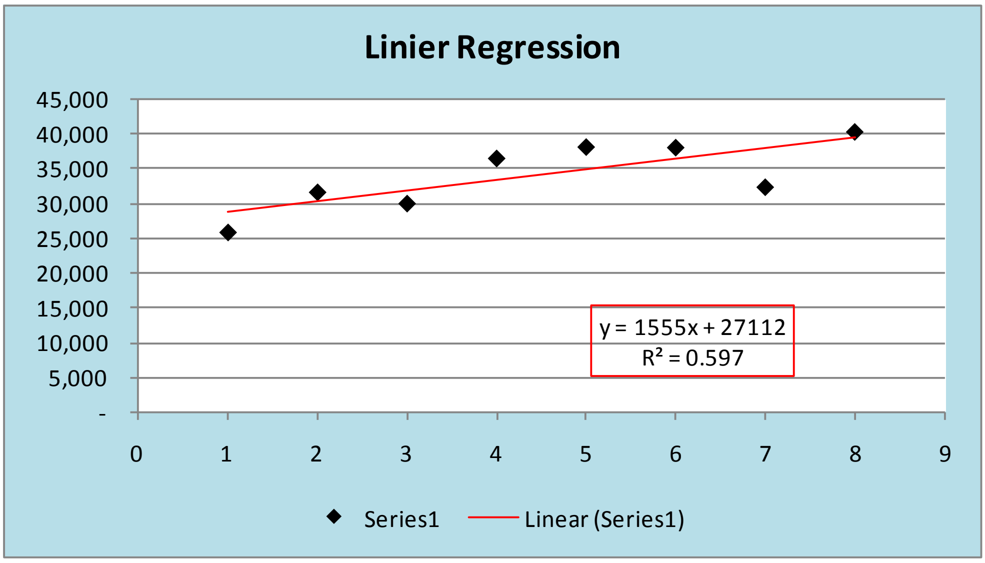


Figure 4.5 - Linier Regression of Inter-Island Container Throughput

Source: Author calculation

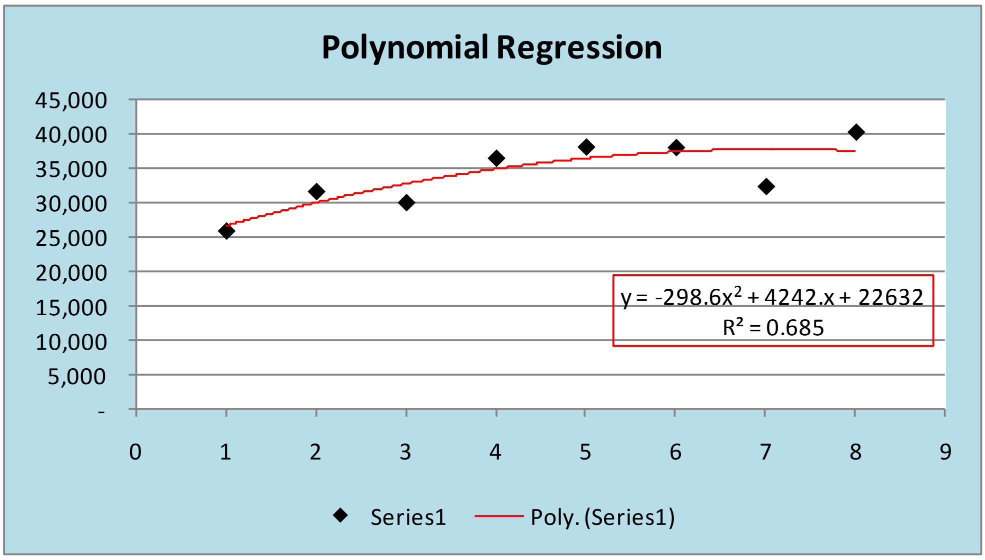


Figure 4.6 - Polynomial Regression of Inter-Island Container Throughput

Source: Author calculation

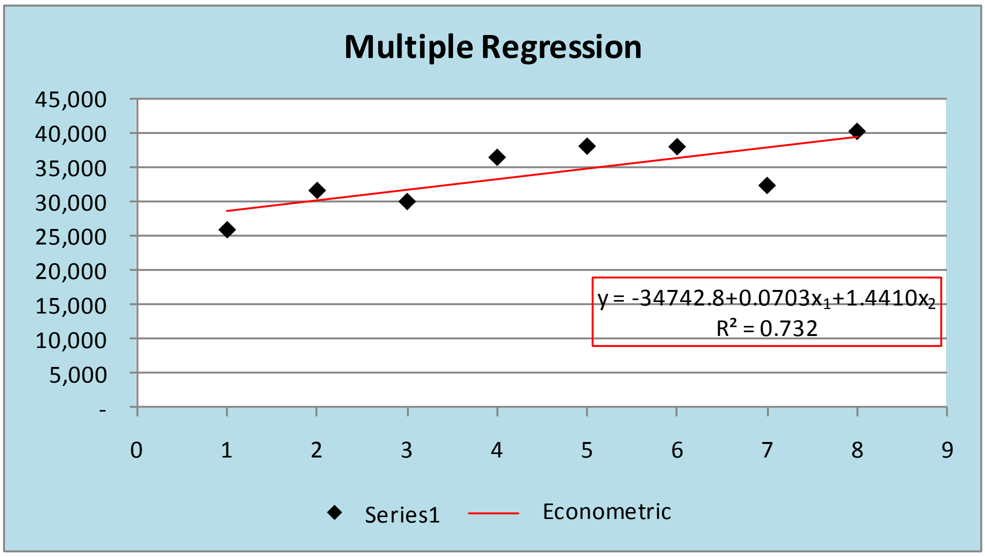


Figure 4.7 - Multiple Regression of Inter-Island Container Throughput

Source: Author calculation

To know the correlation among variables in multiple regression method of GDRP, total value of export and import and container throughput of inter-island service, wherein the independent variable are value of export and import and GDRP and dependant variable is container throughput, the result is presents in table 4.6.

Table 4.6 - Correlation among Variables (Inter-Island)

| | ***Throughput*** | ***GDRP*** | ***Total Exim Value*** |
|---|---|---|---|
| ***Throughput*** | **1** | | |
| ***GDRP*** | **0.745333211** | **1** | |
| ***Total Exim Value*** | **0.833502501** | **0.737054536** | **1** |

Source: Author calculation

The differences among forecasted and actual throughput is illustrated in figure 4.8.

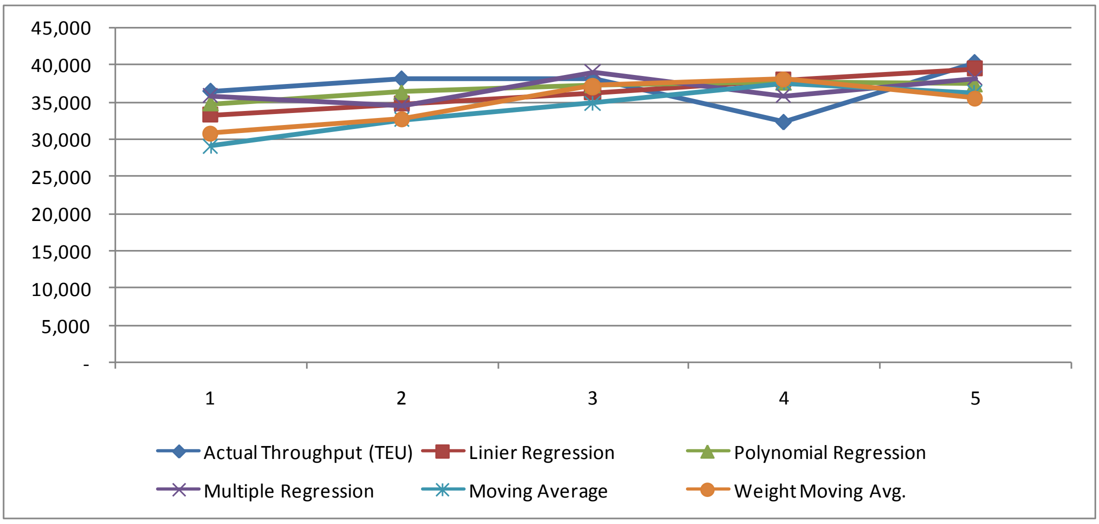


Figure 4.8 - Forecasted and Actual Throughput of Inter-Island Container

Source: Author calculation

The result of MSE values as presents in table 4.7 of all forecasting methods show that multiple regression is the best methods to forecast the ocean going container throughput since it has the smallest MSE equal to 5,689,899.

Table 4.7 - MSE Values (Inter-Island)

| | **Linier Regression** | **Polynomial Regression** | **Multiple Regression** | **Moving Average** | **Weight Moving Average** |
|---|---|---|---|---|---|
| ***MSE*** | **8,559,834** | **6,686,754** | **5,689,899** | **27,463,776** | **23041428.97** |

Source: Author calculation

After selected the multiple regression as a best method to forecast the inter-island throughput for the next five years, then the statistical hypothesis testing conducted to examine the correlation between variables. According to Moon (2012) the steps to conduct the hypothesis testing are as follows:

**Step 1 Formulating 'statistical hypotheses'**

- Null hypothesis ($H_0$) : no effect, no difference, no relations between variables
- Alternative hypothesis ($H_1$)

**Step 2 Selection of 'critical value'**

- A threshold to which the value of the 'test statistic' in a sample is compared to determine whether or not the null hypothesis is rejected
- Depends on the significance level at which the test is carried out, and whether the test is one-sided or two-sided
    - Significance level: a fixed probability of wrongly rejecting the null hypothesis Ho, if it is in fact true.
        - 0.01 (or equivalently, 1%), 0.05, and 0.10
    - Degree of freedom
        - The number of values in the final calculation of a statistic that are free to vary
        - (the number of independent scores that go into the estimate) – (the number of parameters estimated as intermediate steps in the estimation of the parameter itself)

**Step 3 Calculation of 'test statistic'**

- A quantity calculated from the sample of data

$$T = r.\sqrt{(n-2)/(1-r^2)} \qquad (4.1)$$

- Its value is used to decide whether or not the null hypothesis should be rejected in our hypothesis test.

- The choice of a test statistic will depend on the assumed probability model and the hypotheses under question.

**Step 4 Comparison of 2 values: 'critical value' and 'test statistic'**

- If 'the value of test statistic' > 'critical value', 'null hypothesis' is rejected.

**Step 5 Decision-making (in EXCEL format)**

- P(Probability)-values
  - If the P-value is less than the significance level, we reject the null hypothesis.

Table 4.8 – Relations among GDRP, Total Export Import and Inter-Island Throughput

| Year | GDRP | Total Exim | Throughput |
|---|---|---|---|
| Quarter 1 2011 | 233,104 | 31,256 | 25,861 |
| Quarter 2 2011 | 239,714 | 32,906 | 31,631 |
| Quarter 3 2011 | 251,421 | 34,793 | 30,010 |
| Quarter 4 2011 | 258,301 | 36,396 | 36,500 |
| Quarter 1 2012 | 260,694 | 35,384 | 38,137 |
| Quarter 2 2012 | 269,384 | 38,076 | 38,058 |
| Quarter 3 2012 | 280,033 | 35,340 | 32,366 |
| Quarter 4 2012 | 293,627 | 36,261 | 40,313 |

Source: Author calculation

The hypothesis testing between variables are presented as follows:

a) T-test between GDRP and total value of export and import.

- Null hypothesis : $H_0$, no relations between two variables

If 'the value of test statistic' > 'critical value', 'null hypothesis' is rejected.

- $n = 8$
- Degree of freedom: no. of sample – no. of variables = $n - 2 = 6$

  - Significance level: 0.05
- Critical value : 2.447
- Test statistic : $T = 0.737 \times (6 / (1 - 0.737^2))^{0.5} = 2.671$

The results is the value of test statistic 2.671 greater than critical value 2.447 so the hypothesis $H_0$ is rejected means the correlation between GDRP and total value of export import is statistically significant.

b) T-test between GDRP and container throughput.

- Null hypothesis : $H_0$, no relations between two variables

If 'the value of test statistic' > 'critical value', 'null hypothesis' is rejected.

  - n = 8
  - Degree of freedom: no. of sample – no. of variables = n - 2 = 6
  - Significance level: 0.05
- Critical value : 2.447
- Test statistic : $T = 0.745 \times (6 / (1 - 0.745^2))^{0.5} = 2.738$

The results is the value of test statistic 2.738 greater than critical value 2.447 so the hypothesis $H_0$ is rejected means the correlation between GDRP and container throughput is statistically significant.

c) T-test between total value of export and import and container throughput.

- Null hypothesis : $H_0$, no relations between two variables

If 'the value of test statistic' > 'critical value', 'null hypothesis' is rejected.

  - n = 8
  - Degree of freedom: no. of sample – no. of variables = n - 2 = 6
  - Significance level: 0.05
- Critical value : 2.447
- Test statistic : $T = 0.834 \times (6 / (1 - 0.834^2))^{0.5} = 3.695$

The results is the value of test statistic 3.695 greater than critical value 2.447 so the hypothesis $H_0$ is rejected means the correlation between total value of export and import and container throughput is statistically significant.

