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Evaluation of vehicle terminal capacity at Tanjung Priok terminal

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EVALUATING OF VEHICLE TERMINAL CAPACITY AT TANJUNG PRIOK CAR TERMINAL

By

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ABSTRACT

Title of research paper : Evaluating of Terminal Capacity at Tanjung Priok Car Terminal.

Degree : MSc

Terminal capacity is to be considered by the management to keep terminal services smoothly. Lack of terminal capacity will leverage congestion in the port and in turn will influence the growth of international trading. Considering cargo forecasting, Tanjung Priok Car Terminal (TPT) still have idle capacity of berth but having a critical point in the yard capacity where base on proper throughput capacity (PCTC) analysis there is a shortage yard capacity in 2015. Therefore, besides reducing dwelling time as a strategy to increase capacity in the short run, this terminal must expand its yard area to cope cargoes throughput via yard and avoiding terminal congestion in the long run. The expanding yard is a better choice than build car parking building due to it does not reduce the terminal capacity during building construction.

KEYWORDS: Terminal capacity, Forecasting, Car Equivalent Units, queuing model, arrival rate pattern, service rate pattern.

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LIST OF ABBREVIATIONS

TPT	Tanjung Priok Car Terminal
Ro-Ro	Roll on – Roll off
K-S Test	Kolmogorov Smirnov Goodness of Fit Test
MPC	Move per Call
LOA	Length Overall
PCTC	Proper Container Terminal Capacity
CEU	Car Equivalent Unit
GDP	Gross Domestic Product

Chapter 1.INTRODUCTION

1.1. Background

Port is bringing an important role to support an efficient distribution activity in the total chains logistics through faster and safety cargo handling activities. Around 75 percent of world trade is served by sea, 16 percent is by rail and road, 9 percent by pipeline and 0.3 percent by air, in terms of volume (Heiberg, 2012). Furthermore, One of port function is a link between the transportation chain. Port will connect feeder shipping lines and in inland transportation mode which is supported by adequate capacity of facilities and quality of performance (Patrick Fourgeaud, 2000).

In the recent years, port has implemented the specialization strategy through their terminal. The purpose is to enhance the terminal productivity in the competitive condition among ports. Consequently, ports must face up to market demands and deliver quality service and improved efficiency.

Roll on Roll off (Ro-Ro) terminal is a form of specialization strategy in the port beside other specialization such as container terminal and liquid terminal. Ro-Ro ship indicates specialized ship and should be served by specialized terminal to reach optimum productivity. The Ro-Ro is a cargo liner with 'through decks' and roll-on access by means of ramps, rather than via hatches in the weather deck. Key design features are access ramps, open decks allowing fast maneuvering of fork-lift trucks, tractor/trailers and wheeled vehicles, good access between decks, and deck and ramp loadings for heavy cargoes. A major advantage of the Ro-Ro vessel is its ability to provide fast port Turnaround (Martin Stopford, 2009).

This research focuses on Tanjung Priok Car Terminal (TPT) as one of terminal in Indonesia Port Company and the only one vehicle terminal in Indonesia and operated by Ro-Ro handling system. This terminal is dedicated to handle carand heavy cargoes. In the recent years, the growth of automotivesales in Indonesia is sohuge by 25% in 2012 (reuters, 2013) and it leverages the increasing of car throughput and Ro-Ro ship call in the port. To meet shipping line requirement especially for faster berthing at wharf, terminal must present high productivity in cargo handling activity. Adequate capacity of facilities in the terminal is one of key factors to enhance terminal productivity. In the Ro-Ro terminal, the growth of cargo throughput should be covered by adequate facilities such as berth and storage yard because while the maximum capacity is achieved by fully utilization of facilities, the terminal unable to cope with the increasing cargo and will lead to traffic and port congestion.

1.2. The Research Problem

The objective of the Ro-Ro terminals management is to serve cargo handling effectively by provide a sufficient terminal capacity to minimize waiting time and maximize efficiency. Berth and yard is the important facilities to support cargo handling operation. Moreover, the development of cargoes must be followed by the expanding facilities in Ro-Ro terminal.

Capacity is defined as the maximum or the best operating level. The utilization of capacity is defined (Chase et al, 2004) as: Capacity Utilization = Capacity Used / Best Operating Level.

There is a traditional method of strategic capacity planning related capacity involves as the following activities (Gaither et al, 2004):

i) Estimating the capacities of the present facility.
ii) Forecasting the future capacity needs of all products and services.
iii) Identifying and evaluating the sources of capacity to meet the futurerequirements.
iv) Selecting among the alternative sources of capacity.

There is a different point of view to consider proper capacity in the terminal between terminal operators and customer (shipper and shipping lines). For terminal operator, the higher proper throughput means the less additional development cost of facilities. On the other hand, shipper and shipping lines prefer a low throughput in order to receive better services from the terminal

(Daniel Moon,2012). So, in this thesis, the author will determines some research problem such as follows:

1. How to determine proper throughput capacity in the vehicle terminal.
2. How much the expanded facilities are needed to overcome the future throughput development such as berth and yard.

1.3. The Expected Contribution

The expected contribution of this thesis is to determine the proper throughput at Tanjung Priok Car terminal by providing an adequate number of berth and yard facilities with an optimal utilization and how large facility will be expanded in the 5 years later. The analysis in this study can support the vehicle terminal management to appraise an investment plan in expansion of the terminal facilities. In the operational point of view, it can leverage the increasing productivity in the terminal and reduce ship waiting time.

1.4. Problem Limitation

This thesis problem has some limitation to make sharpen and specifically analysis. The limitation of this research can be described as follows:

a. Object of analysis was limited in the Tanjung Priok Car Terminal in Jakarta - Indonesia. The operation of this terminal dedicated for Ro-Ro operation and especially serve ocean going loading and unloading vehicle.
b. This terminal never handled transshipment operation.
c. Scope of operation analysis in this thesis was limited for ship arrival operation, loading and unloading activity, transfer/haulage and storage operation. Whereas receiving and delivery is not discussed because has wide problem such as hinterland access road, number of outside trucking and heavy traffic jams in Jakarta.
d. The primary data will collected from various source in year 2008 until 2012, for ship pattern using data from Tanjung Priok Car Terminal in year 2012, and for determining peak factor using data was collected from January until March 2013.

e. Independent variable in throughput forecasting methods using Indonesia population, gross domestic product (GDP) and Indonesia coal mining production.

1.5. Structure of Thesis

This thesis has a systematic structure which can be illustrated below:

a. Introduction

   Introduction chapter will describe about the background of research, determining research problem, the expected contribution of this study and the limitation of thesis problem.

b. Literature Review and conceptual framework

   This chapter will discuss about some literatures which related with this study. Base on the literature, the Author will arrange the conceptual framework of this research.

c. Research Methodology

   The chapter of research methodology will describe several methods that can be implemented in this research.

d. Data Collection

   This chapter describes about collection of data related with this research. It was collected from various sources but the primarily it collected from Tanjung Priok Car Terminal and some data collected day by day related the operational activities. The Secondary data collected from internet and government institution. In this chapter, The Author will forecast cargo throughputs and counted terminal peaking factor.

e. Analysis of Terminal Requirements

   The analysis of terminal requirement will describes about processing data to arrange the information about this study. Some analysis will be implemented to determine vessel arrival pattern, and the number of proper facilities in that terminal such as berths and yards.

f. Conclusion and Recommendation

This chapter will determine the conclusion of this thesis and try to propose some recommendations related the analysis results.

Chapter 2. LITERATURE REVIEW & CONCEPTUAL FRAMEWORK

Literature review will present relevant theory that can be used to explain some variables to be studied. Some literature related to vehicle terminal operation is needed to support the research topic.Although research on vehicle terminal is not as much container terminal, we can benchmark container terminal activity in automobile terminal and of course there are some differences in implementation. The previous research topics in container terminal operation such container terminal operation, container terminal capacity, and simulation of queuing theory in berth can be used as references in this research. In the last, conceptual framework of this research will be arranged to show the flow of this project.

2.1. Vehicle Terminal Operation

In common practice vehicle terminal operation usually called automobile terminal operation where stevedoring activity is operated by Ro-Ro system. The handling of vehicle terminal is actually a highly specialized business operation in term of the value of good shipped and service requirement of customer. According that cargoes behavior, there are some value added services in vehicle terminal operation such as pre delivery inspection (PDI) damage repair and product customization.

Ro-Ro terminals can be split into three subsystems: berth area, storage area, and delivery and receipt. Unloading and loading process can be describe as follows: (Sauri et.al, 2012)

- Unloading Process

  When the ship is berthed and customs gives its approval, the unloading process starts. The typical unloading process begins with the vehicles driven by their own drivers: passenger automobiles, trucks, buses, and so on. The trucks and vehicles unloaded at this stage go directly to the exit gates of the terminal or parking in the storage yard. After that, the unloading process starts for all the vehicles/freight driven by the stevedoring team (by hands): platforms/semitrailers and whole vehicles (i.e. cars, vans, etc.).

- Loading Process

  The cargo to be loaded on vessel arrives at the terminal either by road or by railroad. Once thecargo arrives at the terminal, it is parked in the yard, waiting to be loaded on board.

In the Ro-Ro stevedoring activity, platforms and semitrailers are usually loaded first and simultaneously with the automobiles. Immediately after, the vehicles driven by their own drivers are loaded: passenger vehicles, trucks, buses, and so on. While waiting to be loaded, trucks and passenger vehicles are stored temporally in the yard of the terminal.

The main processes in the day to day running of a Ro-Ro/Ropax terminal are
8 summarized in Figure 1 below.

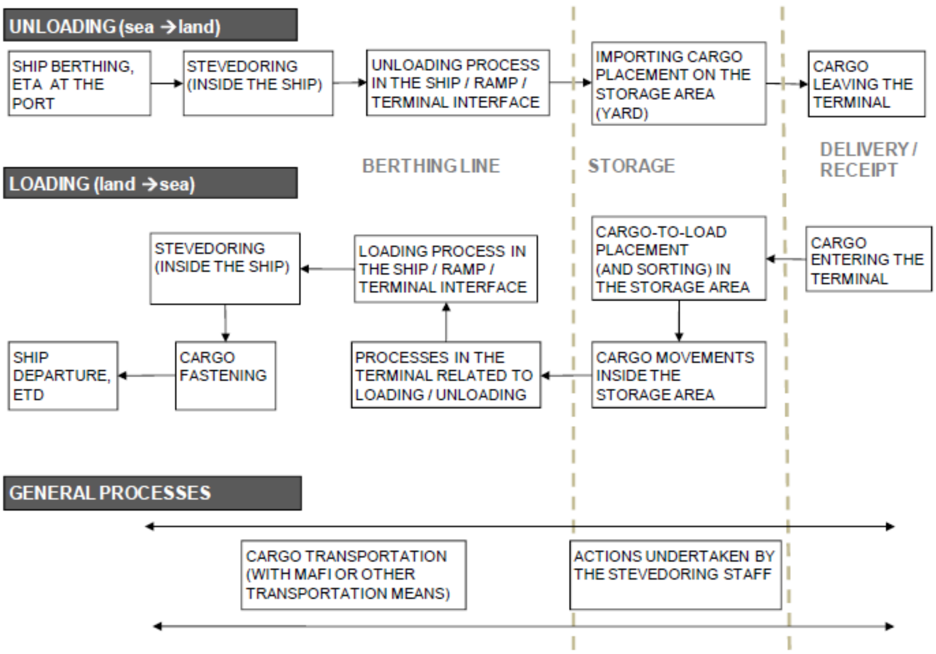

Figure 1. Main Processes Occurring in a Ro/Pax Terminal

Source : Sauri S P, Morales-Fusco, E. Martin, 2012, An empirical analysis of the resiliency of Ro/Ro and Ro/Pax Terminal Operation, P. 2-20.

The principle of operation in Vehicle terminal and container terminal is quite similar but there are some differences as can be exemplified as follow: First, container flows are strongly fragmented, whereas vehicle flows have much in common with unitized and car cargos. Second, containers may be relocated several times during their stay in a hub but for vehicles relocation on terminal is avoided as much as possible to reduce a potential damage on cargo and minimize operating cost. Third, containers can be stacked one upon another to increase storage space, whereas vehicles could not be done. so the storage area in vehicle terminal can be relatively large (D.C. Mattfeld, H. Kopfer,2002).

In a RoPax terminal three main cargo types can be found: full trucks, platforms without tractor capacity, and automobiles. Each kind of cargo has its own process chain.Within a vehicle terminal, receiving areas, also known as the first point of rest are typically located close to the dock for efficient unloading/loading of vehicles via an unloading ramp.

Terminal can handle a single or several vehicle brands and the terminal functions and services provided can also vary depending on the customer or brand. For example, some vehicle terminal functions as a storage/parking area serving as buffer to balance customer demand and dealer forecasts. Terminal dwell time of vehicles can be relatively short. A performance parameter measuring how many times in a year the storage capacity is used productively. PDI area and vehicle repair area as value added activity will enhance the large of land area in vehicle terminal. The structure of the fleet vehicles based on their cargo carrying capacity should meet the requirements of transporting goods in lots of various sizes (Rimants Limba & Olga Fadina, 1995). In total chain logistic of vehicle, Ro-Roterminals for cars have important role as a links to assembly/factories of vehicles localized in the hinterland and concludes that Ro-Ro terminals reduce logistical friction and impedance, as well as promote space/time compression. (Quaresma Diaz, 2008).