The next step is to forecast the GDRP of Jakarta province for the next five years (2013-2017) by using regression forecasting model. Linear regression analysis is used where years as an independent variable and GDRP as a dependant variable, the result is $\mathbf{Y=224273.7+8113.6\ X}$ with $\mathbf{R^2=0.978}$, where $\mathbf{Y}$ is GDRP, $\mathbf{X}$ is series number. The forecasting result of GDRP is shown in table 4.9.

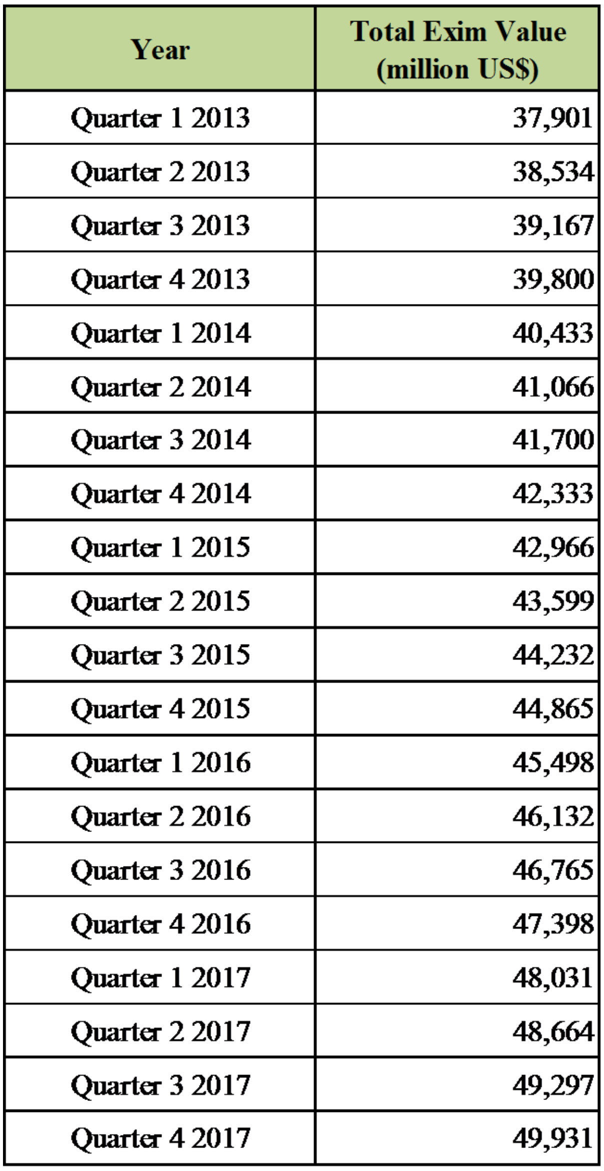
Table 4.9 – GDRP Forecast Quarterly Year 2013 to 2017

| Year | GDRP (billion IDR) |
|---|---:|
| Quarter 1 2013 | 297,296 |
| Quarter 2 2013 | 305,409 |
| Quarter 3 2013 | 313,523 |
| Quarter 4 2013 | 321,636 |
| Quarter 1 2014 | 329,750 |
| Quarter 2 2014 | 337,864 |
| Quarter 3 2014 | 345,977 |
| Quarter 4 2014 | 354,091 |
| Quarter 1 2015 | 362,204 |
| Quarter 2 2015 | 370,318 |
| Quarter 3 2015 | 378,431 |
| Quarter 4 2015 | 386,545 |
| Quarter 1 2016 | 394,658 |
| Quarter 2 2016 | 402,772 |
| Quarter 3 2016 | 410,886 |
| Quarter 4 2016 | 418,999 |
| Quarter 1 2017 | 427,113 |
| Quarter 2 2017 | 435,226 |
| Quarter 3 2017 | 443,340 |
| Quarter 4 2017 | 451,453 |

Source: Author calculation

The forecasting of total value of export import for the next five years (2013-2017) also done by using regression forecasting model where GDRP as an independent variable and total value of export import as dependant variable, the result is **$Y=14700.7+0.078X$** with **$R^2=0.543$**, where **Y** is total value of export import, **X** is GDRP. The forecasting result of total value of export import is shown in table 4.10.

Table 4.10 – Total Export and Import Value Forecast Quarterly Year 2013 to 2017



| Year | Total Exim Value (million US$) |
|---|---:|
| Quarter 1 2013 | 37,901 |
| Quarter 2 2013 | 38,534 |
| Quarter 3 2013 | 39,167 |
| Quarter 4 2013 | 39,800 |
| Quarter 1 2014 | 40,433 |
| Quarter 2 2014 | 41,066 |
| Quarter 3 2014 | 41,700 |
| Quarter 4 2014 | 42,333 |
| Quarter 1 2015 | 42,966 |
| Quarter 2 2015 | 43,599 |
| Quarter 3 2015 | 44,232 |
| Quarter 4 2015 | 44,865 |
| Quarter 1 2016 | 45,498 |
| Quarter 2 2016 | 46,132 |
| Quarter 3 2016 | 46,765 |
| Quarter 4 2016 | 47,398 |
| Quarter 1 2017 | 48,031 |
| Quarter 2 2017 | 48,664 |
| Quarter 3 2017 | 49,297 |
| Quarter 4 2017 | 49,931 |

Source: Author calculation

After calculated the projection of GDRP and total value of export import, finally the container throughput projection will be calculated using multiple regression model, where GDRP and total value of export import are used as independent variables and container throughput as dependant variable.

The result is $\mathbf{Y=-34742.8+0.070X_1+1.441X_2}$ with $\mathbf{R^2=0.732}$, where $\mathbf{Y}$ is container throughput, $\mathbf{X_1}$ is GDRP, $\mathbf{X_2}$ is total value of export import. The result of forecasting throughput for year 2013 to 2017 is presents in table 4.11.

Table 4.11 - Throughput Forecast of Ocean Going Service at MTI
a. Quarterly; b. Yearly 2013-2017

a.

| Year | Throughput (TEU) |
|---|---|
| Quarter 1 2013 | 40,783 |
| Quarter 2 2013 | 42,266 |
| Quarter 3 2013 | 43,749 |
| Quarter 4 2013 | 45,232 |
| Quarter 1 2014 | 46,716 |
| Quarter 2 2014 | 48,199 |
| Quarter 3 2014 | 49,682 |
| Quarter 4 2014 | 51,165 |
| Quarter 1 2015 | 52,648 |
| Quarter 2 2015 | 54,131 |
| Quarter 3 2015 | 55,614 |
| Quarter 4 2015 | 57,097 |
| Quarter 1 2016 | 58,580 |
| Quarter 2 2016 | 60,063 |
| Quarter 3 2016 | 61,546 |
| Quarter 4 2016 | 63,029 |
| Quarter 1 2017 | 64,512 |
| Quarter 2 2017 | 65,995 |
| Quarter 3 2017 | 67,478 |
| Quarter 4 2017 | 68,961 |

b.

| Year | Throughput (TEU) |
|---|---|
| 2013 | 172,031 |
| 2014 | 195,760 |
| 2015 | 219,489 |
| 2016 | 243,218 |
| 2017 | 266,947 |

Source: Author calculation

### 4.3. Ship Calls Projection year 2013-2017

After calculated the container throughput projection in year 2013-2017, the projection of the number of container ship calls which will be berthing at the terminal could be calculated based on container throughput projection. The ship calls historical data in year 2012 of ocean going vessels which presented in table 3.9 shows that the size of the ship in gross tonnage (GT) are vary with the average of 9,607 GT while data of inter-island vessels which presented in table 3.10 shows that the ship size also vary with average size of the ship is 6,562 GT. In term of lift per call (LCP) for ocean going vessels the average is 531 boxes or 687 in term of TEU, meanwhile the average LPC for inter-island vessels is 434 boxes or 515 in TEU.

Ship calls projection for ocean going and inter-island vessels for the next five year can be calculated by dividing the container throughput forecast with call size or average LPC in year 2012 in term of TEU.

For example, ship call of ocean going vessels in year 2013 will be:

$$Ship\ Call = \frac{123{,}696}{687} = 180$$

While ship call of inter-island vessels in year 2013 will be:

$$Ship\ Call = \frac{172{,}031}{515} = 334$$

Using the same method, the ship calls projection for ocean going and inter-island vessels year 2013 to 2017 could be seen in table 4.12 and 4.13.

Table 4.12 - Ship Calls Projection of Ocean Going Vessels year 2013-2017

| Year | Ship Call |
|---|---|
| 2013 | 180 |
| 2014 | 180 |
| 2015 | 180 |
| 2016 | 180 |
| 2017 | 180 |

Source: Author calculation

Table 4.13 - Ship Calls Projection of Inter-Island Vessels year 2013-2017

| Year | Ship Call |
|---|---|
| **2013** | **334** |
| **2014** | **380** |
| **2015** | **426** |
| **2016** | **472** |
| **2017** | **518** |

Source: Author calculation

# Chapter 5

# SIMULATION AND ANALYSIS

This chapter is the essence of the study in which will process and analyze the data that collected and presented in chapter 3 and chapter 4. This chapter will discuss the following subjects:

a. The simulation and analysis of berth capacity using Arena software.

b. The analysis of yard capacity using traditional method.

c. The analysis of Proper Container Terminal Capacity (PCTC).

d. The analysis of future capacity for the next five years within the terminal.

## 5.1. Berth Simulation

In this simulation model the container ship will be used as a main entity, while the container throughput will be determined as performance measurement. The simulation model developed in this study will be processed using ARENA simulation program which is software with predefined modules. The queuing system of ship arrival within the MTI container terminal will be modeled and simulated using appropriate modules. The distribution of histogram graph with data summary can be obtained in this software. The simulation starts by making entity of the “create” module of ship arrivals, then different modules are made up for the process (waiting, berthing, unloading/loading, etc.) and finally at the end of simulation generated entity named “dispose” module means ship leaves the port. The flowchart of terminal operation in the quay is shown in figure 5.1.

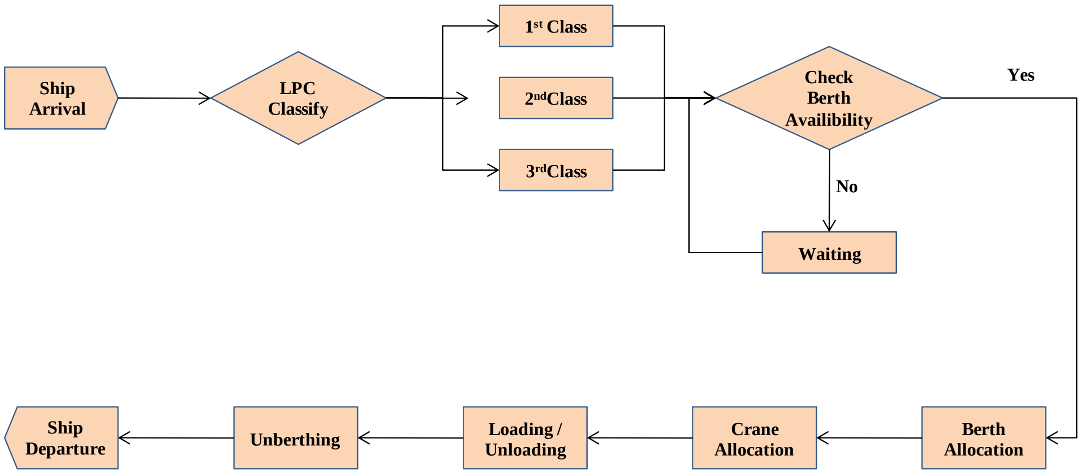


Figure 5.1 - Flowchart of Terminal Operation Simulation

Source: Author

There are several activities used to calculate berth simulation such as ship arrival, berth allocation, crane deployment, berthing time and unberthing time. The proper capacity of berth in MTI container terminal will be simulated using data source collected for one year period from January 2012 to December 2012 is shown in table 5.1.

Table 5.1 - Data Source for Berth Simulation

| **MTI container terminal** | |
|---|---|
| Period of data collection | Jan-Dec 2012 |
| Number of ship | |
| a. Ocean Going | 185 |
| b. Inter-Island | 289 |
| Actual berthing time | O |
| Actual unberthing time | O |
| Length of ships (m) | O |
| Carrying capacity (TEU) | - |
| Box unloaded | O |
| Box loaded | O |
| TEU unloaded | O |
| TEU loaded | O |
| No of assigned crane (average) | O |
| Total working hours per crane | O |

Source: Author

The inputs used and outputs produced for the berth simulation of MTI container terminal shows in table 5.2.

Table 5.2 - Input and Output Variables for Berth Simulation

| **Item** | | **Variables** | **Description** |
|---|---|---|---|
| **Input** | Vessel | Time interval on ship arriving | Distribution on time interval |
| | | The amount of cargo handled | Distribution on LPC |
| | Berth and Time | Number of berth | Berths by the port type |
| | | Working Time | Working days and hours |
| | Quay crane | Number of allocated crane | For each LPC |
| | | Capability per hours | Crane productivity |
| **Output** | Capability | Quay capability | Annual throughput |
| | Berth | Berth occupancy ratio | Berth occupying time/total operating |
| | Vessel | Ship waiting ratio | Berth waiting time/total service time |
| | | Time of staying in the port | Duration time from arriving to leaving |

Source: Author

### 5.1.1. Berth Simulation for Ocean Going Service

Using data of ocean going service in year 2012 at the MTI terminal, form the actual data found that the ratio of container lifts at berth 30% of 40’ and 70% of 20’ containers, therefore in the simulation one lift equals to 1.3 TEU. In addition, within the simulation, the proper throughput will be calculated using the recommended of high berth occupancy ratio (BOR) for one berth which is 45% as presented in chapter 2, table 2.1, and the assumption of the preparation time for ship berthing and unberthing remains unchanged.

a. Input Variables

There are three items in input for berth simulation, vessel, berth and time and quay crane as presented in table 5.2.

1) Vessel

The distribution on time interval among container vessels berthed is “erlang” with expression ERLA(23.7, 2), this distribution has the smallest square error of 0.001484. The histogram of interval time presents in figure 5.2.

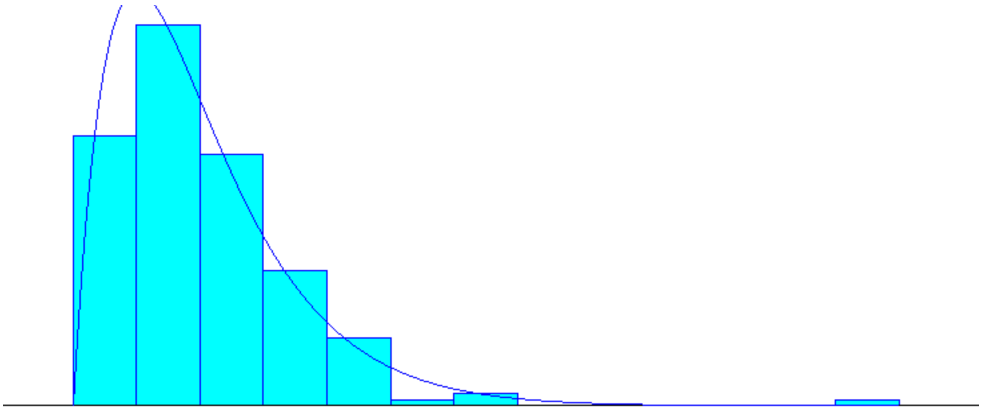


Figure 5.2 - Histogram of Ship Inter-arrival Times of Ocean Going Vessels

Source: Author calculation – Distribution summary presented in Appendix 1

The amount of cargo handled each vessel which called lift per call (LPC), were already divided into three classes in order to make a queue simulation analysis effective and realistic. The first class is LPC1 consist of 1-499 moves, the second class is LPC2 consist of 500-999 moves, and the last is LPC3 consist of 1000 moves and more. The distribution of LPC categories is shown in table 5.3, LPC1 is “gamma” with expression 4+GAMM(204, 0.562), distribution of LPC2 is “beta” with expression 507+488*BETA(1.32, 0.822) and distribution of LPC3 is “triangular” with expression TRIA(1.01e+003, 1.08e+003, 1.39e+003). The histogram of each class of LPC from the ARENA program could be seen in figure 5.3, 5.4 and 5.5.

Table 5.3 - Distribution of LPC Categories for Ocean Going

| LPC Categories | No of LPC | No of ship | % | Distribution Estimation | Expression |
|---|---|---|---|---|---|
| LPC1 | 1-499 | 87 | 47.0% | Gamma | 4 + GAMM(204, 0.562) |
| LPC2 | 500-999 | 73 | 39.5% | Beta | 507 + 488 * BETA(1.32, 0.822) |
| LPC3 | 1000-1499 | 25 | 13.5% | Triangular | TRIA(1.01e+003, 1.08e+003, 1.39e+003) |
| Total | | 185 | 100% | | |

Source: Author calculation

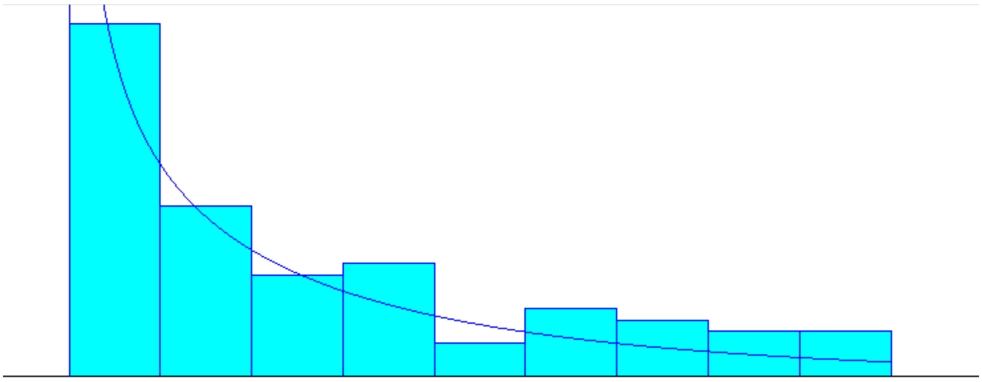


Figure 5.3 - Histogram of LPC1 of Ocean Going Vessels

Source: Author calculation - Distribution summary presented in Appendix 2

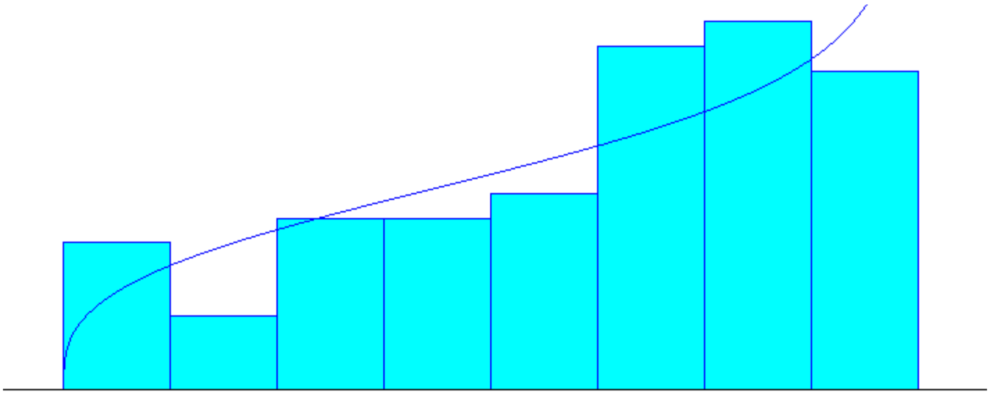


Figure 5.4 - Histogram of LPC2 of Ocean Going Vessels

Source: Author calculation - Distribution summary presented in Appendix 3

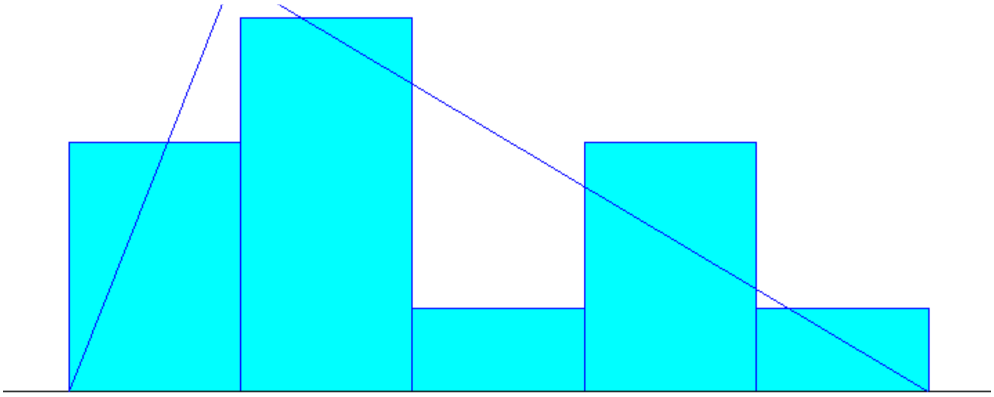


Figure 5.5 - Histogram of LPC3 of Ocean Going Vessels

Source: Author calculation - Distribution summary presented in Appendix 4

2) Berth and Time

The number of berth in MTI container terminal for ocean going service consisted of one berth and working time within the terminal is 365 days in a year and 24 hours in a day.

3) Quay Crane

The empirical distribution of the number of assigned quay cranes corresponding to each LPC category which obtained from actual data in year 2012 is illustrated in Table 5.4.

Table 5.4 - Empirical Distribution of the Number of Assigned Cranes (Ocean Going)

| **LPC1 (1-499)** | | | **LPC2 (500-999)** | | | **LPC3 (1000~)** | | |
|---|---|---|---|---|---|---|---|---|
| **Cranes** | **%** | **Cum %** | **Cranes** | **%** | **Cum %** | **Cranes** | **%** | **Cum %** |
| 1 | 29% | 29% | 1 | 4% | 4% | 1 | 4% | 4% |
| 2 | 54% | 83% | 2 | 51% | 55% | 2 | 36% | 40% |
| 3 | 17% | 100% | 3 | 45% | 100% | 3 | 60% | 100% |
| 4 | 0% | 100% | 4 | 0% | 100% | 4 | 0% | 100% |
| | 100% | | | 100% | | | 100% | |

Source: Author calculation

The productivity of cranes is total moves per call (LPC) divided by total cranes working hours. The distribution is "weibull" with expression 1 + WEIB(4.1, 0.69), this distribution has the smallest square error which is 0.001135, the histogram of the crane productivity presents in figure 5.6.

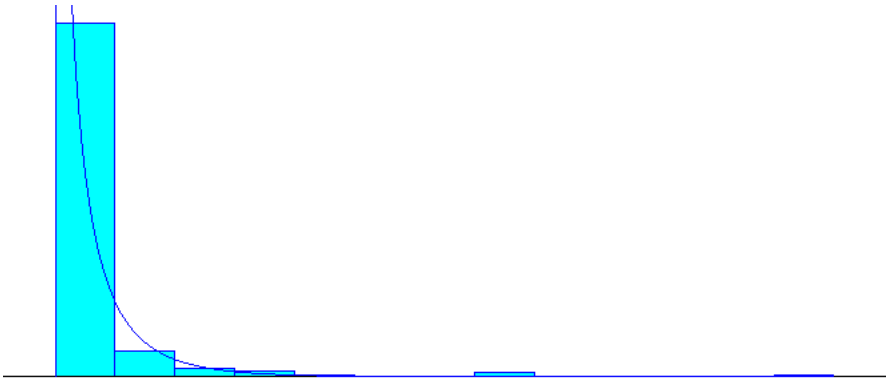
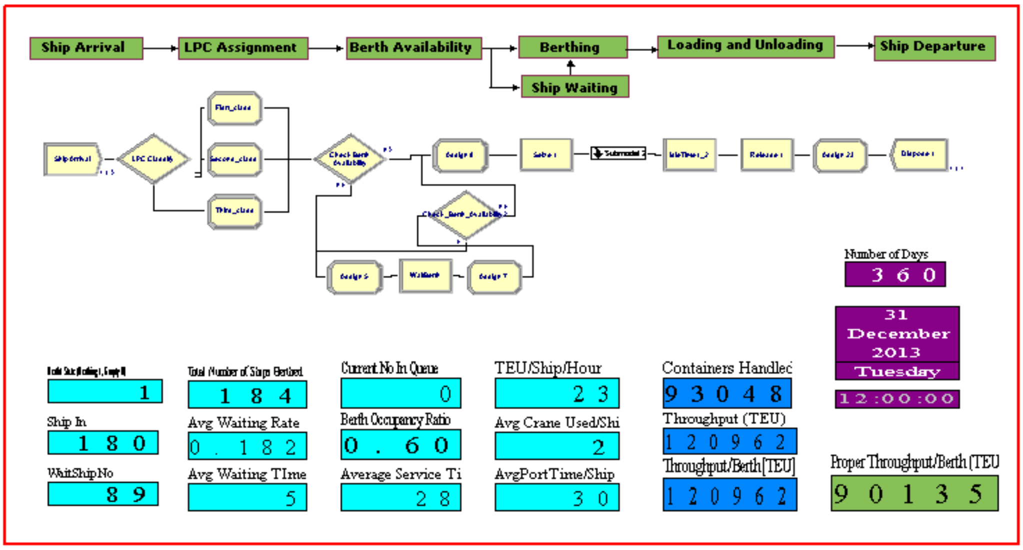


Figure 5.6 - Histogram of Crane Productivity of Ocean Going Vessels

Source: Author calculation - Distribution summary presented in Appendix 5

b. Output Variables

The berth simulation is proposed in figure 5.7 as represent the processes relevant to ship as well as container movement in MTI container terminal for ocean going service. From the simulation output, the annual throughput is 93,048 containers or 120,962 in term of TEU, berth occupancy ratio (BOR) is 60%, ship waiting ratio is 18% and total time of vessel in the port is 30 hours.