In the terminal operation, some philosophies of container activity can be adopted in the vehicle terminal operation management. Ship operation/stevedoring operation, haulage and storage activity always occur in the terminal activities. The essential differences are type of cargoes that will make a difference to handling methods. In the vehicle terminal, optimal allocation of gang worker has an important roleto support stevedoring activity besides facilities and equipments. On the other hand, the type cargoes could not be stacked vertically leverage the terminal to provide an adequate yard.

2.2. Vehicle Throughput Forecasting

It is important for vehicle terminal to keep an appropriate facility such as berths, storage yards, gates, and various handling equipment such as trailer and tug master for heavy cargoes service. To determine how much facilities requirement, we need to estimate cargo throughput in the future to avoid congestion in the terminal. Congestion brings delays for terminal and increases the costs to stakeholders; for example, shipping lines (shipping delays, missed feeders), terminals (yard congestion, re-handling), and shippers (longer lead time) (S. Islam, 2011). The causal relationship between port throughput and demography, socio-economic and industrial development has been studied to estimate port throughput in the future (Dorsser, Wolters and Wee, 2012).

The essence of port forecast is to find out what kinds and unit car, cargo on flat bed and giant truck move through the port. Traffic forecasting requires a combination of commercial and economic knowledge; the mathematical techniques are of minor importance and can often be omitted entirely. Far more important is the need to bear constantly in mind the very high degree of uncertainty in any forecast, and to take steps to minimize the riskwhich this causes. Any forecast of future trade will be uncertain, and ports are particularly vulnerable in view of their long planning time-scale and limited ability to influence demand. All forecasts should be linked with the overall national development plans (Unctad,1985).

2.2.1. Variables Influencing Vehicle Throughput

a. Population

Everybody need transportation in their various activities. Car is one of the supporting good to help them in land transportation. Based on that approaching, population will have a good relationship with car sales and in turn will influence car throughput in the port. Indonesia has the population around 240 million (2011) and if assumed the comparison between car and population 1 : 12 (Burhanuddin, 2012) it means there are demand around 20 million for Indonesia market. Regarding that circumstance, population can be proved as related variable in car throughput in the car terminal.

b. Gross Domestic Product (GDP)

The GDP is treated as more than a positive macroeconomic indicator. It is increasingly viewed as a normative indicator of economic and social well-being. The Gross Domestic Product measures the total value, calculated in dollars, of all final production in a country. At present, GDP is preferred to GNP because policy-makers are usually interested in the level of economic activity within a country's borders. (Blayne Haggart, 2000) On the other side, the high growth of economic can be connected with international trading. Port as a link in the total chain logistics and it supports international trading through sea transport. For this reason, GDP can be put as comparison variable to determine car throughput in vehicle terminal.

Some previous researches have been used GDP indicator to forecast cargo throughput. Jugovic, Hess, and Jugovic (2011), Gosasang, Chandraprakaikul, and Kiattisin (2010), Syafi'i, Kuroda and Takebayashi (2005), is researcher that using GDP for their study. Indeed, UNCTAD (2012) use this indicator to measure the correlation between world merchandise trade, world seabone trade and OECD industrial productionindex.

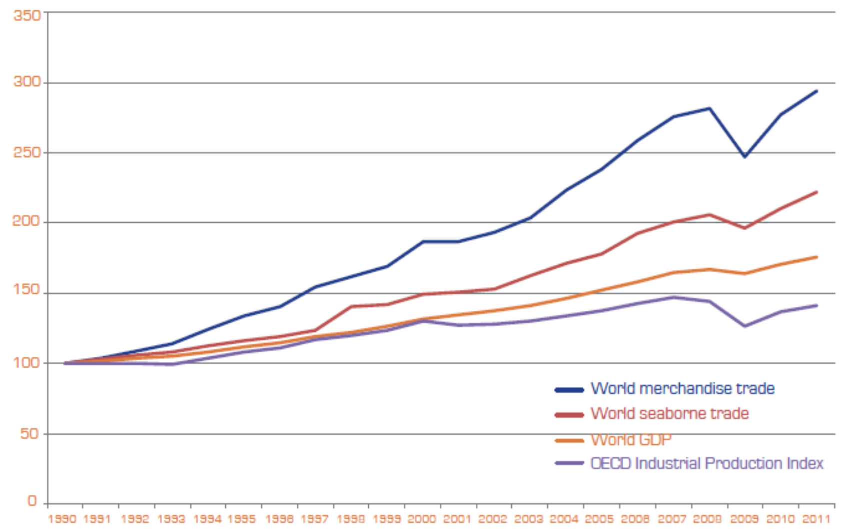

Figure 2. The World Trade and World Production Since 1990
Source : Module International trade and transport (UNCTAD)

c. Coal Production

According Indonesia statistical bureau, Coal industry is the largest mining industry at Indonesia. There are three waves of Indonesia coal mining era in the last two decades (Alan Hopkins and Bill Hewitt, 2013). The first wave occurred 20 years ago which is characterized by modernization of mining system. They can produce good quality coalsand using open cutsystem for production methods which is located close to the coast. In the second wave, coal industry will develop to inland areas whereas very limited infrastructure to support its distribution channels. Government start to construct infrastructure to support coal industry and it is proven by the expanding rail way and road to the inland areas. This condition will leverage the increasing demand of truck as supporting coal distribution channel. On the other hand, the growth of coal industry area will need more equipment excavator and dozer to support their production. However, the market of coal is quite deteriorated in mid of 2012 marked by world coal price depreciation. To anticipate this condition, the third wave of coal industry development will begin. It is time to come back near the coast to eliminate transportation cost and mine the big tonnages available for good quality coal. The third wave of coal mining would require large mechanical equipment the impact is an increasing demand of mining equipment. On the other side, Tanjung Priok CarTerminal is the only one terminal in Indonesia which is support import of excavator and dozer.

Base on condition above, it proves there are correlation between coal production and number of heavy cargoes equipment such as excavator and dozer through Tanjung Priok Car Terminal.

2.2.2. Forecasting Technique

Traffic forecast is being prepared from a detailed analysis of the factors involved, which are combined (either by addition or by multiplication) to produce the final figure, care has to be taken in dealing with optimistic and pessimistic estimates of each separate factor. Clearly, if there are three independent factors affecting the forecast, then the probability of it turning out that all three variables have a high correlation between variables. There are simple statistical methods of calculating this overall probability (Unctad, 1985). Statistical forecasting is how to estimate the value of independent variable in the future which is can be compared with one or some variables behavior (J.Supranto,1991).

In this research, before using Indonesia GDP, population and coal production as comparison variable in cargo throughput forecasting, it should be tested by correlation test. Data analysis module in excel can be used to get information about correlation among some variables. Forecasting method in this study use simple regression analysis and multiple regression analysis in which Indonesia's GDP, population of Indonesia and coal production as independent variables, while cargo throughput as the dependent variable. Length of historical data used from the year 1996-2012 and it will be divided per semester to make data longer. Cargo Throughput is calculated based on multiple regression analysis, in addition, to estimate GDP, Indonesia population and coal productionwill use simple regression analysis.

a. Simple Regression Analysis

Simple regression analysis based on the functional relation between dependent variable and independent variable. The equation can be shown as follow (Sugiyono,1999):

$$Y = a + bX_1 + e_1$$

The formula above will represents a straight line function, where ‘a’ and ‘b’ are parameters and ‘e’ is the error term. The parameter ‘a’ reflects the value of Y if X equal zero and then ‘b’ reflects the slope of the line. The difference in the value between the actual and predicted is represented in ‘e’. There are three basic test statistics that are used to analyze a regression equation in order to explain the significance of the equation in the overall model. The test statistics are the standard error, t-test and the correlation coefficient.

b. Multiple Regression Analysis

Multiple regression analysis is an extension of the single regression analysis using more than one independent variable. This formula will used to forecast dependent variable behavior if there are two or more independent variables. The equation can be shown below:

$$Y = a + b_1X_1 + b_2X_2$$

Similar to the single regression analysis the parameter ‘a’ illustrates the value of Y when X_1 and X_2 is zero and b_1 and b_2 indicate the degree of contribution to Y for every change in X.

2.3. **Concept of Car Equivalent Unit**

The term passenger car equivalent (PCE) was known since 1965 in the Highway Capacity Manual. So many considerable research efforts have been directed toward the estimation of PCE value for various roadway types and the passenger car has been used as the basic vehicles for converting other vehicle into passenger car equivalent (PCE) in the traditional approach (Nguyen,2003).

Nguyen counted Motorcycle equivalent unit (MCU) and defined as the number of motorcycles that can be displaced for one vehicle. The modified formula that is applied for MCU conversion is depicted as follows:

$$MCU_k = \frac{S_k}{S_{mc}} \qquad (1)$$

Where : MCU_k =motorcycle equivalent unit of type *k* vehicle;

S_k =Space for type*k* vehicle (m^2),

S_{mc} =effective space for motorcycles (m^2)

If $MCU_k$is changed as standard car equivalent unit of type k vehicle (CEU_k),S_k can be used as measurement other type vehicle such as bus/truck and heavy cargoes in vehicle terminal. The formula of CEU as follow:

$$CEU_k = \frac{S_k}{S_c} \qquad (2)$$

Where, CEU_k = Car equivalent unit of type *k* vehicle;

S_k = The effective space type k vehicle (m^2)

S_c = The mean effective space of car (m^2);

There is an observation to determine parking dimension standard which is already done in Calgary city (Ezekiel Dada and Mike Furuya, 2008). Base on their observation result of statistical analysis all vehicle model 2008 – 2009 which can be shown in table 1:

Table 1. Measurement Standard of Parking Dimension for All Vehicles Model

RESULTS OF THE STATISTICAL ANALYSIS – ALL 2008 AND 2009 VEHICLE MODELS			
	Length (m)	Width (m)	Height (m)
Average	5.02	1.98	1.76
Median	4.89	1.87	1.78
85th Percentile	5.66	1.99	1.95
90th Percentile	5.81	2.01	1.97
95th Percentile	6.2	2.03	2.01
Minimum	3.88	1.68	1.39
Maximum	6.68	2.44	2.06

Source : Ezekiel Dada And Mike Furuya, Parking Dimensions, 2009.

In the vehicle terminal operation, the vehicle dimensions above should be added with safety clearance in the length and width to avoid bumping between vehicles in handling operation.

2.4. **Vehicle Terminal Capacity**

It is essential to minimize time ofhandling process at the terminal. The mainly pre conditioned caused delay in Ro-Ro terminal is an insufficient of terminal gateways, the shortage of customs and border control units, and inadequate parking/storage capacity and arrangement at the terminal (Ricardas, 2007). An adequate facility in the vehicle terminal is very important to support cargo handling operation smoothly and enhance productivity. The role of capacity calculations is to provide alink between the level of service achieved and threefactors such as the throughput demand placed on port facilities, the capacity provided and the performance that can be expectedin local conditions. This task is also known as performance analysis. The results of the calculations will berequired for financial and economic analyses.When planning facilities, it is generally necessary to try out several different capacities with several different traffic forecasts, and to do this for differentpoints of time. A good method must therefore be quickand easy. The calculation will be used in various ways:for example, setting performance (productivity) andproposed capacity (number of berths) and varying traffic demand to determine the effect on level of service(ship waiting time). Alternatively, for a proposed waiting time, traffic and number of berths for the requiredproductivity can be determined. (UNCTAD, 1985)

The characteristic of the Ro-Ro terminal is facilitated an adequately fenced, protected and large surfaced storage areas, paved access way. The transit storage area requirement for a Ro-Ro terminal could be larger than container terminal.

In the container terminal, throughput is counted in Twenty feet equivalent units (TEUs)to make easy calculating container storage area. This principle can be allowed by the planner tocalculate the corresponding area requirements for the Ro/Ro terminal (UNCTAD,1985). As one type of Ro/Ro terminal,vehicle terminal can use car equivalent unit (CEU) measurement to calculate vehicle terminal capacity.The Proper Container Terminal Capacity (PCTC) principle can be used in vehicle terminal as well. Itis calculated by comparing berth capacity with yard capacity, i.e. whichever is lower is considered as PCTC (Moon,2012). In Figure 3 will illustratehow to determine PCTC between berth and yard.

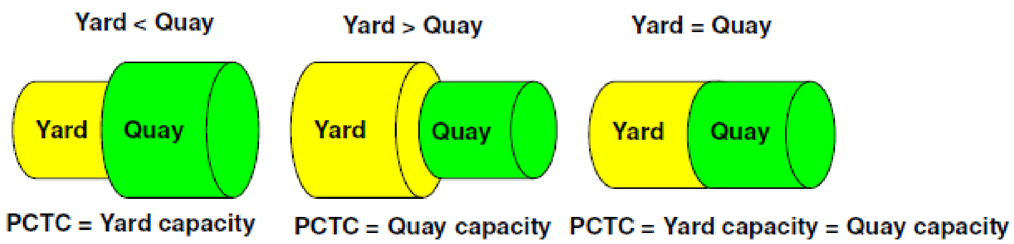

Figure 3. Determining PCTC between Yard and Quay

Source : Daniel Moon, 2012, Port Logistics Lecture Handbook, Unpublished lecture handout, WMU, Malmo, Sweden.