Total Number of Ships Berthed: 1 8 4
Current No In Queue: 0
TEU/Ship/Hour: 2 3
Containers Handlec: 9 3 0 4 8
Ship In: 1 8 0
Avg Waiting Rate: 0 . 1 8 2
Berth Occupancy Ratio: 0 . 6 0
Avg Crane Used/Shi: 2
Throughput (TEU): 1 2 0 9 6 2
WaitShipNo: 8 9
Avg Waiting TIme: 5
Average Service Ti: 2 8
AvgPortTime/Ship: 3 0
Throughput/Berth [TEU]: 1 2 0 9 6 2
Number of Days: 3 6 0
31 December 2013 Tuesday
12:00:00
Proper Throughput/Berth (TEU: 9 0 1 3 5

Figure 5.7 - Berth Simulation and Current Performance (Ocean Going) in ARENA

Source: Author calculation

### 5.1.2. Berth Simulation for Inter-Island Service

Using data of inter-island service in year 2012 at the MTI terminal, form the actual data found that the ratio of container lifts at berth 20% of 40’ and 80% of 20’ containers, therefore in the simulation one lift equals to 1.2 TEU. In addition, the same as simulation for ocean going, the proper throughput will be calculated using the recommended of high berth occupancy ratio (BOR) for one berth which is 45% as presented in chapter 2, table 2.1, and the assumption of the preparation time for ship berthing and unberthing remains unchanged.

a. Input Variables

There are three items in input for berth simulation, vessel, berth and time and quay crane as presented in table 5.2.

1) Vessel

The distribution on time interval among container vessels berthed is “weibull” with expression WEIB(33, 1.38), this distribution has the smallest square error of 0.003284. The histogram of interval time presents in figure 5.8.

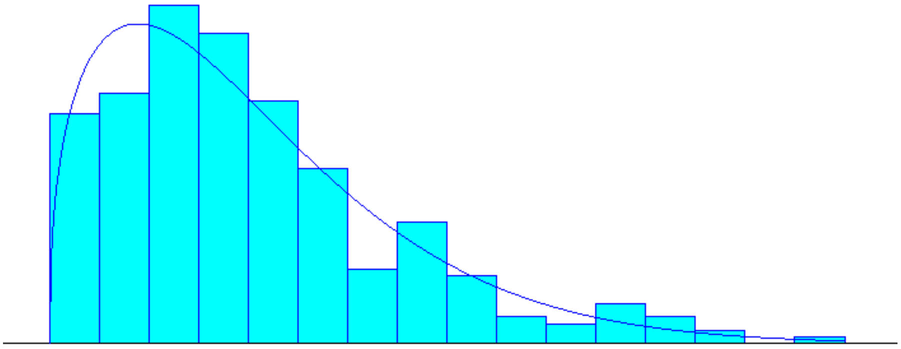


Figure 5.8 - Histogram of Ship Inter-arrival Times of Inter-Island Vessels

Source: Author calculation - Distribution summary presented in Appendix 6

The same way as ocean going simulation, the LPC divided into three classes in order to make a queue simulation analysis effective and realistic. The first class is LPC1 consist of 1-499 moves, the second class is LPC2 consist of 500-999 moves, and the last is LPC3 consist of 1000 moves and more. The distribution of LPC categories is shown in table 5.5, LPC1 is “beta” with expression 20+479*BETA(1.57, 1.31), distribution of LPC2 is “weibull” with expression 501+WEIB(150, 1.11) and distribution of LPC3 is “exponential” with expression 1e+003+EXPO(91). The histogram of each class of LPC from the ARENA program could be seen in figure 5.9, 5.10 and 5.11.

Table 5.5 - Distribution of LPC Categories for Inter-Island

| LPC Categories | No of LPC | No of ship | % | Distribution Estimation | Expression |
|---|---|---|---|---|---|
| LPC1 | 1-499 | 191 | 66.1% | Beta | 20 + 479 * BETA(1.57, 1.31) |
| LPC2 | 500-999 | 79 | 27.3% | Weibull | 501 + WEIB(150, 1.11) |
| LPC3 | 1000-1499 | 19 | 6.6% | Exponential | 1e+003 + EXPO(91) |
| Total | | 289 | 100% | | |

Source: Author calculation

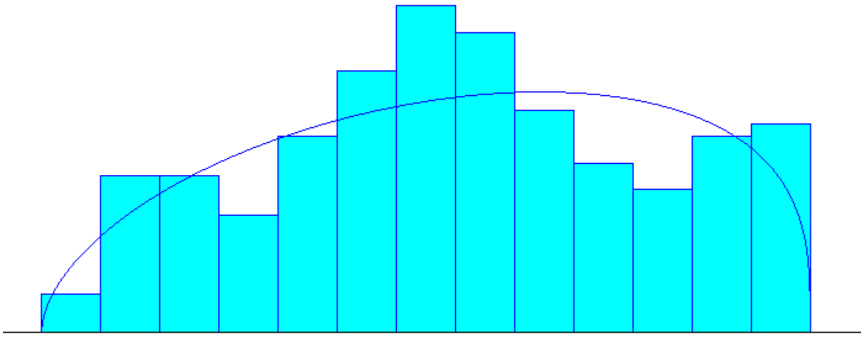


Figure 5.9 -Histogram of LPC1 of Inter-Island Vessels

Source: Author calculation - Distribution summary presented in Appendix 7

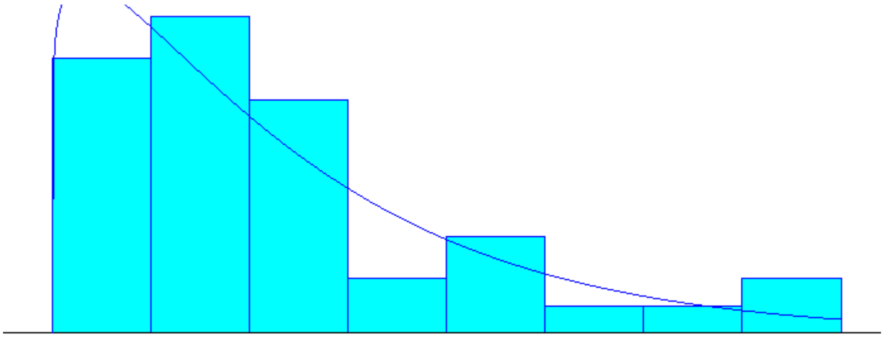


Figure 5.10 - Histogram of LPC2 of Inter-Island Vessels

Source: Author calculation - Distribution summary presented in Appendix 8

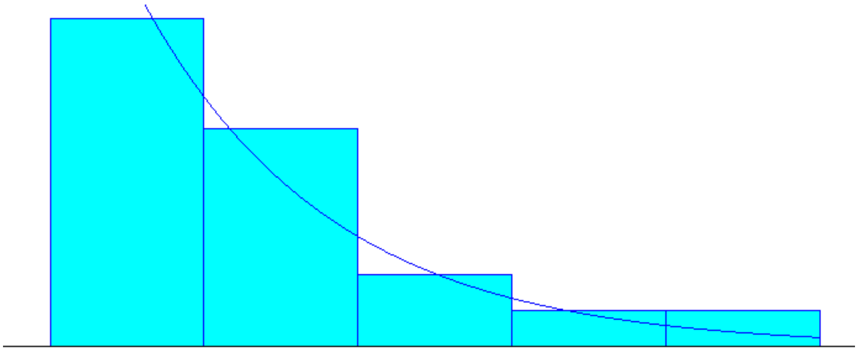


Figure 5.11 - Histogram of LPC3 of Inter-Island Vessels

Source: Author calculation - Distribution summary presented in Appendix 9

2) Berth and Time

The number of berth in MTI container terminal for inter-island is same with ocean going service consisted of one berth as well as working time within the terminal is 365 days in a year and 24 hours in a day.

3) Quay Crane

The empirical distribution of the number of assigned quay cranes corresponding to each LPC category which obtained from actual data in year 2012 is illustrated in Table 5.6.

Table 5.6 - Empirical Distribution of the Number of Assigned Cranes (Inter-Island)

| **LPC1 (1-499)** | | | **LPC2 (500-999)** | | | **LPC3 (1000~)** | | |
|---|---|---|---|---|---|---|---|---|
| **Cranes** | **%** | **Cum %** | **Cranes** | **%** | **Cum %** | **Cranes** | **%** | **Cum %** |
| 1 | 17% | 17% | 1 | 9% | 9% | 1 | 21% | 21% |
| 2 | 77% | 94% | 2 | 84% | 92% | 2 | 68% | 89% |
| 3 | 6% | 100% | 3 | 8% | 100% | 3 | 11% | 100% |
| 4 | 0% | 100% | 4 | 0% | 100% | 4 | 0% | 100% |
| | 100% | | | 100% | | | 100% | |

Source: Author calculation

The productivity of cranes in inter-island service is illustrated by distribution of "lognormal" with expression 1 + LOGN(3.38, 2), this distribution has the smallest square error which is 0.002534, the histogram of the crane productivity presents in figure 5.12.

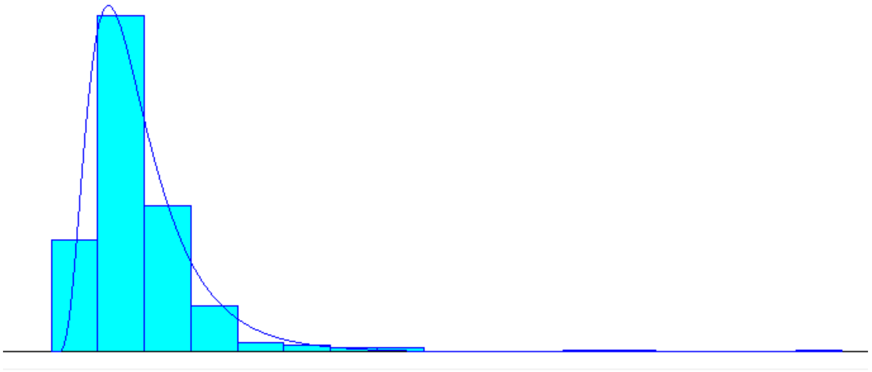
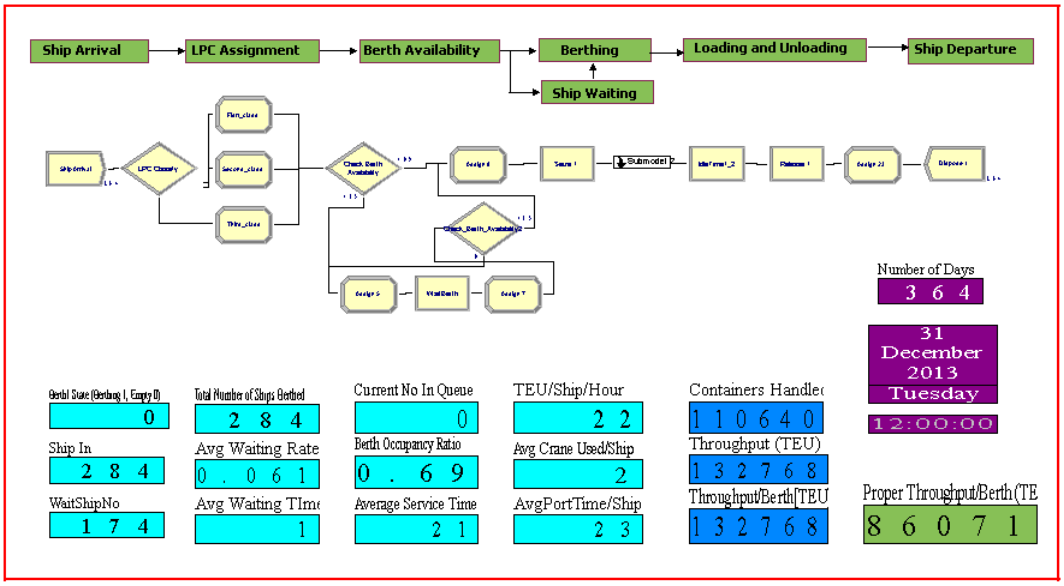


Figure 5.12 - Histogram of Crane Productivity of Inter-Island Vessels

Source: Author calculation - Distribution summary presented in Appendix 10

b. Output Variables

The berth simulation for inter-island service is proposed in figure 5.13 as represent the processes relevant to ship as well as container movement in MTI container terminal. From the simulation output, the annual throughput is 110,640 containers or 132,768 in term of TEU, berth occupancy ratio (BOR) is 69%, ship waiting ratio is 6% and total time of vessel in the port is 23 hours.



Berth State (Berthing 1, Empty 0) 0
Ship In 2 8 4
WaitShipNo 1 7 4
Total Number of Ships Berthed 2 8 4
Avg Waiting Rate 0 . 0 6 1
Avg Waiting TIme 1
Current No In Queue 0
Berth Occupancy Ratio 0 . 6 9
Average Service Time 2 1
TEU/Ship/Hour 2 2
Avg Crane Used/Ship 2
AvgPortTime/Ship 2 3
Containers Handle 1 1 0 6 4 0
Throughput (TEU) 1 3 2 7 6 8
Throughput/Berth[TEU 1 3 2 7 6 8
Number of Days 3 6 4
31 December 2013 Tuesday
12:00:00
Proper Throughput/Berth(TE 8 6 0 7 1

Figure 5.13 - Berth Simulation and Current Performance (Inter-Island) in ARENA

Source: Author calculation

### 5.1.3. Verification and Validation of The Model

The last step is to verify and validate the simulation model. Verification performed to know whether the model used is compliant with the concepts that have been defined. By running the simulation model, it is observed that the generated entities move to follow the right path through the entire modules from “create” to “dispose” module. During running the simulation model, the performance of all modules, entities and resources are examined, and it can be observed that the model is correctly represent design concept.

Moreover, validation performed to ensure that the model can represent the real system properly. The validation was conducted by comparing the actual operation data with the simulation results i.e. container throughput in TEU and total number of ship berthed. The actual throughput of ocean going vessel is 127,124 TEU while throughput from simulation is 120,962 TEU, at the same time, actual throughput of inter-island vessel is 148,874 TEU while from simulation output is 132,768 TEU. In addition, the actual number of ship berthed in ocean going is 185 ships while from simulation result is 184 ships, at the same time, actual number of ship berthed in inter-island is 289 ships while from simulation result is 284 ships. The validation data for simulation accuracy is presents in figure 5.14 shows that the developed simulation model has a good ability to represent the real operation status of terminals.

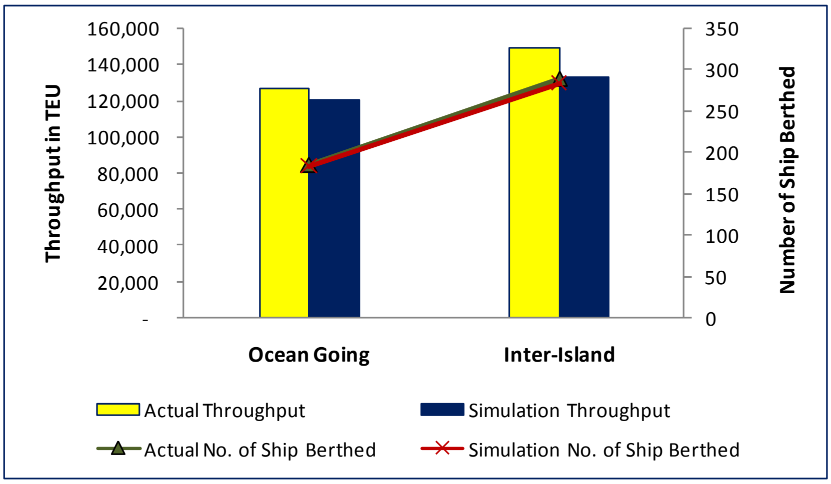


Figure 5.14 - Validation Data for Berth Simulation Accuracy

Source: Author calculation

### 5.1.4. Conclusion

Finally, after running the simulation model it was found that the proper berth throughput for ocean going service is 90,135 TEU as shown in figure 5.7 while for inter-island service is 86,071 TEU as shown in figure 5.13.

## 5.2. Analysis of Yard Capacity Required in Terminal

In this study, the proper yard throughput will be calculated using traditional method proposed by Dally (1983) in equation 2.4. Based on the data collected, it was found that:

- TEU ground slot (TGS) of ocean going service is 702 TEU.
- TGS of inter-island service is 712 TEU.
- Average stacking height (H) for import and export is 4.5 containers high, the same as for inbound and outbound.
- Land utilization ratio (U) is 80% for both services.
- Operating days (K) in a year is 365 days.
- Dwell time (DT) import and export is 7 days.
- Dwell time (DT) inbound and outbound is 5 days.
- Peaking factor is 1.30.

The yard throughput of ocean going service will be calculated using the above points as follow:

$$Cc = \frac{(\text{Tgs x H x U x K})}{(\text{DT x PF})} = \frac{702 \text{ x } 4.5 \text{ x } 80\% \text{ x } 365}{7 \text{ x } 1.3} = 101{,}366\, TEU$$

Meanwhile, yard throughput of inter-island service will be calculated using the above points as follow:

$$Cc = \frac{(\text{Tgs x H x U x K})}{(\text{DT x PF})} = \frac{712 \text{ x } 4.5 \text{ x } 80\% \text{ x } 365}{5 \text{ x } 1.3} = 143{,}934\, TEU$$

### 5.3. Analysis of Proper Container Terminal Capacity (PCTC)

Proper Container Terminal Capacity (PCTC) is handling capacity to cope with incoming cargoes with no congestion which leads to the port with competitive edge and to satisfy customers. According to Moon (2012), PCTC is calculated by comparing berth capacity with yard capacity, i.e. whichever is lower is considered as PCTC. From the berth simulation and analysis of yard capacity, it was found that for ocean going service the berth capacity is 90,135 TEU and yard capacity is 101,366 TEU, it means that berth capacity is lower than yard capacity so the PCTC for ocean going service is 90,135 TEU. Meanwhile, in inter-island service the berth capacity is

86,071 TEU and yard capacity is 143,934 TEU, means the berth capacity also lower than yard capacity so the PCTC for inter-island service is 86,071 TEU. The PCTC of both services illustrated in figure 5.15.

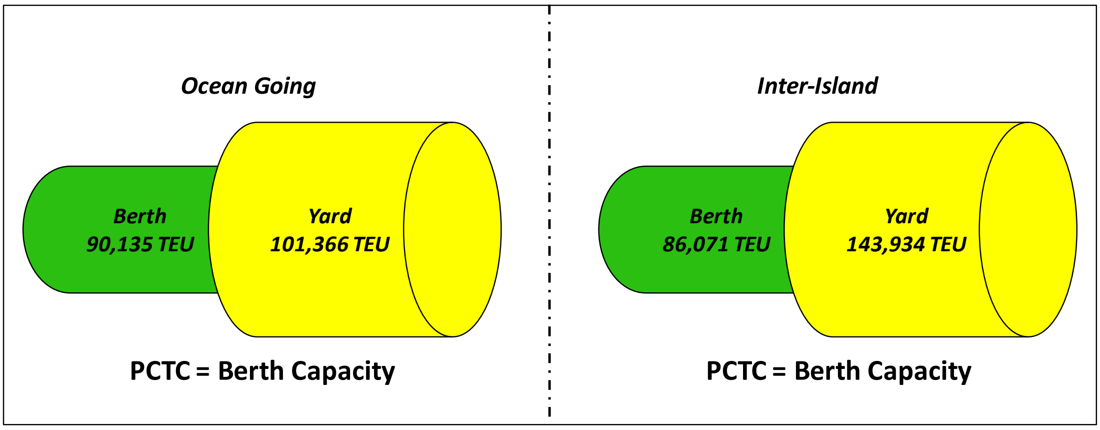


Figure 5.15 - Proper Container Terminal Capacity (PCTC) of MTI

Source: Author calculation

### 5.4. Analysis of Future Capacity for the Next Five Years within Terminal

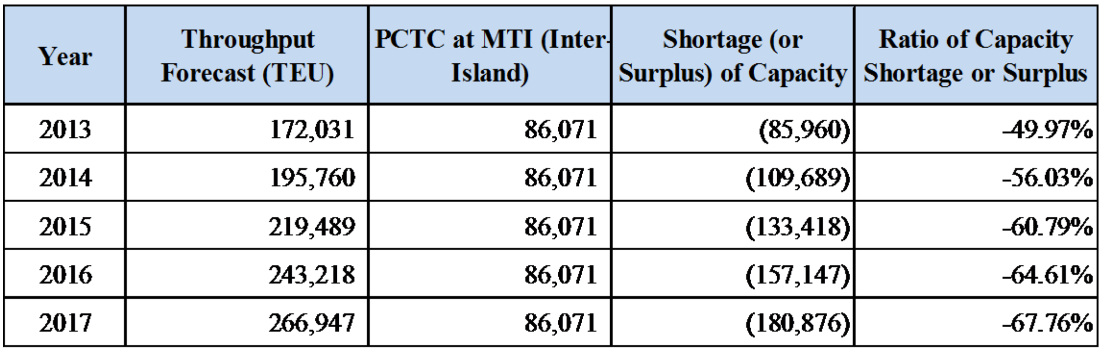
After getting the container throughput projections for the year 2013 to 2017 in chapter 4 and PCTC in chapter 5 section 5.3 then by comparing both of these two, it will be seen whether the terminal shortage or surplus capacity. The result is shown in table 5.7 and 5.8.

Table 5.7 - Terminal Capacity Shortage or Surplus of Ocean Going Service

| Year | Throughput Forecast (TEU) | PCTC at MTI (Ocean Going) | Shortage (or Surplus) of Capacity | Ratio of Capacity Shortage or Surplus |
|---|---|---|---|---|
| 2013 | 123,696 | 90,135 | (33,561) | -27.13% |
| 2014 | 123,840 | 90,135 | (33,705) | -27.22% |
| 2015 | 123,831 | 90,135 | (33,696) | -27.21% |
| 2016 | 123,832 | 90,135 | (33,697) | -27.21% |
| 2017 | 123,832 | 90,135 | (33,697) | -27.21% |

Source: Author calculation

Table 5.8 - Terminal Capacity Shortage or Surplus of Inter-Island Service



| Year | Throughput Forecast (TEU) | PCTC at MTI (Inter-Island) | Shortage (or Surplus) of Capacity | Ratio of Capacity Shortage or Surplus |
|---|---|---|---|---|
| 2013 | 172,031 | 86,071 | (85,960) | -49.97% |
| 2014 | 195,760 | 86,071 | (109,689) | -56.03% |
| 2015 | 219,489 | 86,071 | (133,418) | -60.79% |
| 2016 | 243,218 | 86,071 | (157,147) | -64.61% |
| 2017 | 266,947 | 86,071 | (180,876) | -67.76% |

Source: Author calculation

From the above table 5.7 and 5.8 shows that there are shortage capacity in both services for the year 2013 to 2017, for ocean going service the shortage ratio is around 27% for the next five years, while shortage ratio for inter-island service is around 49% in year 2013 and continue to rise to 67% in year 2017.

# Chapter 6

# CONCLUSION AND RECOMMENDATION

The simulation model presented in this study is a tool for evaluating the quay performance at MTI container terminal. There are various outputs from simulation that reflect the measurement of service level. The results obtained from simulation model have been verified using actual data. The simulation model shows that the terminal has over throughput handled for ocean going and inter-island as well.

The mathematical model presented in this study is a tool for evaluating the yard performance at MTI container terminal. The calculation considering operational matter, i.e. TGS, dwell time, stacking height, operating days in a year, land utilization as well as peaking factor.

The future demand of the container terminal calculated using the smallest MSE of five forecasting methods, i.e. single regression method, polynomial regression method, multiple regression method, moving average method and weight moving average method.

The contributions of this study are berth simulation development to find the proper berth throughput, analysis of the calculation of container yard capacity to find the proper yard throughput and analysis of future capacity. By comparing the proper berth throughput and yard throughput it has been found out that the proper capacity of ocean going terminal and inter-island terminal are same as berth throughput.

Furthermore, from the analysis of future capacity, it has been found out that the ocean going terminal and inter-island terminal will suffer from lack of capacity. Our recommendation to the management of the terminal is to develop the capacity of the ocean going terminal and inter-island terminal as well in order to improve the quality of service. The recommendation for future research is adding the calculation of total cost model to know the minimum total cost in order to meet the requirements of the customers in term of reducing waiting cost as well as service cost in term of the terminal.