If Yard capacity less than quay capacity, yard capacity can be determined as PCTC and vice versa. Traditionalmathematical model that can be used is queuing theory by considering the distribution of ship's arrival and service time to determine ship behavior at berth.

There is a method to calculate berth throughput capacity as can be showed as follow:

$CC = \alpha_1 . \alpha_2 . \alpha_3 . N . V_q . E_q . t$ (Ding,2010) (1)

where, C is the throughput capacity of a terminal in a year (TEUs/year) but in the vehicle terminal, it can be changed as throughput capacity of vehicle in car equivalent unit; α_1 is the conversion coefficient of TEUs per Move which effected by the types of the containers and in vehicle terminal can be changed as gang productivity; α_2 is the rate of the quay cranes in good condition. In the vehicle terminal, crane can be change as gang of work. It is easy to change if one gang is not available. So, in this case α_2 can be assumed 100%; α_3 is the ratio of terminal operation time per day (hours/day); N is the total number of the quay cranes at a container terminal, it can be change as number of gang to serve cargo handling; V_q is the utilization rate of the gang; E_q is the average operation efficiency of gang worker (Moves/hour); t is the total terminal operation hours in a year.

Related to the yard capacity, Dally (1983) propose a formula to calculate the throughput capacity of storage yard as follow,

$$Cc = \frac{Tgs .H .U .K}{DT .PF} \quad (2)$$

Required Tgs =Cc x DT x PF)/(H x U x K)

Where Cc is yard throughput in a year; Tgs is total ground slot; H is average stacking height , in vehicle terminal case always has 1 high because car could not be stacked; U is land utilization ratio; K is service days of the yard, usually 365 days; DT is dwell time of car; PF is peaking factor. Peaking factor will counted by analyze daily data of cargo in the storage yard.

2.5. Queuing Theory

Queuing theory is a branch of applied probability theory and its subject is to consider a service center and population of the customer, which at some times enter the service center in order to obtain service, It is often the case that service center can only serve a limited number of the customer (Willig, 1999). Queue will occur if the number of customer more than number of service. While the system gets congested, the service delays in the system will increase. Queuing models can be used as a tool to understand and measure the effect of variability in arrival and service processes in the system. Queuing theory try to answer q spends in the queue, Average length of the waiting line (mean number of customers in the queue), average time spent in the system, the probability that an arriving customer must wait for service (Moon,2012). In the port operation, queuing theory can be implemented to get information about ship waiting time and analysis ship arrival pattern. A queuing system consists of some elements, such as input source, arrival pattern, queue discipline, queue length, service pattern and output as described in figure 4.

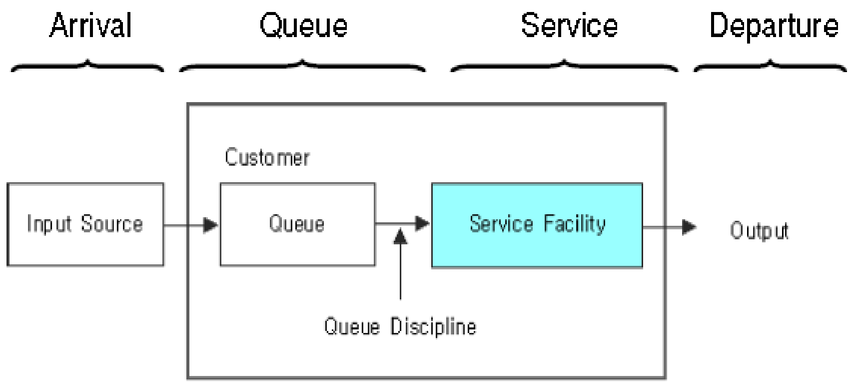

Figure 4. General Structure of Queuing System

Source: Moon, S. H. (2010b). Port Logistics (Queuing Theory), Unpublished lecture handout, WMU, Malmo, Sweden.

Some common service disciplines in queuing theory are: (Willig, 1999)

- **FIFO** : (First in, First out), a customer that finds the service center busy goes to the end of the queue.

- **LIFO** : (Last in, First out), a customer that finds the service center busy proceeds immediately to the head of the queue. She will be served next, given that no further customer arrives.
- **Random Service**: the customers in the queue are served in random order.
- **Round Robin**: every customer gets a time slice. If her service is not completed, she will re-enter the queue.
- **Priority Discipline**: every customer has a (static or dynamic) priority, the server selects always the customers with the highest priority. This scheme can use preemption or not.

The ship arrival pattern and service time distribution can be notated with one of the following, M (Markov) for exponential distribution, D (Deterministic) when all customers have the same value, G (General) for general distribution, E_k (Erlang–k) for erlangian distribution or H_k (Hyper-k) for hyper-exponential distribution.

Queuing theory can analyze the behavior of ships waiting by investigating the components of a multiple operation system (Branislav and Nam, 2006). Random pattern ship arrival, berthing directly after arrival has to wait until a berth to be empty. This random pattern is relating with vessel service time in a berth which depending on the number of loading and unloading cargo per ship and the berth capacity. Hence, a queuing model of M/M/k can be implemented to analyze the ships pattern in a port that has a Poisson arrivals, exponential service times, and k unit servers. For this model, the operating characteristics are as follows:

$$P_0 = \frac{1}{\sum_{n=0}^{k-1} \frac{1}{n!}\left(\frac{\lambda}{\mu}\right)^n + \frac{1}{k!}\left(\frac{\lambda}{\mu}\right)^k \left(\frac{k\mu}{k\mu - \lambda}\right)} \quad (3)$$

$$W_q = \frac{\left(\frac{\lambda}{\mu}\right)^k \mu}{(k-1)!(k\mu - \lambda)^2} P_0 + \frac{1}{\mu} \quad (4)$$

$$L_q = P_0 \frac{\left(\frac{\lambda}{\mu}\right)^k}{k!} \frac{\rho}{(1-\rho)^2} \quad (5)$$

$$\rho = \frac{\lambda}{k\mu} \quad (6)$$

$$W = W_q + \frac{1}{\mu} \quad (7)$$

$$L = \lambda\left(W_q + \frac{1}{\mu}\right) = L_q + \frac{\lambda}{\mu} \quad (8)$$

Where ;

Λ	:	Average rate of arrival (no. of customers per unit time)
Μ	:	Average rate of service (no. of customers per unit time)
S	:	Number of server
Ρ	:	Utilization rate for each server
P_0	:	Probability that there are no customer in the system
L	:	Average number of customers in the system
L_q	:	Average number of customers in the queue
W	:	Average time a customer spends in the system
W_q	:	Average time a customer spends in the queue

If the number of server only one, it should be used a simple formula as follow:(Andreas Willig, 1999)

$$\rho = \frac{\lambda}{\mu} \quad (9)$$

$$Po = 1 - \frac{\lambda}{\mu} \quad (10)$$

$$L = \frac{\rho}{1-\rho} \quad (11)$$

$$Lq = L - \rho \quad (12)$$

$$W = \frac{1}{\mu-\lambda} \quad (13)$$

$$Wq = \frac{Lq}{\lambda} \quad (14)$$

Where ,

Λ	:	Average rate of arrival (no. of customers per unit time)
μ	:	Average rate of service (no. of customers per unit time)

ρ	:	Utilization rate for each server
P_0	:	Probability of server idling
L	:	Average number of customers in the system
L_q	:	Average number of customers in the queue
W	:	Average time a customer spends in the system
W_q	:	Average time a customer spends in the queue

2.6. Conceptual Framework

In the vehicle terminal operation, there are some activities such as stevedoring, quay transfer/haulage and storage operation. For Vehicle terminal operation, car will be handled from ship to storage yard by 1 driver or usually called one car one driver principle. So, stevedoring, quay transfer and car parking in the storage area might be served together in the same time. On the other hand, heavy cargo such as excavator and dozer use wheel chassis tugged by tug master or tractor for quay transfer operation.

This research only discuss about stevedoring process and storage operation to determine proper vehicle throughput and proper yard capacity. Moreover, by forecasting this research will evaluate the quantity requirement of yard and berth capacity in the future. Peaking factor will be calculated by analyze daily data of cargo in the storage yard. Sample daily data use 90 days periods. Gate capacity is not discussed at this research because gate activity has influenced by other external factors such as the different width of access road in the outside port, terrible traffic jams in Jakarta and the different standard of car carrier. The analysis will use queuing model toanalyze the incoming ships at the port then will be served at a berth and cargo handling activities between the quay and storage yard. Various assumption of number gang worker for loading/unloading operation and transfer operation to the storage yard will needed to determine the ships service rate a berth. This estimation is made by analyzing the arrival rate at a berth in units of vehicle per unit time. Forecasting model will be used to estimate the future throughput. Finally, the cargo throughput forecasting will be compared with existing terminal capacity and analyze how many required berth and yard in the future (until 2020). This conceptual framework is developed in order to answer the following question,

1) What is the ship arrivals pattern and ship service rate?
2) What is the relation betweenthe existing facilities and the number of vessel queuing in the port?
3) What is the proper utilization of berth and yard facilities in the terminal?
4) How large yard needed in the eight years later?

Chapter 3. RESEARCH METHODOLOGY

Methodology in this thesis consists of two major objectives. Firstly, analyzing the pattern of ships arrival in the Jakarta Ro-Ro terminal and service rate for ship and develop hypotheses regarding their pattern to determine a suitable queuing model and then measuring proper existing throughput. Second, forecast throughput used to determine an ideal number of facilities required in the terminal such as berth and yard. Lack of cargo standard in Ro-Ro terminal, requires the Author to create a standard car equivalent units for each type of vehicle that has such different magnitudes. Cargo density in the yard will be collected daily for three months to measure peak factor as the additional factor of the yard requirement wide.

The steps of thesis can be show in the figure 5 below.

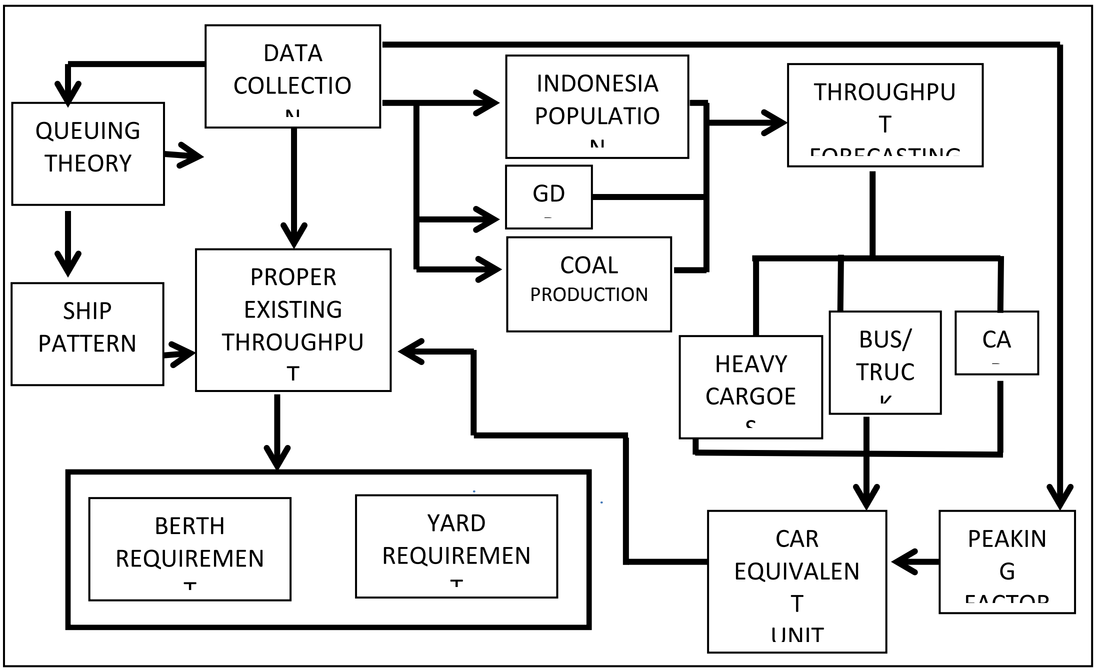

Figure 5. Research Methodology

Source: author

Aiming to study on those two research objectives above, it will be applied several methods as follows:

1) Kolmogorof Smirnov goodness of fit test is used to examine the distribution of ship and service rate to determine ship arrival pattern.
2) A suitable mathematical model in queuing theory is used to estimate the performance parameters in the queuing system.
3) Analyze the optimum number of facilities required.
4) T-test and T-distribution (P-value) to examine relation between two variables before cargoes forecasting.
5) Forecasting future cargoes throughput which is using multiple and single regression methods.
6) Evaluate the shortage of berth and yard in the future.

3.1. Ship arrival pattern

It is important to get information about existing ship performance by evaluating ship arrival pattern in this terminal. For helping analysis activities, some statistical tools will be used as can be explained follows:

3.1.1. **Histogram**

A *histogram* is a representation of a frequency distribution by means of rectangles whose widths represent class intervals and whose areas are proportional to the corresponding frequencies (Amity University, 2010). Data time arrival and service time will be collected and showed in the histogram graph. The width of each bar is called a bin or class, and the height of bar showing data frequency in the particular bin /class.