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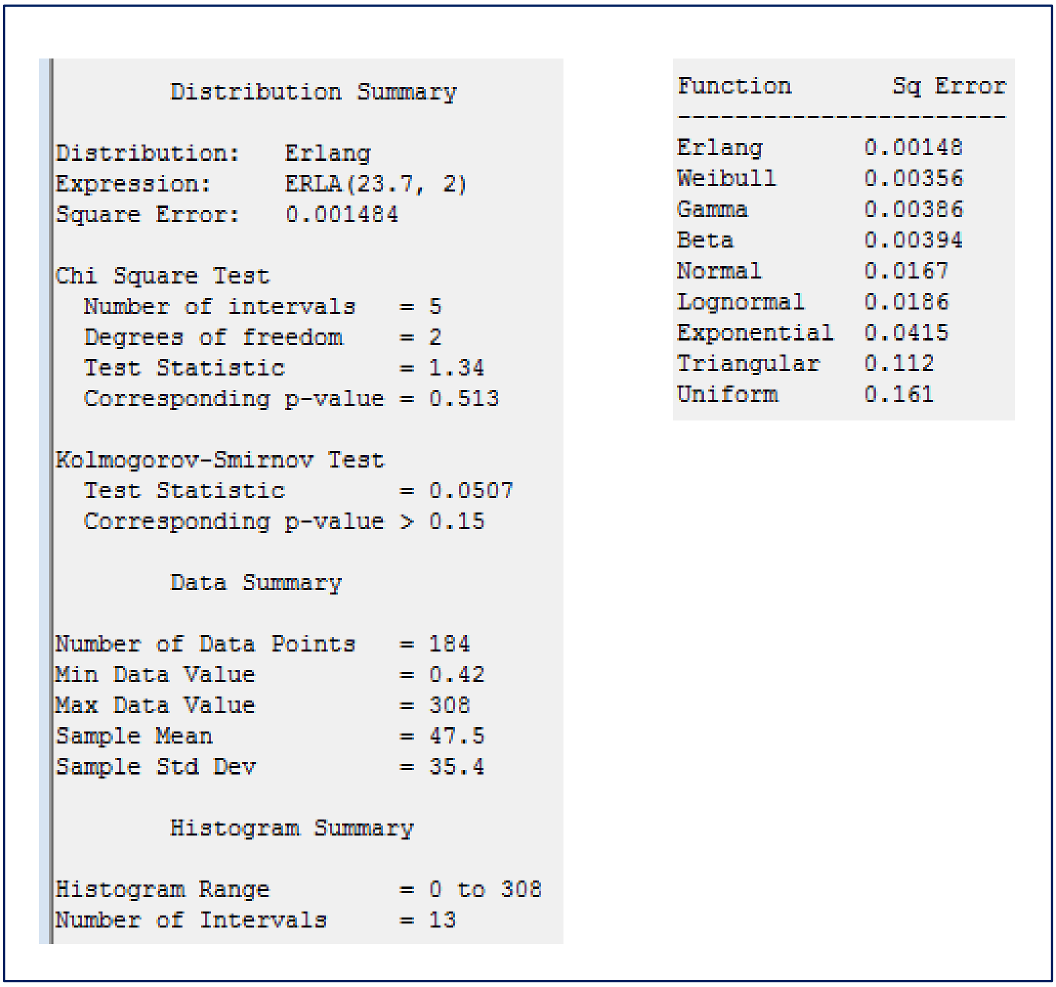
# APPENDICES

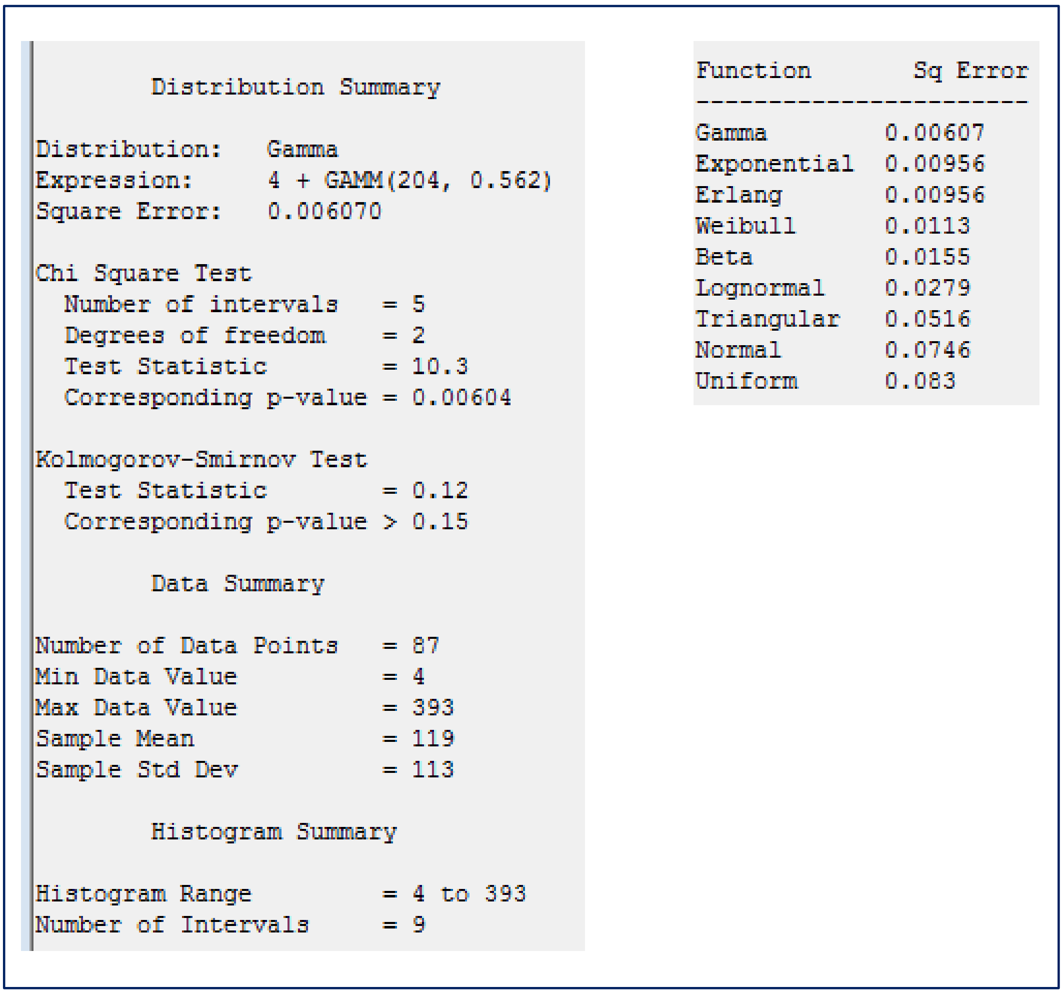
## Appendix 1 Summary of Ship Inter-arrival Times Histogram (Ocean Going)



```
        Distribution Summary

Distribution:   Erlang
Expression:     ERLA(23.7, 2)
Square Error:   0.001484

Chi Square Test
  Number of intervals    = 5
  Degrees of freedom     = 2
  Test Statistic         = 1.34
  Corresponding p-value  = 0.513

Kolmogorov-Smirnov Test
  Test Statistic         = 0.0507
  Corresponding p-value  > 0.15

        Data Summary

Number of Data Points    = 184
Min Data Value           = 0.42
Max Data Value           = 308
Sample Mean              = 47.5
Sample Std Dev           = 35.4

        Histogram Summary

Histogram Range          = 0 to 308
Number of Intervals      = 13
```

```
Function        Sq Error
-----------------------
Erlang          0.00148
Weibull         0.00356
Gamma           0.00386
Beta            0.00394
Normal          0.0167
Lognormal       0.0186
Exponential     0.0415
Triangular      0.112
Uniform         0.161
```

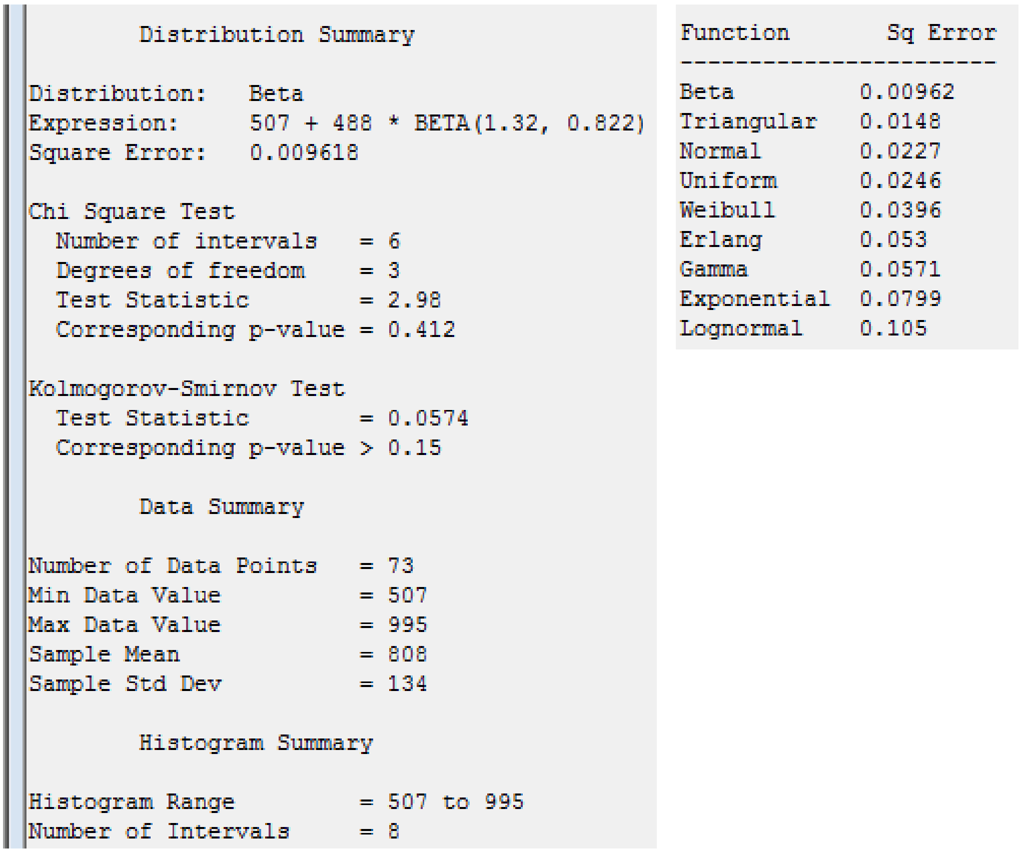
## Appendix 2 Summary of LPC1 Histogram (Ocean Going)



```
        Distribution Summary

Distribution:   Gamma
Expression:     4 + GAMM(204, 0.562)
Square Error:   0.006070

Chi Square Test
  Number of intervals   = 5
  Degrees of freedom    = 2
  Test Statistic        = 10.3
  Corresponding p-value = 0.00604

Kolmogorov-Smirnov Test
  Test Statistic        = 0.12
  Corresponding p-value > 0.15

        Data Summary

Number of Data Points   = 87
Min Data Value          = 4
Max Data Value          = 393
Sample Mean             = 119
Sample Std Dev          = 113

        Histogram Summary

Histogram Range         = 4 to 393
Number of Intervals     = 9
```

```
Function        Sq Error
-----------------------
Gamma         0.00607
Exponential   0.00956
Erlang        0.00956
Weibull       0.0113
Beta          0.0155
Lognormal     0.0279
Triangular    0.0516
Normal        0.0746
Uniform       0.083
```

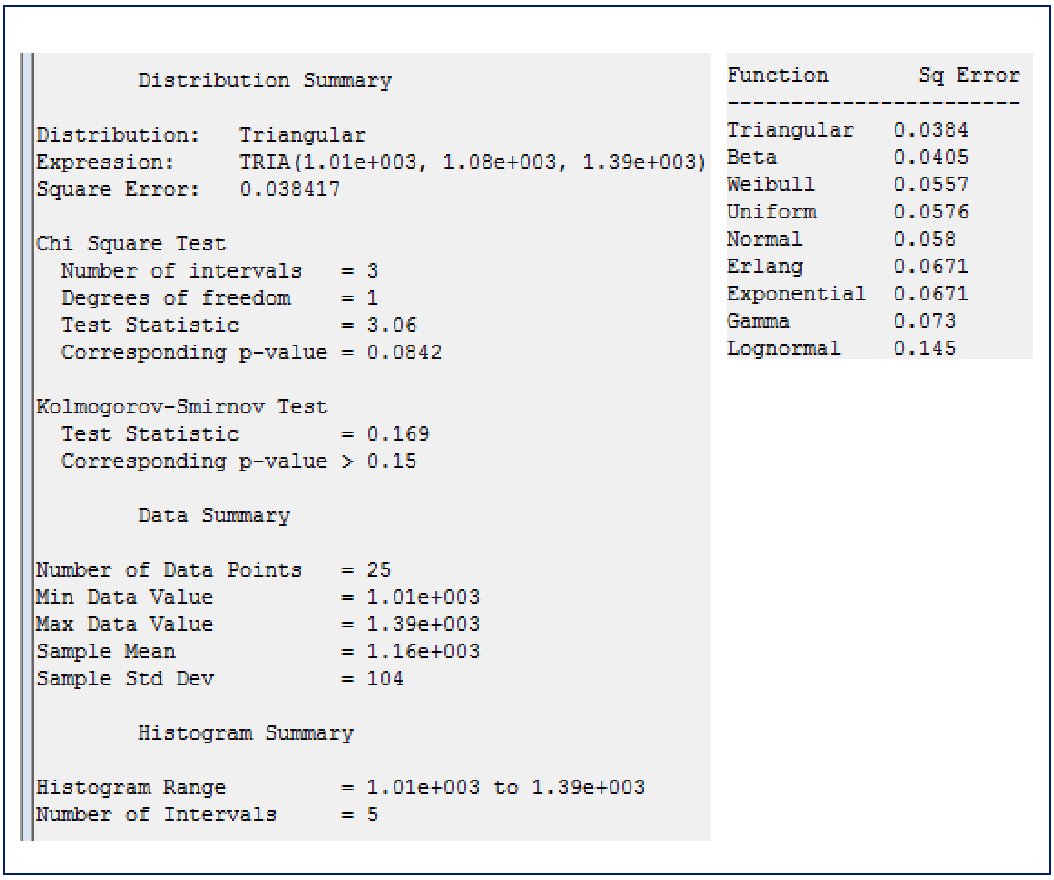
## Appendix 3 Summary of LPC2 Histogram (Ocean Going)



```
        Distribution Summary

Distribution:   Beta
Expression:     507 + 488 * BETA(1.32, 0.822)
Square Error:   0.009618

Chi Square Test
  Number of intervals   = 6
  Degrees of freedom    = 3
  Test Statistic        = 2.98
  Corresponding p-value = 0.412

Kolmogorov-Smirnov Test
  Test Statistic        = 0.0574
  Corresponding p-value > 0.15

        Data Summary

Number of Data Points   = 73
Min Data Value          = 507
Max Data Value          = 995
Sample Mean             = 808
Sample Std Dev          = 134

        Histogram Summary

Histogram Range         = 507 to 995
Number of Intervals     = 8
```

```
Function        Sq Error
-----------------------
Beta            0.00962
Triangular      0.0148
Normal          0.0227
Uniform         0.0246
Weibull         0.0396
Erlang          0.053
Gamma           0.0571
Exponential     0.0799
Lognormal       0.105
```