Base on classical density estimators, the idea of grouping and tabulating data into bins to form a modern frequency curve. The first step to create histogram graph is determining the width of bin with using formula as follows (Calyampudi et al, 2005, p231):

- Sturges rule for the bin width of a histogram of a random sample (X_1, X_2…..X_n) can be expressed as :

$$h = \frac{X(n) - X(1)}{1 + log2\ (n)}$$

Where X(1) is the i^{th} order statistic of sample or as X minimum in the other hand, X(n) as X maximum. In the expression Log2(n), n is the number of data observation. The frequency data raised in range of the bin can be shown as the height of histogram.

3.1.2. **Kolmogorof-Smirnov Goodness of Fit Test**

Frequency distribution of arrival and time of service test is as a requirement to determine ship arrival pattern in the queuing model. Before determining the queuing model, firstly conducted testing on frequency distribution of arrival and time of service (Bagus D, 2011). Base on frequency distribution test which is conducted by using Kolmogorov Smirnov Goodness of fit test (K-S test), It can be described as follow (Rajagopalan, 2006, p.197):

a. Aim

To test the population distribution F(x) be regarded as $F_0(x)$, based on a random sample.

b. Source

Let X_i, (i = 1,2,…,n) a random sample of n observations be drawn from a population. Let $F_0(x)$ be the cumulative distribution function (CDF) of a specified (given) population.

c. Null Hypothesis

H_0: the population distribution F(x) is $F_0(x)$

d. Alternative Hypothesis

H_1: the population distribution F(x) is not $F_0(x)$

e. Level of significance (α) and critical value (D_α)

The critical value D_α for the level of significance α and the sample size, n is obtained from table 2.

Table 2. Critical Values of the Kolmogorov-Smirnov Statistic

Sample Size (n)	Level of Significance α for D = max $\mid F_0(X) - F_n(X) \mid$				
	.20	.15	.10	.05	.01
Over 35	$\frac{1.07}{\sqrt{n}}$	$\frac{1.14}{\sqrt{n}}$	$\frac{1.22}{\sqrt{n}}$	$\frac{1.36}{\sqrt{n}}$	$\frac{1.63}{\sqrt{n}}$

Source : Rajagopalan, V. (2006). Selected Statistical Tests

f. Method

1) Calculate the cumulative distribution $F_0(x)$ base on the sample observations and the specified (given) population distribution.
2) Obtain the cumulative distribution of the sample, $F_n(x)$ be the empirical distribution function, $F_n(x)$ = (Number of observations $X_i \leq x)/n$.
3) Find the absolute difference $|F_0(x) - F_n(x)|$

g. Test Statistic

$$D = \max |F_0(x) - F_n(x)| \qquad (3.3)$$

h. Conclusion

If $D \leq D_\alpha$, accept H_0 and If $D > D_\alpha$, reject H_0 or accept H_1

3.2. **Queuing Theory**

After counting the Ship arrival pattern and service time hypothesis accepted as an exponential distribution, the queuing model can be determined. The queuing model can be declared as Poisson distributed for arrival rate and service time as an exponential distribution. The goal of queuing theory in this study only for analyze ship on berth behavior, so model queuing theory use M/M/1 as the most simple queuing system. The system consists of only one server with First In and First Out (FIFO) service. The system shows where after the long running time, the system will tend to reach a stable state and the distribution of the customers in the system does not change.Queuing system can be applied to various related problems as any system with a very large number of independent customers can be determined as a Poisson process.

M/M/1 queuing systems assume a poison arrival process. This assumption is a very good approximation for arrival process in real systems that meet some rule as follows (Daniel Moon, 2012,P.5):

1. Number of customer in the system very large.
2. Impact of single customer on the performance of the system is very small, i.e. a single customer consumes a very small percentage of the system resources.
3. All customers are independent, i.e. their decisions to use the system are independent of other users.

3.3. T-Test and T-distribution (P-value) Test

The relation between independent variable and dependent variable should be tested by related statistical tool. T-test and T-distribution test are common tools which can be used before forecasting methods is applied. Next, this statistical step can be described as follows: (Daniel Moon,2012)

a. Determining a number of population data (n), degree of freedom (n-2) (Φ) and significance level (α)for case two tailed test.

b. Determining correlation coefficient (r) using excel formula :

   =CORREL(array1,array2)

   Array1 can be found by blocking data1, array 2 can be found by the second data.

c. Find the critical value of t (2-tailed) t(α/2,Φ) from T-table or using excel formula as follows :

   =TINV(significance level, degree of freedom)

d. Measuring test statistic (T) with formula :

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

e. Measuring T distribution (P-value) by using excel formula as follows :

   =Tdist(test statistic(t), degree of freedom(Φ), 2)

f. Hypothesis:

   - Null hypothesis : Ho = no relation between two variables

Ha = there is relation between two variables

- If T-test statistic > critical value, Ho rejected, it means there is relation between two variables.
- If T distribution (P-value) < significance level (α), Ho rejected, it means there is relation between two variables.

3.4. Forecasting method

In this study, forecasting will needed to predict future throughput. Cargo behavior in the terminal will employ existing berth and yard area. To keep high facilities availability and avoiding terminal congestion, Terminal needs preparing adequate facilities to handle cargo throughput. In this terminal there are various forms of vehicle cargoes.

Car and bus/truck forecasting use multiple regression model where population and Indonesia Gross Domestic Product (GDP) will be used as independent variables. Coal production also used as independent variable to forecast heavy cargo such as dozer, excavator and forklift. The coefficient of correlation is the most commonly used measure to describe the relation between two variables. Another measure does exist is coefficient determination or usually call r^2. The value of r^2will always be positive number in range $0 < r^{2<}1$. (Barry Render. et.all, 2003). The coefficient of determination is the percent of variation in the dependent variable (Y) that is explained by the regression equation. The closer the R-square is to 1, the “better” the overall fit of the estimated regression equation to the actual data. Unfortunately, there is no simple cutoff that can be used to determine whether an $r^2$is close enough to 1 to indicate a “good” fit. With time series data, $r^2$are often in excess of .9; with cross-sectional data .5 might be considered a reasonably good fit. (Michael R Baye, 2010). Other considerations are T-test and T distribution test (P-value) as statistical tools to measure the relationship between two variables. If there is no relation between two variables, forecasting methods will use simple regression method.

The growth of Indonesia GDP use simple regression model and the growth of Indonesia population use average growth from data interpolation before. Due to the use of trucks allocated to support coal mining in Indonesia, the growth of coal productions wasused as independent variables in truck throughput forecasting.

3.5. Data Requirement

Data required to analyze the research problem and support the optimal decision is explained as follow:

1) Time between arrivals of the ships in the port will be observed and collected at Tanjung Priok Car Terminal.
2) The number cargo in the storage yard per day to determine peaking factor
3) The number of Indonesia Population, Indonesia Gross Domestic Product, and coal productionwill be collected from Indonesian Statistical Centre Bureau.

Chapter 4. Data Collection

In this study, data was divided to primary sources and secondary sources. The primary data was collected by field observation such as daily storage density and service time. On the other hand, secondary data was collected from the internal corporate data centre, Indonesia Statistical Center Bureau and internet source such as ship pattern in year 2012 and data cargo throughput.

4.1 Corporate Overview

The Tanjung Priok Car Terminal (TPT) was inaugurated by the vice president of Indonesia on Nov. 28, 2007 and starting operated in the middle of December 2007 for handling a dedicated stream of vehicle ships or RO-RO ships. The creating of this company was formed as a response to the increasing vehicle cargo that requiring a dedicated services and high quality standard cargo safety.TPTis a subsidiary corporate under Indonesia Port Company (IPC, below 2012 usually called PT. Pelabuhan Indonesia II) and located in the North coastal of Jakarta, Indonesia as can be shown at figure 6 below.

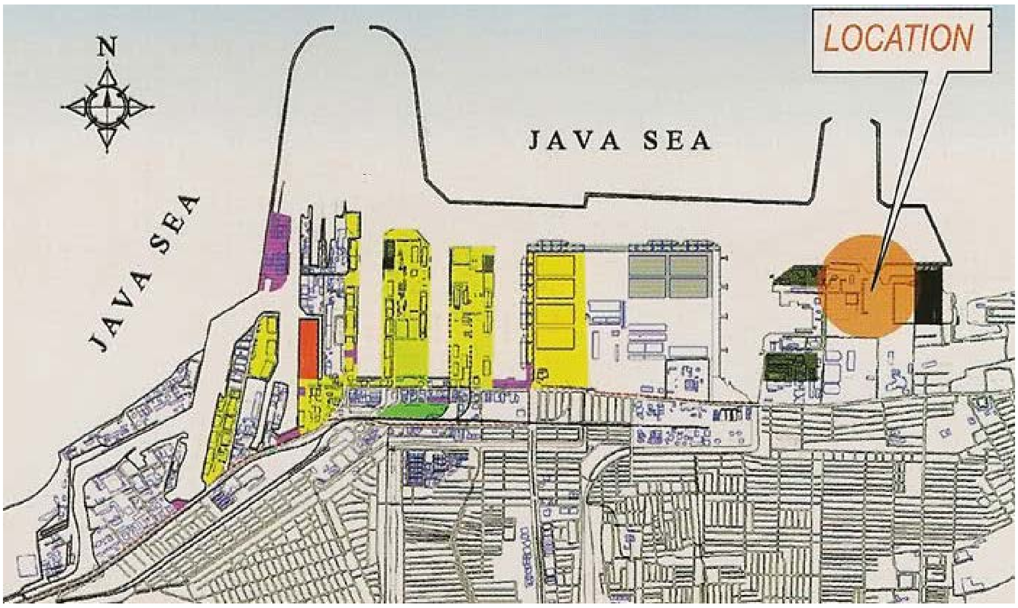

Figure 6. Tanjung Priok Car Terminal Location
Source : IPC portal, http://www.indonesiaport.co.id/menu/terminal-mobil-tanjung-priok.html

The main service of this terminal are loading/unloading vehicle service, Pre delivery inspection service, minor repair service for export car and storage service. In line with the development of the export and import of vehicles in the recent years, TPT will further improve the service by develop its facilities to keep the speed of service.

In the first of 2013, TPT was changed its name to be "Indonesia Kendaraan Terminal" (IKT). It is as a result of the management system changes to support the increasing service performance. New investments plan began to be launched such as the expanding berth, yard, warehouse, parking building and equipments.

4.1.1. Terminal Facilities and Equipments

When first operated, TPT has only 7 hectares land area consist of storage area, office area, access road, car wash building and 1 unit three floors parking building, each floor area has 1 ha wide or total area that can be used for stacking in the parking building is 3 hectares. So the total storage area on TPT only 5 hectares or it has 4,166 cars stacking ground slot with the assumption one ground slot use 12 m^2 area. On the other hand, there are 2 unit berths in TPT. The first berth has length 88 m and depth 6 m. Berth II has length 220 m with 12 m depth. In practice, berth I have never used for ships berthing because the dimensions are not eligible to serve ship call which is have an average length of 170 m and draft of 8.5 m. So, only dock II is used to ship berthing.

In year 2011, TPT invests 2 unit tug master to support loading and unloading heavy cargo on flat bed. The goal is this investment is to increase loading and unloading speed heavy cargo in the terminal.

As a result of cargorapid growth per year, In 2011, TPT has made 8,5 Ha expandingarea and increase the parking height from three floors to 5 floors. Nowadays, the facilities and equipment in TPT can be shown in table 3 below.

Table 3. Facilities and Equipment of Tanjung Priok Car Terminal

No	Facilities	Length, Wide and Capacity	
a	**Berth Facilities**		
1	Channel		
2	Berth I	Length	88 m
		Depth	-6 m
	Berth II	Length	220 m
		Depth	-12 m
b	**Storage Facilities**	wide	Capacity
1	Land Area	13,5 Ha	
2	Storage area		
	- Yard A	1.2 Ha	720 unit cars
	- Yard B	0.7 Ha	420 unit cars
	- Yard C	1 Ha	600 unit cars
	- Yard E	4.9 Ha	2,352 unit cars
	- Yard F	2.1 Ha	1.260 unit cars
	- Buffer Area	1 Ha	600 unit cars
	- Parking Building1 Ha, 5 Floors	5Ha	3,000 unit cars
	Total	15.5 Ha	8,952 unit cars
C	**Other Facilities**		
1	Access Road	500 m	
2	Ware House	3,000 m^2	
3	Car Wash	3 lines	
4	Office and Workshop	1 units	
5	Gate In/Out	6 ways	
6	Service Point	2 units	
7	Yard Sweeper	3 units	
8	Tug Master	2 units	

Source: Tanjung Priok Car Terminal Data Centre

Base on table 3 above, terminal yard capacity available for 8,952 slot car equivalent where the terminal lay out can be seen in figure 7 below.

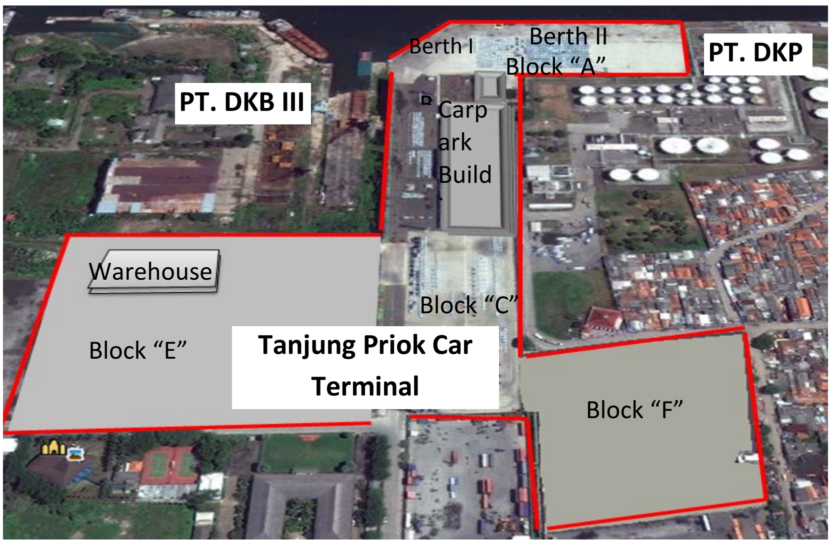

Figure 7. Tanjung Priok Car Terminal Lay Out

Source: TPT data centre

At the right side of terminal is chemical terminal owned by PT. Dharma Karya Persada (DKP) which has 150 meter berth for loading/unloading chemical vessel. The left side of Tanjung Priok car Terminal is ship docking owned by PT. Dock Koja Bahari III (PT.DKB III). This docking has 12 Ha land area and it is not full operated

4.1.2. Operational Data

4.1.2.1. Throughput

This terminal only serves Ro-Ro ship and it will bring operational impact which loading and unloading activity served by Ro-Ro system. It does not need specific equipments but need more land area to store cargoes. The most cargo type in this terminal is car and the other cargoes are bus/truck and heavy cargo. Using average throughput data from 2008 till 2012, cargo composition is dominated by the car 95%, followed by heavy cargo 3% and bus / truck 2%. The composition of cargo base on type can be shown in figure8.

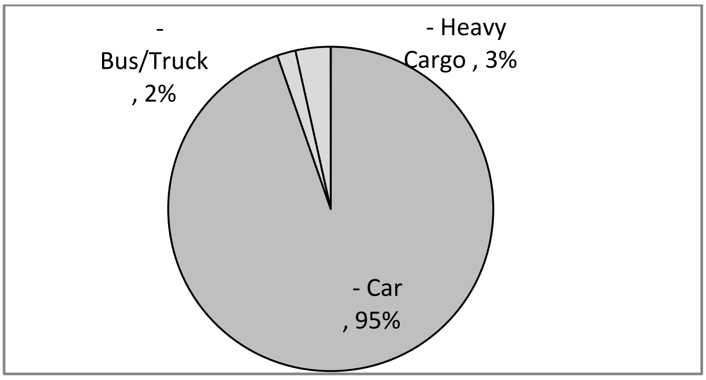

Figure 8. Cargoes Composition at Tanjung Priok Car Terminal
Source : Author compilation base on TPT data centre

Base on timeline data in table 4, there was a significant growth of loading and unloading car, bus/truck and heavy cargo year by year. Based on data 2012, Car import and export almost balance with 49% import and 51% export. It caused Toyota-Daihatsu has built the car manufacture in Indonesia and start to export some type of car to Asia and Middle East. On the other hand, bus/truck and heavy cargo is imbalance which dominated by import activity 98% and export only 2%. The heavy cargo vehicle mostly used to support the productivity of coal mining in the middle and the east of Indonesia with 87% import and 13% export.

Table 4. Ships and Cargoes Throughput at Tanjung Priok Car Terminal

CARGO TYPE	2008	%	2009	%	2010	%	2011	%	2012	%
SHIPS Call	250		208		271		268		282	
IMPORT (UNIT)										
- Car	80,787	45%	47,840	46%	101,926	54%	112,425	51%	168,694	49%
- Bus Truck	2,613	98%	1,141	98%	4,150	99%	5,234	99%	6,450	98%
- Heavy Cargoes	4,648	89%	2,591	86%	7,003	89%	9,641	89%	9,611	87%
EXPORT (UNIT)										
- Car	99,317	55%	55,423	54%	86,212	46%	107,376	49%	172,715	51%
- Bus Truck	51	2%	18	2%	57	1%	70	1%	152	2%
- Heavy Cargoes	578	11%	432	14%	904	11%	1,154	11%	1,460	13%
TOTAL EX/IMP (UNIT)										
- Car	180,104	100%	103,263	100%	188,138	100%	219,801	100%	341,409	100%
- Bus/Truck	2,664	100%	1,159	100%	4,207	100%	5,304	100%	6,602	100%
- Heavy Cargo	5,226	100%	3,023	100%	7,907	100%	10,795	100%	11,071	100%

Source : TPT data centre

4.1.2.2. Ship time between arrival

The meaning of ship time between arrivals is time interval between two ship arrivals. This data is important to evaluate ship arrival pattern in the port. Data was collected from operational data 2012 and it will be presented to be distribution data of ship time between arrivals. Firstly, the number of binswill be determined by Sturgess rule through formulation as follow:

$K = 1 + \log_2 n$, where K is number of bins and "n" is number of data. For examples:

Number of ship call in 2012 at Tanjung Priok Car Terminal is 282 vessels so we have number data of ship time between arrival is 282 -1 = 281 data. This, the number of bin is $K = 1 + \log_2(281)$, K = 9.13.

Bin width was determined by the difference of maximum and minimum data value. Maximum value is 44.48 and minimum value is 0.45 and then bin width is:

$$h = \frac{44.48 - 0.45}{9.13} = 4.87 \approx 5$$

According calculation above, the tabulation of data frequency ship time between arrivals can be shown in table 5 below:

Table 5. Distribution of Ship Time between Arrivals

Bin	Interval (hours)			Frequency
1	-	-	5.00	103
2	5.00	-	10.00	52
3	10.00	-	15.00	38
4	15.00	-	20.00	32
5	20.00	-	25.00	18
6	25.00	-	30.00	19
7	30.00	-	35.00	11
8	35.00	-	40.00	5
9	40.00	-	45.00	3
Average		11.63	Hours	
Total				281

Source : Author elaboration base on TPT data centre

Base on table above the histogram graph can be in figure 9 :

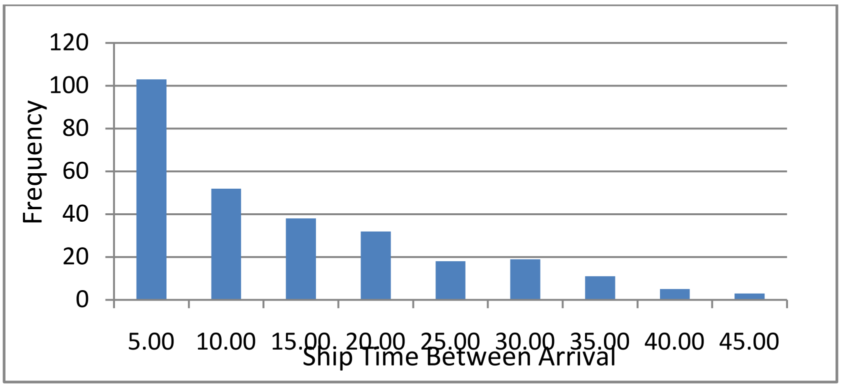

Figure 9. Histogram of Ship Time between Arrivals
Source : Author elaboration base on TPT data centre

4.1.2.3. Move per call

Crane production which served cargo on container vessel usually called Lift per Call (LPC). In Ro-Ro terminal which cargo served by Roll on – Roll off use move per gang worker as productivity measurement and then we can callit Movement per Call (MPC) as similarity of LPC. Data distribution of MPC can be shown in table 6.

Table 6. Distribution of cargo move per call

Bin	Interval (units)			Frequency
1	-	-	416	69
2	416	-	832	46
3	832	-	1,248	29
4	1,248	-	1,664	36
5	1,664	-	2,080	42
6	2,080	-	2,496	32
7	2,496	-	2,912	18
8	2,912	-	3,328	7
9	3,328	-	3,744	2
10	3,744	-	4,160	1
Average		1,265	Units	
Total				282

Source : Author elaboration base on TPT data centre

Base on table above the histogram graph of MPC distribution can be shown in figure 10 below.

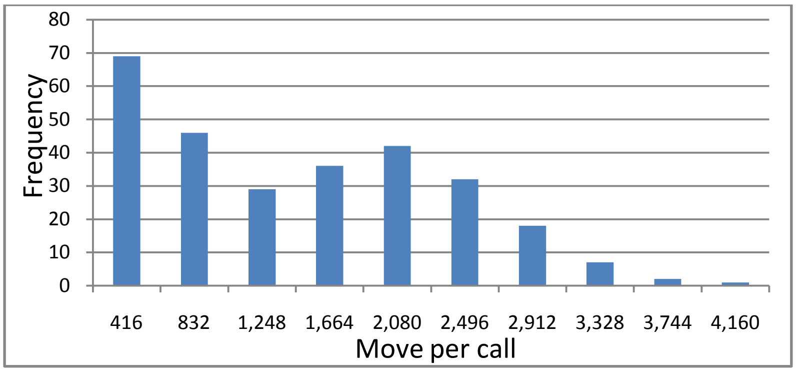

Figure 10. Histogram of Move per Call (MPC)
Source : Author elaboration base on TPT data centre

4.1.2.4. Loading/unloading service time

Loading/unloading service time reflect time to serve loading and unloading vehicle per unit per gang. The gang worker consists of 15 persons who served loading/unloading process from ship to the ship side for heavy cargoes, from ship to the storage yard for car and vice versa. In every gang, 1 person has function as gang coordinator, 4 persons as signal man and the other 10 as drivers. Data was collected from loading/unloading activities in year 2012 and data distribution can be shown in table 7 below.

Table 7. Distribution of Loading/Unloading Service Time

Bin	Interval (minutes)			Frequency
1	-	-	1.95	155
2	1.95	-	3.90	88
3	3.90	-	5.84	18
4	5.84	-	7.79	10
5	7.79	-	9.74	2
6	9.74	-	11.69	5
7	11.69	-	13.64	0
8	13.64	-	15.58	2
9	15.58	-	17.53	0
10	17.53	-	19.48	2
Average		2.48	minutes	
Total				282

Source: Author elaboration base on TPT data centre

The histogram graph of service time can be shown in figure 11.

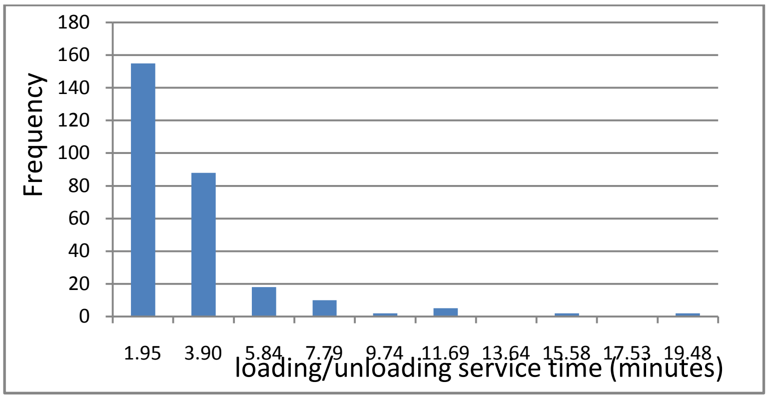

Figure 11. Histogram of Loading/Unloading Service Time
Source: Author elaboration base on TPT data centre

4.1.2.5. Number of Gang Workers Distribution

In loading/unloading activity, there is various allocation of gang workers number when served stevedoring activity at berth. It depends on the number of move per call cargoes in the ship. As shown in table 8, the distribution of gang workers allocation in year 2012.

Table 8. Distribution of Gang Workers Allocation

Bin	Interval (Gang)			Frequency
1	-	-	1.00	5
2	1.00	-	2.00	43
3	2.00	-	3.00	51
4	3.00	-	4.00	17
5	4.00	-	5.00	127
6	5.00	-	6.00	26
7	6.00	-	7.00	13
Average		4.22	Gang	
Total				282

Source : Author elaboration base on TPT data centre

4.1.2.6. Ship Length overall (LOA)

LOA show the length of ship which berthing at TPT, Based on data year 2012 the distribution of LOA can be in table 9 below.

Table 9. Distribution of LOA

Bin	Interval (meter)			Frequency
1	108	-	118	1
2	118	-	128	0
3	128	-	138	2
4	138	-	148	8
5	148	-	158	11
6	158	-	168	21
7	168	-	178	74
8	178	-	188	113
9	188	-	198	11
10	198	-	208	41
Average		178.75	m	
Total				282

Source : Author elaboration base on TPT data centre

4.1.3. Operational Service Process

Operational process in this terminal is serving loading/unloading cargo by Ro-Ro system, transfer cargo from ship side to storage yard, storage operation and receiving/delivery. This study only discuss about cargo operation process until storage area and vice versa. The loading/unloading process using two systems i.e. direct system and indirect system. Direct system use one driver philosophy which cargo was driven from ship directly to the storage area. It usually applied for car and bus. Indirect system used for heavy cargo such as excavator, dozer, and other heavy cargoes. In this system, cargo would be unloaded/loaded from ship to ramp side. In the quay, cargo will be rolled on to the trailer or flat bed and then transferred to the storage area. In the storage area, heavy cargo will be roll down from trailer/flat bed and placed to the storage area. The comparison of two stevedoring systems in Ro-Ro terminal can be shown in figure 12 below.