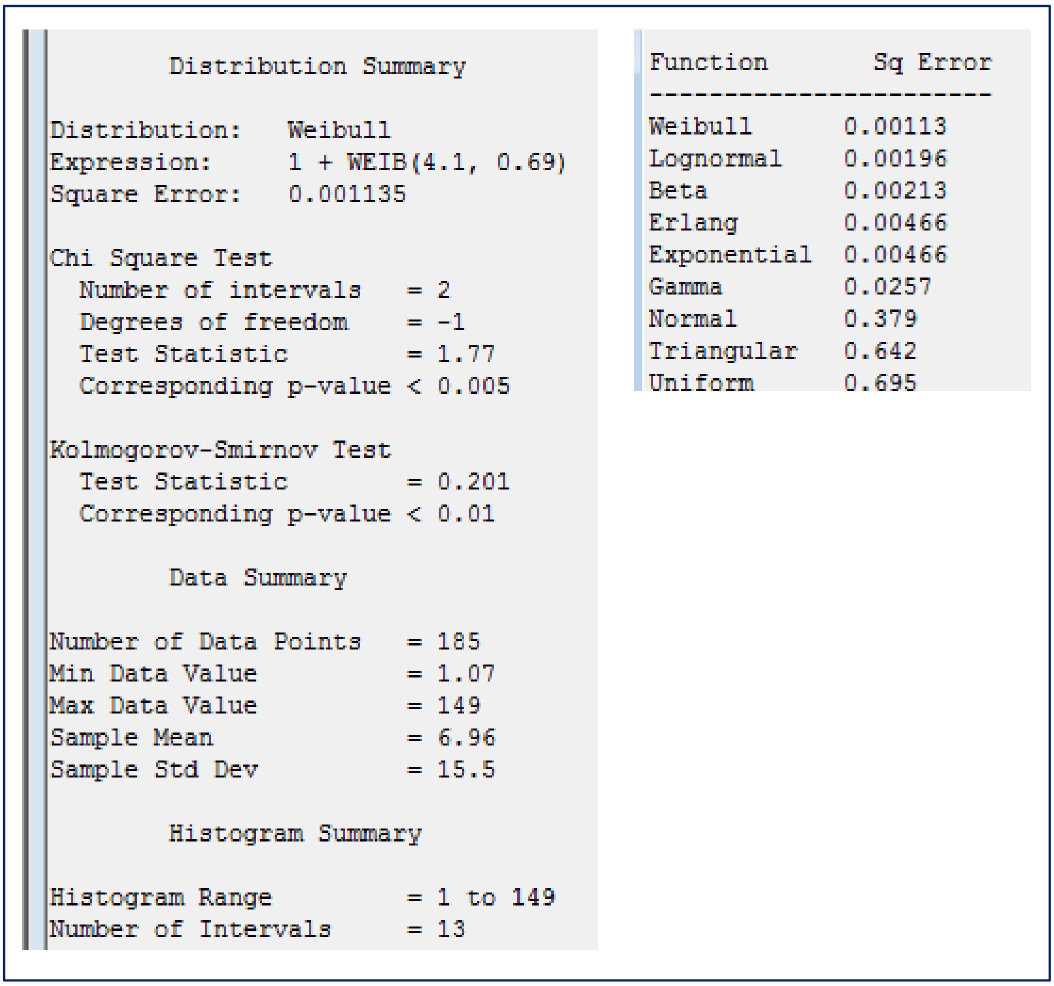
## Appendix 4 Summary of LPC3 Histogram (Ocean Going)



```
        Distribution Summary

Distribution:   Triangular
Expression:     TRIA(1.01e+003, 1.08e+003, 1.39e+003)
Square Error:   0.038417

Chi Square Test
  Number of intervals   = 3
  Degrees of freedom    = 1
  Test Statistic        = 3.06
  Corresponding p-value = 0.0842

Kolmogorov-Smirnov Test
  Test Statistic        = 0.169
  Corresponding p-value > 0.15

        Data Summary

Number of Data Points   = 25
Min Data Value          = 1.01e+003
Max Data Value          = 1.39e+003
Sample Mean             = 1.16e+003
Sample Std Dev          = 104

        Histogram Summary

Histogram Range         = 1.01e+003 to 1.39e+003
Number of Intervals     = 5
```

```
Function        Sq Error
-----------------------
Triangular      0.0384
Beta            0.0405
Weibull         0.0557
Uniform         0.0576
Normal          0.058
Erlang          0.0671
Exponential     0.0671
Gamma           0.073
Lognormal       0.145
```

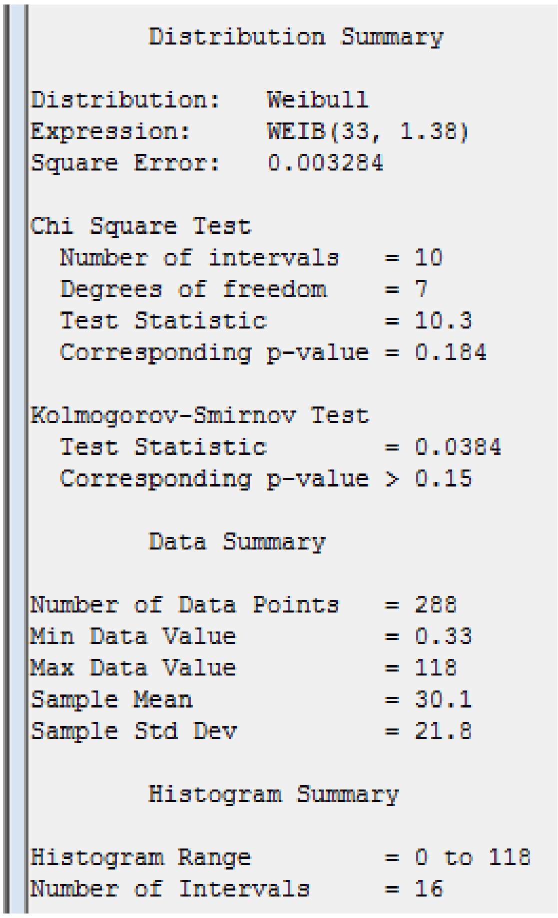
## Appendix 5 Summary of Crane Productivity Histogram (Ocean Going)



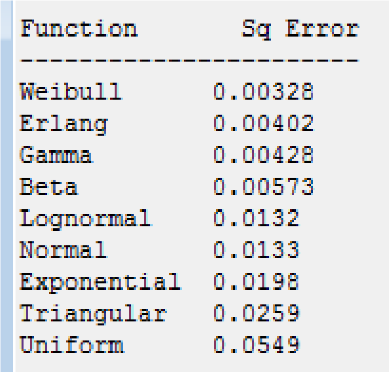
```
        Distribution Summary

Distribution:   Weibull
Expression:     1 + WEIB(4.1, 0.69)
Square Error:   0.001135

Chi Square Test
  Number of intervals   = 2
  Degrees of freedom    = -1
  Test Statistic        = 1.77
  Corresponding p-value < 0.005

Kolmogorov-Smirnov Test
  Test Statistic        = 0.201
  Corresponding p-value < 0.01

        Data Summary

Number of Data Points   = 185
Min Data Value          = 1.07
Max Data Value          = 149
Sample Mean             = 6.96
Sample Std Dev          = 15.5

        Histogram Summary

Histogram Range         = 1 to 149
Number of Intervals     = 13
```

```
Function        Sq Error
-----------------------
Weibull        0.00113
Lognormal      0.00196
Beta           0.00213
Erlang         0.00466
Exponential    0.00466
Gamma          0.0257
Normal         0.379
Triangular     0.642
Uniform        0.695
```

## Appendix 6 Summary of Ship Inter-arrival Times Histogram (Inter-Island)

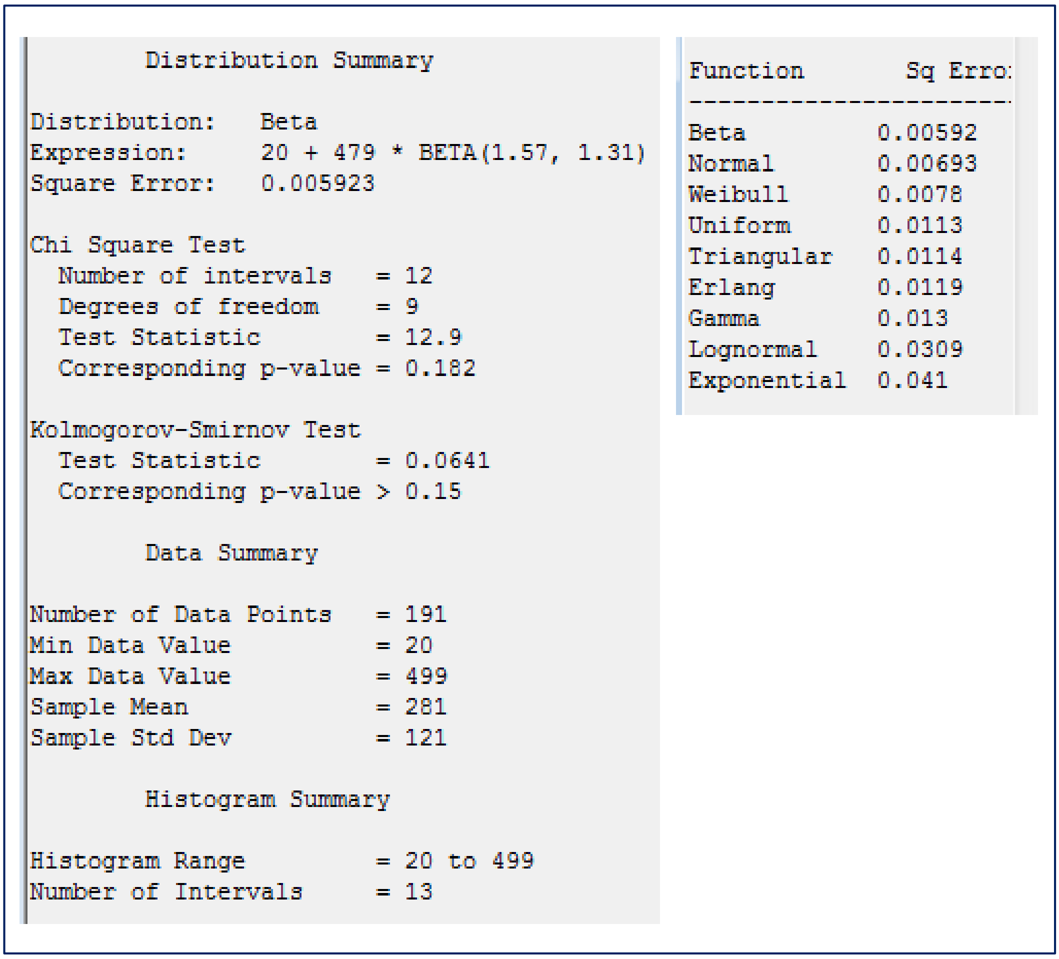


```
        Distribution Summary

Distribution:   Weibull
Expression:     WEIB(33, 1.38)
Square Error:   0.003284

Chi Square Test
  Number of intervals   = 10
  Degrees of freedom    = 7
  Test Statistic        = 10.3
  Corresponding p-value = 0.184

Kolmogorov-Smirnov Test
  Test Statistic        = 0.0384
  Corresponding p-value > 0.15

        Data Summary

Number of Data Points   = 288
Min Data Value          = 0.33
Max Data Value          = 118
Sample Mean             = 30.1
Sample Std Dev          = 21.8

        Histogram Summary

Histogram Range         = 0 to 118
Number of Intervals     = 16
```



```
Function       Sq Error
-----------------------
Weibull       0.00328
Erlang        0.00402
Gamma         0.00428
Beta          0.00573
Lognormal     0.0132
Normal        0.0133
Exponential   0.0198
Triangular    0.0259
Uniform       0.0549
```