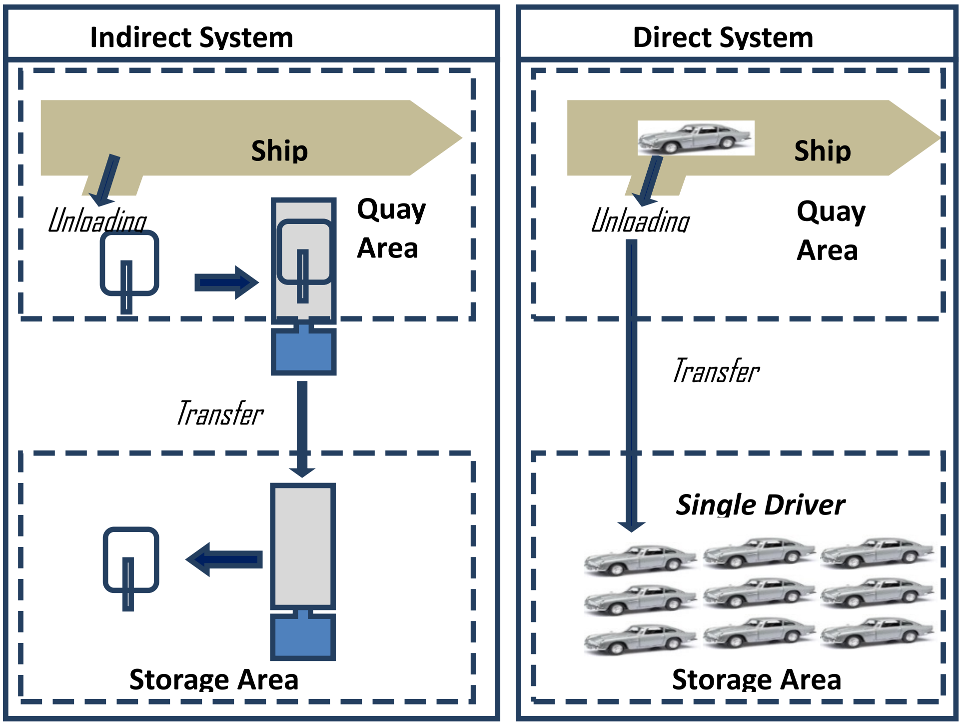

Figure 12. Comparison Unloading Process by Indirect & Direct System

Source: Author elaboration

4.2.Indicator of Independent Variables

Compared to other countries affected by the financial crisis in 1997, Indonesia underwent the slowest economic recovery. Closed political system, inefficient bureaucracy, weak law enforcement and less of attention for real sector are as the variables which influence slow economic recovery in Indonesia. (Faisal Basri, 2009). Nowadays, The Changes of political conditions has been encouragedeconomic policy changed, leverage the growth of economic conditions, support international trading and in turn will affect cargo throughput in the port. In this case, there are three factors which are used to consider the cargo throughput at Tanjung Priok Car Terminal. They are Indonesia GDP and Population which are influencing car and bus/truck throughputs, other factor is Indonesia coal production which is influencing heavy cargoes throughput.

The gross domestic product (GDP) is the market value of the total quantity of final goods and services produced over the specified time period and it usually used to measure the economic growth. There are four elements of GDP; these are Investment (I), Government expenditure (G), consumption of goods and services (C) and excess of export and import (Nx).Base formula to calculate GDP is : (Gregory Mankiw, 2000)

$Y = C + I + G + NX$

From these elements, It seems GDP has a big relationship with cargo throughput in the port and next GDP will be used as independent variable to predict cargo low in TPT. Table 10below is an illustration of Indonesia GDP per semester (based on current price include oil and gas).

Table 10. Indonesia GDP

Indonesia GDP (in billion USD)							
Year	P.a	Semester		Year	P.a	Semester	
		I	II			I	II
1996	227.37	106.59	120.78	2005	285.87	134.86	151.01
1997	215.75	110.63	105.12	2006	364.57	157.19	207.38
1998	95.45	61.03	34.42	2007	432.11	196.04	236.06
1999	140.00	53.66	86.34	2008	510.23	245.10	265.12
2000	165.02	75.14	89.88	2009	539.35	277.84	261.51
2001	160.45	81.34	79.11	2010	706.56	326.45	380.11
2002	195.66	87.09	108.57	2011	846.83	377.61	469.23
2003	234.77	105.65	129.12	2012	859.00	428.49	430.51
2004	256.84	122.38	134.45				

Source : Indonesia Statistical Center Bureau

Indonesia GDP showsa slightly growth year by year with average 5 - 6% per year. In 1998 – 1999, GDP fall off to the lowest point due to global crisis in the world where almost all country in the world occur a decreasing economic growth. The higher GDP was expected to enhance the purchasing power of the community, especially for the purchasing of transportation equipment such as car, bus and truck. Finally, this condition will can influence cargo throughput growth in Tanjung Priok Car Terminal.

Another factor is Indonesia Population. Base on CIA world Factbook, Indonesia has the fourth largest population after China, India and the USA. Larger Indonesia population is a potential market for world retail and industries goods. Base on Indonesian statistical report, the average growth of Indonesia population occurs around 1.49% peryear. The existing population per semestercan be shown in table 11 below.

Table 11. Indonesia Population

Indonesia Population in millions							
Year	P.a	Semester		Year	P.a	Semester	
		I	II			I	II
1996	195.58	98.28	97.31	2005	220.70	110.89	109.81
1997	198.54	99.76	98.78	2006	223.99	112.54	111.45
1998	201.54	101.27	100.27	2007	227.33	114.22	113.11
1999	204.59	102.80	101.79	2008	230.71	115.92	114.79
2000	206.26	103.64	102.62	2009	234.15	117.65	116.50
2001	208.02	104.52	103.50	2010	237.64	119.40	118.24
2002	211.12	106.08	105.05	2011	241.18	121.18	120.00
2003	214.27	107.66	106.61	2012	244.78	122.99	121.79
2004	217.46	109.26	108.20				

Source : Indonesia Statistical Center Bureau

Another factor which is influencing cargoes throughputs is Indonesia coal production. According BP statistical review 2012, Indonesian coal production accounts more less 5% of total world coal production.In this case, Coal production will determined as dependent variable which is influencing the number of import of heavy cargo at TPT. Excavator and dozershould be used to support coal mining operations such as excavation, dozing and open / extend mining area. The higher coal productivity will need the more number equipment and thus, heavy cargo demand suppose have relation with coal production. In the recent year, Indonesia coal production shows an increasing trend from 2004 until 2011, even though in first semester and the second semester 2012 there is a decreasing production. From data elaboration, Indonesia coal production has average growth 10% per semester or 13% per year.

The data of Indonesia coal production can be shown in table 12 bellow.

Table 12. Indonesia Coal Production

Coal Production In Million Tones							
Year	P.a	Semester		Year	P.A	Semester	
		I	II			I	II
1996	50.33	23.25	27.08	2005	149.67	72.33	77.34
1997	55.98	19.38	36.60	2006	162.29	74.71	87.59
1998	58.50	28.27	30.23	2007	188.66	101.88	86.79
1999	62.11	29.81	32.30	2008	188.72	90.58	98.13
2000	67.11	23.23	43.88	2009	208.01	72.00	136.01
2001	71.07	34.35	36.73	2010	256.79	124.10	132.69
2002	105.54	48.58	56.96	2011	370.00	170.32	199.68
2003	113.53	54.49	59.03	2012	332.01	179.28	152.72
2004	128.48	44.47	84.01				

Source : Indonesia Statistical Center Bureau

4.3. Car Equivalent Units

Car Equivalent Unit was measured base on car dimension which is came to Tanjung Priok Car Terminal in 2012 period. Firstly, we must determine rectangular area standard as can be called “ground slot” for 1 car. There is various dimension type which attending to the terminal and the highest dimension of car has to be determined from set of data. Safety clearance 500 mm has to be added for front and 700 mm in the side of the car dimension. Data and standard dimension of car can be shown at table 13 as follow:

Table 13. Ground Slot Dimension Standard for Car at TPT

No	type	length (mm)	wide (mm)	slot m^2
1	Cherry	3,550	1,508	5.4
2	Honda Brio	3,610	1,680	6.1
3	Yaris	3,614	1,600	5.8
4	Daihatsu Sirion	3,690	1,665	6.1
5	Mitsubishi Mirage	3,710	1,665	6.2
6	Nissan March	3,780	1,665	6.3
7	Ford Figo	3,795	1,680	6.4
8	Gelly LC Cross	3,815	1,648	6.3
9	Suzuki Swift	3,850	1,695	6.5
10	Honda Jazz	3,900	1,695	6.6
11	Mazda Hatchback	3,913	1,695	6.6
12	Etios	3,995	1,695	6.8
13	Ford Fusion	4,018	1,720	6.9
14	Daihatsu Grand Max	4,045	1,665	6.7
15	avanza	4,120	1,635	6.7
16	VW new beetle	4,129	1,721	7.1
17	Nissan Juke	4,135	1,765	7.3
18	Daihatsu Xenia	4,140	1,660	6.9
19	DaihatsuLuxio	4,165	1,665	6.9
20	Honda Freed	4,215	1,700	7.2
21	Suzuki APV	4,225	1,655	7.0
22	Ford Fiesta	4,291	1,722	7.4
23	Rush	4,410	1,695	7.5
24	Honda City	4,410	1,715	7.6
25	Nissan Grand Livina	4,420	1,690	7.5
26	Daihatsu Terios	4,425	1,695	7.5
	…			
27	Mazda RX8	4,470	1,770	7.9
28	Prius	4,480	1,745	7.8
29	Corolla H5	4,530	1,705	7.7
30	Honda Civic	4,540	1,755	8.0
31	Honda CRV	4,545	1,820	8.3
32	Innova	4,555	1,770	8.1
33	Mitsubishi Lancer	4,570	1,760	8.0
34	Chevrolet Cruze	4,597	1,788	8.2
35	Audi A5	4,625	1,854	8.6
36	ChevroletCaptiva	4,660	1,870	8.7
37	Isuzu Panther	4,692	1,771	8.3
38	Mitsubishi Pajero	4,695	1,815	8.5
39	Fortuner	4,705	1,840	8.7
40	Mazda Biante	4,715	1,770	8.3
41	Land Cruiser Prado	4,760	1,885	9.0
42	Camry	4,815	1,820	8.8
43	Nissan Teana	4,850	1,795	8.7
44	Honda Accord	4,935	1,845	9.1
45	Isuzu D Max	5,035	1,800	9.1
46	Mitsubishi Strada	5,040	1,800	9.1
47	Ford Endeavour	5,060	1,788	9.0
48	Mazda CX 9	5,099	1,936	9.9
49	Nissan Frontier	5,230	1,850	9.7
	n	**49**		
	Average (mm)	**4,359**	**1,738**	**7.6**
	Safety Clearance (mm)	**500**	**700**	
	Average + clearance (mm)	**4,859**	**2,438**	
	Rectangular area (m^2)/unit car			**11,8**

Source : Author elaboration

According data set above, the dimension of 1 ground slot for car parking is 11,8 m^2 ≈ 12 m^2. This measurement still between minimum (6.5 m^2=3.88 mx 1.68 m) and maximum (16.30 m^2= 6.68 m x 2.44 m) car dimension parking standard as can be shown in table 1. Next, this dimension can be used to measure Car

Equivalent Unit for other type vehicle such as bus/truck and heavy cargoes. The variety of bus/truck dimension can be shown in table 14 below.

Table 14. The Variety of Rectangle Area for Bus/Truck

No	Truck Type	length (mm) (mm)	wide (mm) (mm)	slot m^2	Throughput 2012	% Throughput
A	**Truck**					
1	Man Truck	12,000	2,574	30.9	292	4.4%
2	Iveco Truck	8,007	2,200	17.6	378	5.7%
3	Hino Truck	8,087	3,190	25.8	395	6.0%
4	Doosan Truck	9,488	2,990	28.4	458	6.9%
5	Nissan	9,010	2,400	21.6	488	7.4%
6	Scania Truck	9,790	2,430	23.8	725	11.0%
7	Mercedes benz	8,255	2,490	20.6	839	12.7%
8	Mitsubishi Fuso	10,140	2,490	25.2	978	14.8%
9	Volvo Truck	6,800	3,200	21.8	1,445	21.9%
	Average	**9,064**	**2,662**	**24.0**		
	Safety Clearance	**500**	**700**			
	Average + Clearance	**9,564**	**3,362**	**32.2**	**5,998**	**90.9%**
B	**Giant Truck**					
1	Terex Dump Truck	10,900	3,400	37.1	60	0.9%
2	Caterpillar Dump Truck	9,780	4,457	43.6	259	3.9%
3	Komatsu Dump Truck	11,310	3,450	39.0	285	4.3%
	Average	**10,663**	**3,769**	**40**		
	Safety Clearance	**500**	**700**			
	Average + Clearance	**11,163**	**4,469**	**50**	**604**	**9.1%**
	Grand Total				**6,602**	**100%**

Source : Author elaboration

According table 8 above, type of bus/truck divide by truck and giant truck which is has different standard. Average dimension of truck is 32.2 m^{2}and it has proportion 90.9% from all bus/truck throughputs 2012. Giant truck has standard dimension 50 m^2 and it has proportion 9.1% from total bus/truck throughput in 2012.On the other hand there are different standard for Heavy cargoes. As described previously, heavy cargoes have some type of cargoes. These are excavator, forklift and dozer. Table 15 shows the variety of heavy cargo dimension.

Table 15. The Variety of Rectangle Area for Heavy Cargo

No	Heavy Cargo	length (mm) (mm)	wide (mm) (mm)	slot m2	Throughput 2012	% Throughput
A	Forklift					
1	Toyota	2,606	1,151	3	1,303	11.8%
2	Sakai	2,650	1,430	4	38	0.3%
3	Nissan	3,340	1,490	5	240	2.2%
4	Manitou	3,055	2,070	6	340	3.1%
5	John Deere	3,810	1,725	7	114	1.0%
6	Mitsubishi	3,625	2,063	7	267	2.4%
7	Volvo	4,851	1,575	8	729	6.6%
8	Hyundai	4,465	1,746	8	14	0.1%
9	KATO	4,020	2,600	10	46	0.4%
10	Kobelco	3,660	3,190	12	2,660	24.0%
11	Sumitomo	3,720	3,200	12	304	2.7%
12	Kalmar	4,978	2,530	13	12	0.1%
	Average	3,732	2,064	8		
	Safety Clearance	500	700			
	Average + Clearn	4,232	2,764	11.7	6,067	54.8%
B	Excavator					
1	JCB	7,490	2,440	18	83	0.7%
2	LIEBHERR	5,192	4,334	23	13	0.1%
3	TADANO	13,480	1,820	25	33	0.3%
4	Komatsu	9,875	3,060	30	2,043	18.5%
5	Caterpillar	11,400	2,990	34	1,442	13.0%
6	Hitachi	11,050	3,390	37	1,306	11.8%
7	Terex	10,642	3,669	39	42	0.4%
	Average	9,876	3,100	29		
	Safety Clearance	500	700			
	Average + Clearc	10,376	3,800	39.4	4,962	44.8%
C	Dozer/roller					
1	Kawasaki	6,045	2,350	14	42	0.4%
	Average	6,045	2,350	14		
	Safety Clearance	500.0	700			
	Average + Clearc	6,545	3,050	20	42	0.4%
	Grand Total				11,071	100%

Source : Author elaboration

According data variety above, forklift needs average space 11.7 m^2 and the proportion is around 54.8% from total heavy cargo throughput in year 2012. Excavator needs space 39.4 m^2 and the throughput proportion 44.8% from total heavy cargo. Dozer needs 20 m^2 and it only has 0.4% from total heavy cargo base on year 2012.

Car equivalent units can be calculated based on data above and it is using a formula as follow:

$$CEU_k = \frac{S_k}{S_c}$$

Where,

CEU_k = car equivalent unit of type *k* vehicle;

S_k = the effective space type k vehicle (m^2),

S_c = the mean effective space of car (m^2).

For the example: CEU_{truck} = 32 / 12 = 2.72, $CEU_{Excavator}$ = 39/12 = 3.33. The CEU calculation for all of cargoes can be shown in table 16 below.

Table 16. Car Equivalent Unit of Cargo at Tanjung Priok Car Terminal

No	Type of Cargo	Average Space Requirement m²	Car Equivalent Unit	Unit Throughput 2012	% Throughput 2012
1	Car	12	1.00	341,409	95.08%
2	Truck	32	2.72	5,998	1.67%
3	Giant Truck	56	4.21	604	0.17%
4	Forklift	12	1.00	6,067	1.69%
5	Excavator	39	3.33	4,962	1.38%
6	Dozer	20	1.69	42	0.01%
	Total Unit year 2012			359,082	

Source: Author elaboration

4.4. Storage Yard Peaking Factor

Storage behavior at yard area has been measured to determine storage yard peaking factor. Data of storage density have been collected every morning at 9.00 am for 90 days from 1/1/2013 until 31/3/2013. Cargoes consist of three types and every type will be converted by car equivalent unit (CEU). Distribution data of storage density daily can be shown in table 17 below.

Table 17. Distribution of The Storage Density Daily

Bin	Interval (hour)			Frequency
1	2,863	-	3,576	5
2	3,576	-	4,288	6
3	4,288	-	5,001	9
4	5,001	-	5,714	8
5	5,714	-	6,426	16
6	6,426	-	7,139	27
7	7,139	-	7,851	14
8	7,851	-	8,564	5
Average		6,134	Hours	
Total				90

Source : Author elaboration

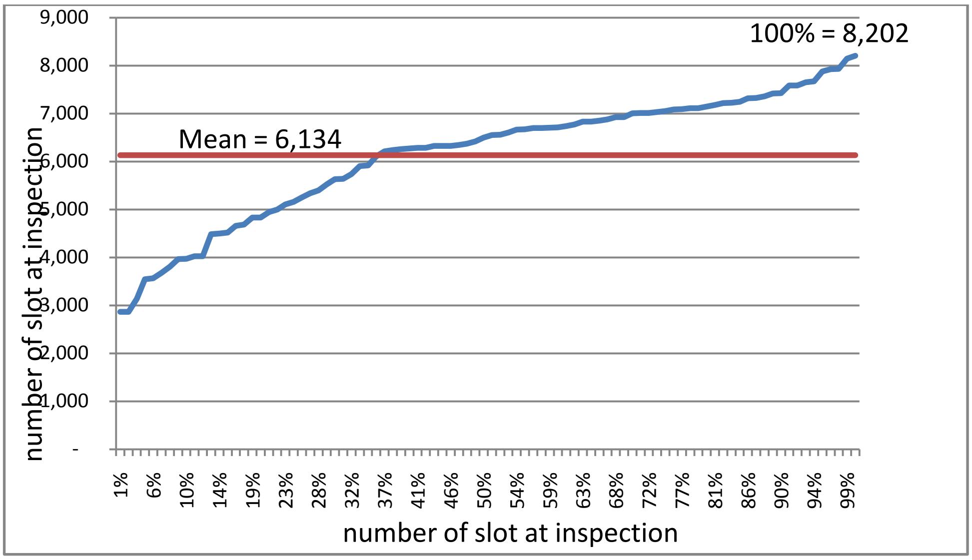

Figure 13. Cumulative Frequency Diagram of TPT Storage Inventory
Source : Author elaboration

According table 17 and figure 13 above, average storage inventory for three months is 6,134 slot car equivalent units. The maximum inventory 8,202 slot (100%). Peaking factor will be predicted 8,202 / 6,134 = 1.34.

Chapter 5. TERMINAL FACILITIES REQUIREMENTS ANALYSIS

This chapter will analyze data chapter before. The main analyze are determining cargo forecasting until next 8 years, analyze ship pattern base on year 2012 and determining the shortage or excess facilities such as berth and yard. This information is expected can help Car Terminal Management for planning their facilities in the future.

5.1. **Cargo Forecasting**

Generally, cargo type at Tanjung Priok Car Terminal divided by three types,i.e. car, bus/truck and heavy cargo. Forecasting will be done for each type of three cargoes. On the other hand, there are some independent variable which will used to compare cargo behavior such as Indonesia GDP, Indonesia Population and Indonesia coal production. The cargoes throughput forecasting will be applied using common statistical tools such as simple regression, multiple regressions and measuring relation between variables. Firstly, the relation test between variables will be done as follows.

5.1.1. **Correlation, T-test and T Distribution Test**

Before forecasting calculated, the correlation among these variables should be determined. Correlation test, T-test and T distribution test (P-Value) can be used for this purpose. Correlation among variables can be counted by excel formula which can be shown in table 18below.

Table 18. Correlation between Variables

	Ship Calls	*Car*	*Bus /Truck*	*Heavy Cargo*	*GDP*	*Pop*	*Coal Prod*
Ship Calls	1.00						
Car	0.67	1.00					
Bus/Truck	0.87	0.79	1.00				
Heavy Cargo	0.82	0.78	0.94	1.00			
GDP	0.69	0.75	0.90	0.91	1.00		
Population	0.61	0.80	0.80	0.84	0.94	1.00	
Coal Production	0.60	0.61	0.79	0.92	0.86	0.84	1.00

Source : Author elaboration

Based on information above, correlation (r) between ship calls – car = 0.67, ship calls – bus/truck = 0.87, ship calls – heavy cargoes = 0.82, car - GDP = 0.75, car - population = 0.8, bus/truck - GDP = 0.90, bus/truck – population = 0.80, and heavy cargo – coal production = 0.92. The measurement of correlation shows close relation between variables because all of the correlation above 60% and it shows that independent variable which taken has close correlation with dependent variablesand it can be used to compare car, bus/truck and heavy cargo forecasting.

Next, T-test and T distribution test can be applied to measure the relation between variables. In this case, the comparing variables will be applies such as:

- Ship calls compare bus/truck
- Ship calls compare heavy cargoes
- Car compare Indonesia GDP,
- Car compare Indonesia Population
- Bus/Truck compare Indonesia GDP
- Bus/Truck compare Indonesia Population
- Heavy cargoes compare Indonesia coal production.

For example, test between car and Indonesia GDP as follow:

Base on table 18, the correlation between car and Indonesia GDP is 0.75. Number of sample 10, degree of freedom (Φ) = 10 – 2 = 8 and the significant level (α) =0.5.

The Critical values of t (2-tailed) t(α/2,Φ) = 2.31. This result can be found in the appendix 1(distribution critical value), where α/2 = 0.5/2 = 0.26 and df = 8. In another way, the critical value can be calculated using excel formula =tinv(α,Φ).

- Test statistic (t-test) can be calculated with formula :

  $$T = 0.75 * \sqrt{(10-2)/(1-0.75^2)} \quad , \quad T = 3.21$$

- T distribution test (P-value), it can be calculated by excel formula as follow: P =Tdist(T,Φ,2). 2 means two tails distribution. = 0.0123.
- Based on these result above, the hypothesis can be described as follow:

- Null hypothesis : Ho = no relation between two variables
  Ha = there is relation between two variables
- If T-test statistic > critical value, Ho rejected,
- If T distribution (P-value) < significance level (α), Ho rejected,
- T-test statistic: T (3.21) > critical value of t (2.31), it means there is good relation between two variables.
- P-Value : P (0.0124) < significance level (0.05), it means there is good relation between two variables.

The result of T test and P-value between two variables for all pairs can be summarized in table 19 below:

Table 19. T-Test and P-Value between Variables

Statistical Measurement	Ship Call - Truck/Bus	Ship Calls - Heavy Cargo	Car - GDP	Car - Pop	Trck/Bus - GDP	Trck/Bus - Pop	Heavy Cargo - Coal Production
Correlation coefficient (r)	0.87	0.82	0.75	0.80	0.90	0.80	0.92
Number of samples (n)	10	10	10	10	10	10	10
Degree of freedom (Φ)	8	8	8	8	8	8	8
Significance level (α)	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Critical values of t (2-tailed)	2.31	2.31	2.31	2.31	2.31	2.31	2.31
Test statistic (t)	5.11	3.98	3.21	3.83	5.71	3.82	6.59
T distribution (p-value)	0.001	0.004	0.0124	0.0050	0.0005	0.0051	0.0002

Source : Author elaboration

According table 18 above, all of pairs have test statistic (t) more than critical value and P-value below significance level (α).It means Ho rejected Hence, the specified independent variable can be used to forecast cargo throughput at TPT because there is relation between variables.

5.1.2. **Demand Forecasting**

5.1.2.1. Indonesia GDP

As an economic indicator, GDP will influence international trading in a country and will affect cargo throughput.According table 18, GDP has a big relationship with cargo throughput at Tanjung Priok Car Terminal and next GDP will be used as independent variable to predict cargo flow in TPT. Figure 14 below is an illustration of Indonesia GDP (based on current price include oil and gas).

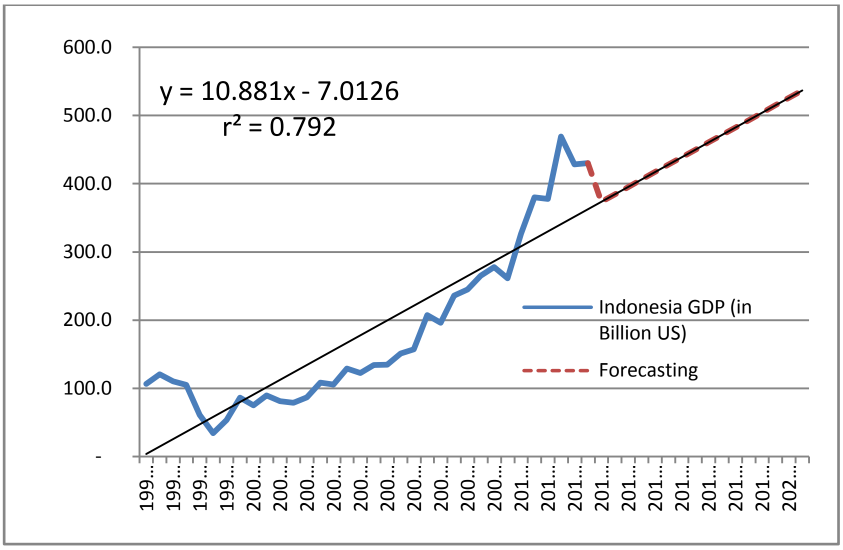

Figure 14. Indonesia GDP and Forecasting
Source : Indonesia Statistical Center Bureau and Author elaboration

The GDP forecasting use simple linear regression with equation $Y = 10.881X - 7.0126$ and $r^2 = 0.792$. The higher growth of Indonesia GDP was expected to increase the purchasing power of the community, especially for the purchasing of transportation vehicle and finally it influence cargo throughput growth in Tanjung Priok Car Terminal. A decreasing of forecasting trend in line with government regulation to reduce oil subsidy start from the middle of 2013 which entrepreneur and Indonesia people will bear an increasing transportation cost. Base on the equation above, the result of GDP forecasting can be shown in table 20 below.