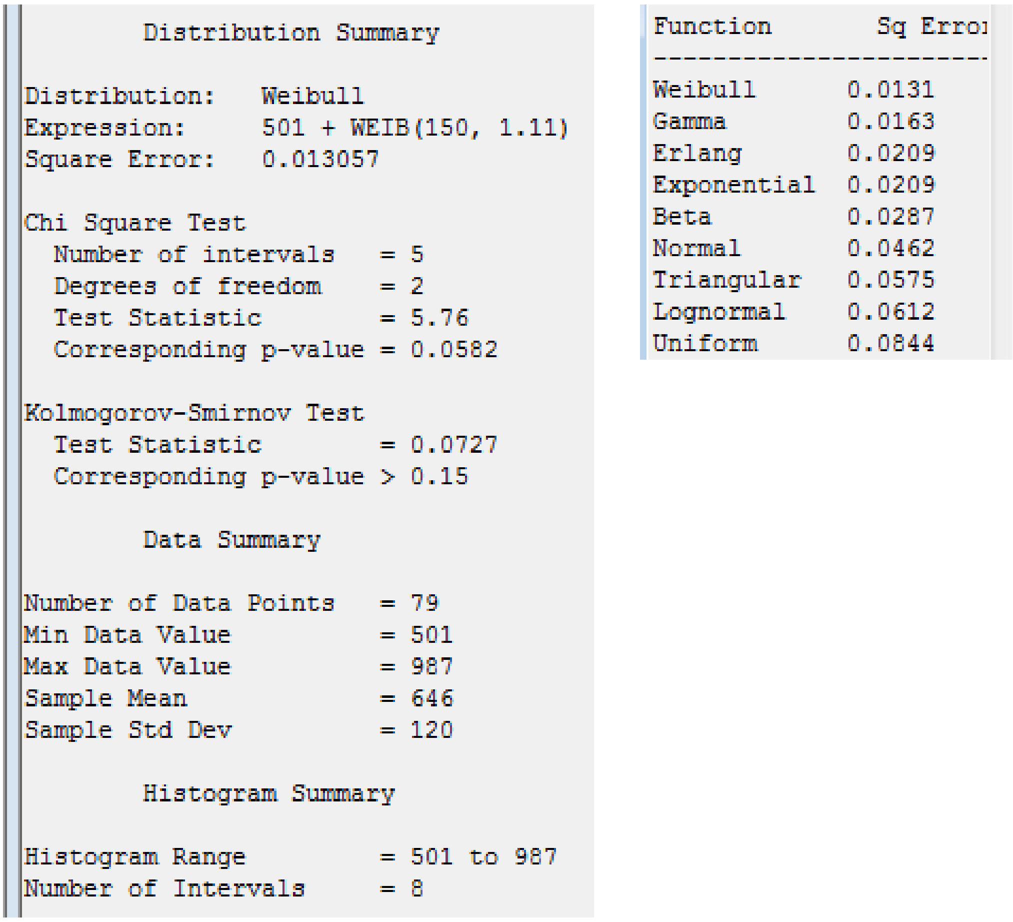
## Appendix 7 Summary of LPC1 Histogram (Inter-Island)



```
        Distribution Summary

Distribution:   Beta
Expression:     20 + 479 * BETA(1.57, 1.31)
Square Error:   0.005923

Chi Square Test
  Number of intervals   = 12
  Degrees of freedom    = 9
  Test Statistic        = 12.9
  Corresponding p-value = 0.182

Kolmogorov-Smirnov Test
  Test Statistic        = 0.0641
  Corresponding p-value > 0.15

        Data Summary

Number of Data Points   = 191
Min Data Value          = 20
Max Data Value          = 499
Sample Mean             = 281
Sample Std Dev          = 121

        Histogram Summary

Histogram Range         = 20 to 499
Number of Intervals     = 13
```

```
Function       Sq Erro
-----------------------
Beta           0.00592
Normal         0.00693
Weibull        0.0078
Uniform        0.0113
Triangular     0.0114
Erlang         0.0119
Gamma          0.013
Lognormal      0.0309
Exponential    0.041
```

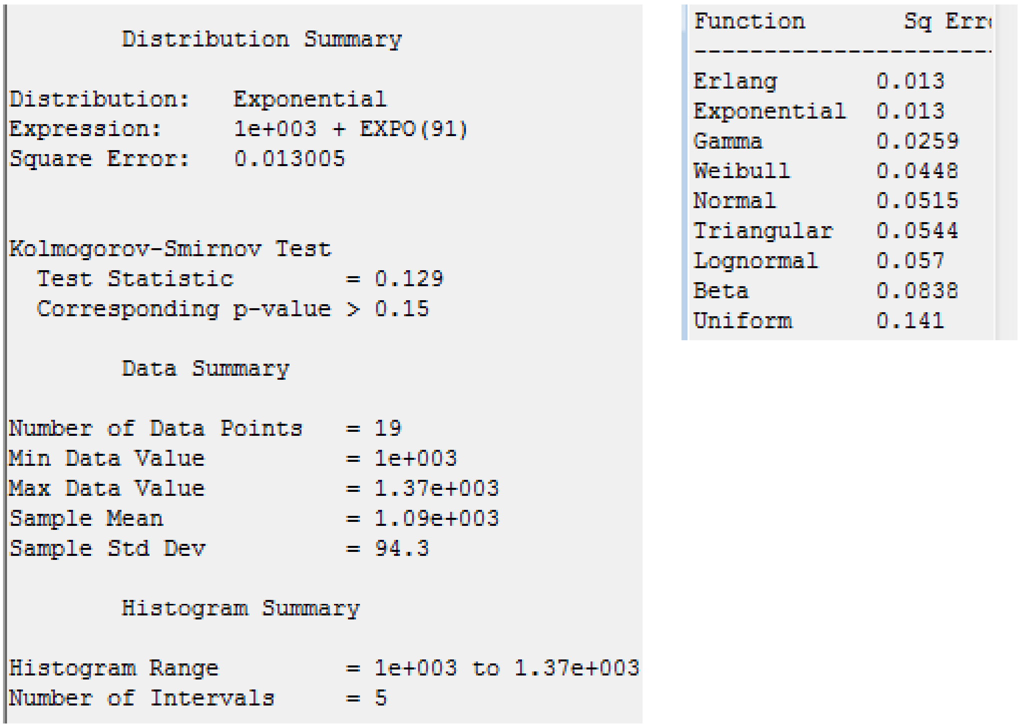
## Appendix 8 Summary of LPC2 Histogram (Inter-Island)



```
        Distribution Summary

Distribution:   Weibull
Expression:     501 + WEIB(150, 1.11)
Square Error:   0.013057

Chi Square Test
  Number of intervals   = 5
  Degrees of freedom    = 2
  Test Statistic        = 5.76
  Corresponding p-value = 0.0582

Kolmogorov-Smirnov Test
  Test Statistic        = 0.0727
  Corresponding p-value > 0.15

        Data Summary

Number of Data Points   = 79
Min Data Value          = 501
Max Data Value          = 987
Sample Mean             = 646
Sample Std Dev          = 120

        Histogram Summary

Histogram Range         = 501 to 987
Number of Intervals     = 8
```

```
Function       Sq Erro
-----------------------
Weibull       0.0131
Gamma         0.0163
Erlang        0.0209
Exponential   0.0209
Beta          0.0287
Normal        0.0462
Triangular    0.0575
Lognormal     0.0612
Uniform       0.0844
```

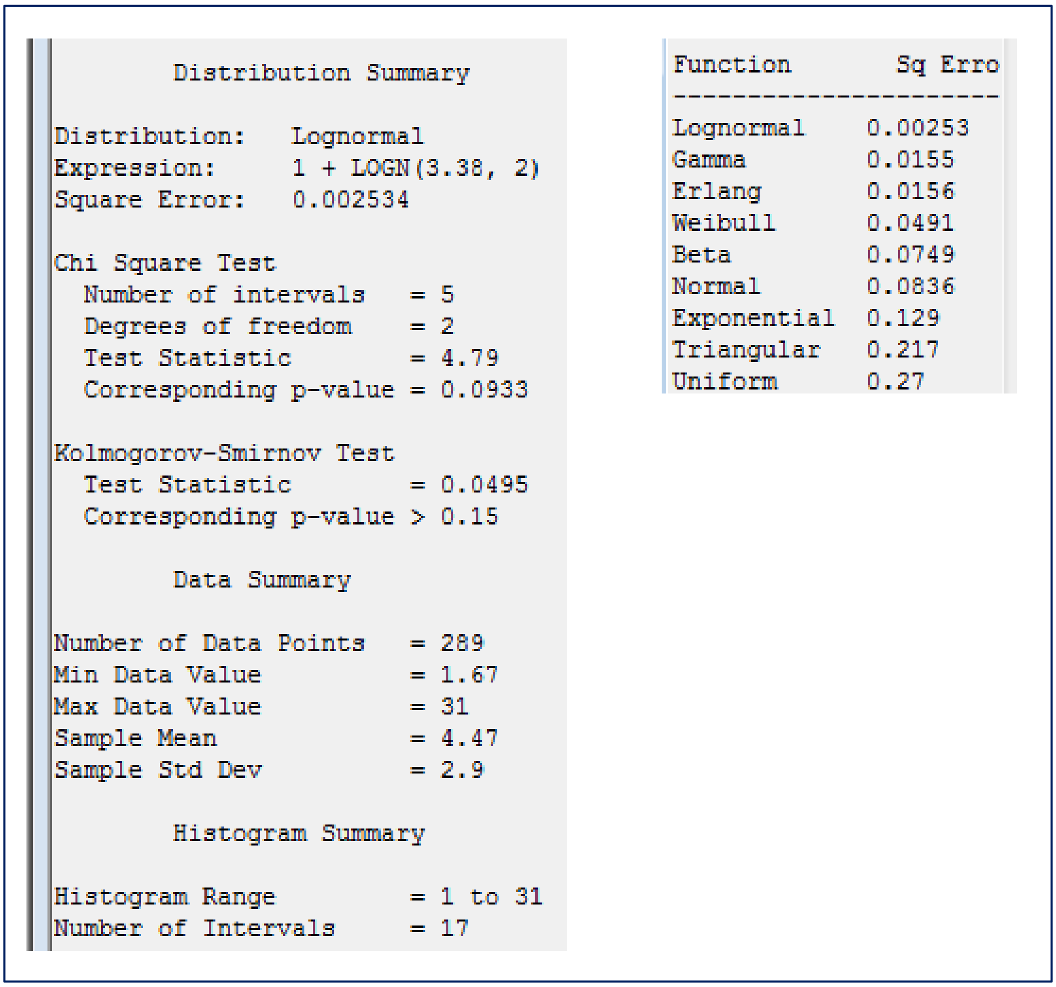
## Appendix 9 Summary of LPC3 Histogram (Inter-Island)



```
        Distribution Summary

Distribution:   Exponential
Expression:     1e+003 + EXPO(91)
Square Error:   0.013005


Kolmogorov-Smirnov Test
  Test Statistic        = 0.129
  Corresponding p-value > 0.15

        Data Summary

Number of Data Points   = 19
Min Data Value          = 1e+003
Max Data Value          = 1.37e+003
Sample Mean             = 1.09e+003
Sample Std Dev          = 94.3

        Histogram Summary

Histogram Range         = 1e+003 to 1.37e+003
Number of Intervals     = 5
```

```
Function       Sq Err
----------------------
Erlang        0.013
Exponential   0.013
Gamma         0.0259
Weibull       0.0448
Normal        0.0515
Triangular    0.0544
Lognormal     0.057
Beta          0.0838
Uniform       0.141
```

## Appendix 10 Summary of Crane Productivity Histogram (Inter-Island)



```
        Distribution Summary

Distribution:   Lognormal
Expression:     1 + LOGN(3.38, 2)
Square Error:   0.002534

Chi Square Test
  Number of intervals   = 5
  Degrees of freedom    = 2
  Test Statistic        = 4.79
  Corresponding p-value = 0.0933

Kolmogorov-Smirnov Test
  Test Statistic        = 0.0495
  Corresponding p-value > 0.15

        Data Summary

Number of Data Points   = 289
Min Data Value          = 1.67
Max Data Value          = 31
Sample Mean             = 4.47
Sample Std Dev          = 2.9

        Histogram Summary

Histogram Range         = 1 to 31
Number of Intervals     = 17
```

```
Function       Sq Erro
----------------------
Lognormal     0.00253
Gamma         0.0155
Erlang        0.0156
Weibull       0.0491
Beta          0.0749
Normal        0.0836
Exponential   0.129
Triangular    0.217
Uniform       0.27
```