Table 20. GDP Forecasting

Y'	GDP Forecast (In Billion USD)	Growth
2013	758.5	-
2014	802.1	5.7%
2015	845.6	5.4%
2016	889.1	5.1%
2017	932.6	4.9%
2018	976.2	4.7%
2019	1,019.7	4.5%
2020	1,063.2	4.3%
		4.9%

Source : Author elaboration

5.1.2.2. Population

Using simple linear regression, the population forecasting can be shown in Figure 15 below.

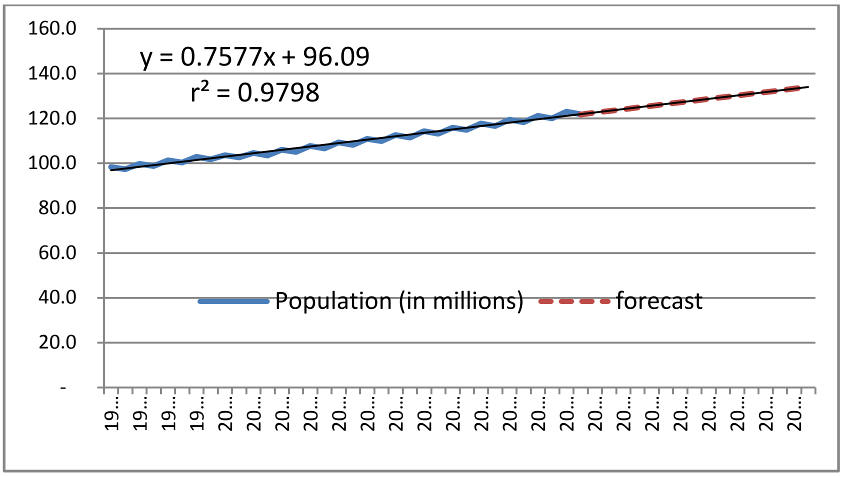

Figure 15. Indonesia Population Trends per Semester
Source : Indonesia Statistical Center Bureau and Author elaboration

According the past trend of population data, showing a good correlation between empiric data and time variable which is has equation as follow:

Y = 0.7577X + 96.09, where r^2 = 0.9798. The result of that equation canbe calculated yearly as can be shown in table 21below.

Table 21. Indonesia Population Forecasting Yearly

Y'	Population Forecast (in millions)	Growth
2013	246.0	
2014	247.5	0.6%
2015	250.5	1.2%
2016	255.1	1.8%
2017	258.1	1.2%
2018	261.1	1.2%
2019	264.2	1.2%
2020	267.2	1.1%

Source : Author elaboration

*5.1.2.3*Coal Production

Coal production mayinfluence the number of import of heavy cargo at TPT. Excavator has been used in coal mining industries.There is a high fluctuation of coal production per semester but simple regression methods still relevant to forecast coal production in the future. It is proved by r^2 = 0.8392result which is above 0.36. The forecasting of Indonesia coal production can be shown infigure 16 below.

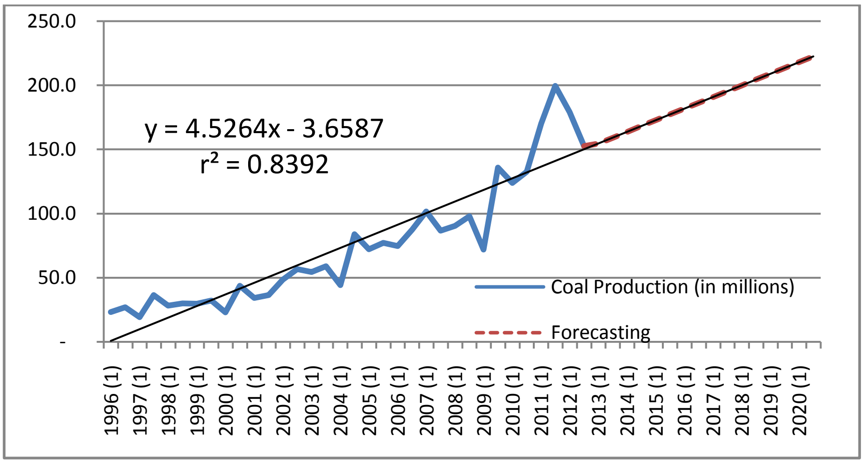

Figure 16. Indonesia Coal Production in Million Tones

Source : Indonesia Statistical Center Bureau and Author elaboration

Base on equation Y = 4.5264X – 3.6587, the forecasting result can be calculated as can be shown in table 22 below.

Table 22. Coal Production Forecasting Yearly

Y'	Coal Production Forecasting (in millions)	Growth
2013	314.1	
2014	332.2	5.8%
2015	350.3	5.5%
2016	368.4	5.2%
2017	386.5	4.9%
2018	404.6	4.7%
2019	422.7	4.5%
2020	440.8	4.3%
		5.0%

.Source : Author elaboration

5.1.2.4. Terminal Demand Forecasting

5.1.2.4.1. Car and Bus/Truck Forecasting

Car and Bus/Truck forecasting use multiple regression methods with Indonesia GDP and population as independent variable which have been forecasted before at the previous sub chapter5.1.2.1 and 5.1.2.2. The equation of car and bus/truck compare Indonesia GDP and Indonesia population as follows:

- $Y_{car} = -1,403,752.5 - 10.38X_{GDP} + 12,710.64X_{population}$, with $r^2 = 0.647$

- $Y_{Bus/Truck} = 10,937.80 + 16.70X_{GDP} - 123.89X_{population}$, with $r^2 = 0.812$

According the equation above, the forecasting of car and bus/truck throughput can be shown in table 23below.

Table 23. Car and Bus/Truck Throughput Forecasting until 2020

Year	Variable			
	Dependent		Independent	
	Car	Bus/Truck	GDP (Billion US)	Population (in million)
2008	180,104	2,664	510.23	230.71
2009	103,263	1,159	539.35	234.15
2010	188,138	4,207	706.56	237.64
2011	219,801	5,304	846.83	241.18
2012	341,409	6,602	859.00	244.78
2013	311,130	4,065	758.53	245.98
2014	349,201	4,416	802.06	249.01
2015	387,272	4,767	845.58	252.04
2016	425,343	5,119	889.10	255.07
2017	463,413	5,470	932.63	258.10
2018	501,484	5,821	976.15	261.13
2019	539,555	6,172	1,019.68	264.16
2020	577,626	6,523	1,063.20	267.19

Source : Author elaboration

Base on forecasting above, car and Bus/Truck throughput in the Tanjung Priok Car Terminal increase significantly from 2013 until 2020. Even though, from 2012 – 2013 occurs a decreasing trend. This condition accordsto a decreasing economic growth in 2013.

5.1.2.4.2. Heavy Cargo Forecasting

The forecasting of heavy cargo throughput takes similar methods with car and bus/truck but using different independent variable. Coal production was used to compare heavy cargo behavior. In the previous sub chapter 5.1.2.3, we have forecasted Indonesia coal production with the slightly growth year by year.The calculation of heavy cargo forecast resulted equation as follows:

$Y_{\text{Heavy cargo}}$ =- 1618.331715 + 39.98857792 X coal production, with r^2 = 0.844.

r^2 above shows a good correlation between variables and multiple regression meet the requirement to be used. With using equation above gains the forecasting result as can be shown at table 24 below.

Table 24. Heavy Cargo Throughput Forecasting until 2020

Year	Variable	
	Dependent	Independent
	Heavy Cargo (Units)	Coal Production (Mill Tones)
2008	5,226	188.72
2009	3,023	208.01
2010	7,907	256.79
2011	10,795	370.00
2012	11,071	332.01
2013	9,322	314.05
2014	10,046	332.16
2015	10,770	350.27
2016	11,494	368.37
2017	12,218	386.48
2018	12,942	404.58
2019	13,666	422.69
2020	14,390	440.79

Source : Author elaboration

Base on forecasting above, heavy cargoes show an increasing growth significantly according the growth of Indonesia coal production and similar with car and truck behavior which is has a decreasing heavy cargo throughput in year 2012 – 2013.

5.1.2.4.3. Ship calls forecasting

Ship call forecasting method use multiply regression which is truck/bus and heavy cargo as independent variable. Both of dependent variable was selected by considering a high correlation between independent and dependent variables (more than 0.8). Car variable was ignored as dependent variable because it only has correlation 0.6. So, even though this correlation still meet statistical requirement but the author prefers choose other larger correlation to compare.

According this assumption, the multiply regression show equation as follow:

$Y = 102.948 + 0.0144X_{bus/truck} - 0.000989X_{heavy\ cargoes}$, where $r^2 = 0.766$.

The result of ship calls forecasting can be shown in table 25 below.

Table 25. Ships Call Forecasting

Year	Variable		
	Dependent	Independent	
	Ship Calls (Units)	Bus/Truck (units)	Heavy Cargo (Units)
2008	250	2,664.0	5,226.00
2009	208	1,159.0	3,023.00
2010	271	4,207.0	7,907.00
2011	268	5,304.0	10,795.00
2012	282	6,602.0	11,071.00
2013	255	4,065.2	9,321.94
2014	260	4,416.3	10,045.95
2015	264	4,767.5	10,769.96
2016	268	5,118.6	11,493.98
2017	273	5,469.7	12,217.99
2018	277	5,820.8	12,942.00
2019	281	6,171.9	13,666.01
2020	286	6,523.0	14,390.03

Source : Author elaboration

The growth of ship call shows a decreasing trend in the 2012 – 2013. It is in line with a decreasing cargoes throughput in 2013. Mostly, Vessel berthing in TPT has LOA around 178.75 m. It should be ship generation 2 which has capacity around 3000 – 4000 car equivalent unit. On the other hand, average MPC 2012 is 1.265 units per ship. The little growth of ship call was estimated to increase MPC per ship so that the growth margin of cargo throughput growth will bigger than ship call growth margin.

5.2. The Distribution Test of Ships Pattern

Kolmogorov Smirnov Goodness of fit test will be used to test the frequency distribution of ship arrival pattern and service time. The step of this test will arranged with ship time between arrivalswhich is has an example as follow:

- The critical value (D_α) is assumed using significant level (α) 0.5 and according data of ship time between arrivals, the number of sample (n) is 281. Hence, the calculation of critical value based on table 2 is :

$$D_{0.95} = \frac{1.36}{\sqrt{281}} = 0.0811$$

- Calculate the frequency probability for each number sample between the interval as can be shown in the example below :
  - Interval 0 – 5 = F(0<x≤5) = 103 / 281 = 0.3665
  - Interval 5 – 10 = F(5<x≤10) = 52 / 281 = 0.1851
  - Interval 10 – 15 =F(10<x≤15) = 38 / 281 = 0.1352

  This calculation can be continued until the last interval
- Cumulative distribution of the sample $F_n(X)$can be calculated by adding frequency probability per interval.
- The probability density function is assumed follow exponential distribution with formula as follow :

$$f(t < x \leq T) = \left| e^{-(\frac{t}{m})} - e^{-(\frac{T}{m})} \right|$$

Where : f(t<x<T) = probability density between t and T

m = average time between arrivals (11.63)

Base on formula above, the calculation of probability density can be described as follow :

- $f(0 < x \leq 5) = \left| e^{-(\frac{0}{11.63})} - e^{-(\frac{5}{11.63})} \right|$ = 0.3494
- $f(5 < x \leq 10) = \left| e^{-(\frac{5}{11.63})} - e^{-(\frac{10}{11.63})} \right|$ = 0.2273
- $f(10 < x \leq 15) = \left| e^{-(\frac{10}{11.63})} - e^{-(\frac{15}{11.63})} \right|$ = 0.1479

The calculation can be continued until the last interval.

- Cumulative density distribution of the specified distribution $F_0(X)$can be calculated by adding frequency of probability density per interval.
- Calculate the difference between $F_0(X)$ and Fn(X). In this difference, minus sign is ignored. For the complete calculation of ship time between arrivals can be shown in table 26 as follows.

Table 26. Distribution Function of Ship Time between Arrivals

Class	*Interval*			*Empirical Distribution*			Specified Distribution		Different
				Frequency	*Probability*	Cum Prob. $F_n(X)$	*Probability*	Cum Prob. $F_0(X)$	D
I	0.0	-	5.0	103.0	0.3665	0.3665	0.3494	0.3494	0.0172
II	5.0	-	10.0	52.0	0.1851	0.5516	0.2273	0.5767	0.0251
III	10.0	-	15.0	38.0	0.1352	0.6868	0.1479	0.7246	**0.0377**
IV	15.0	-	20.0	32.0	0.1139	0.8007	0.0962	0.8208	0.0201
V	20.0	-	25.0	18.0	0.0641	0.8648	0.0626	0.8834	0.0186
VI	25.0	-	30.0	19.0	0.0676	0.9324	0.0407	0.9241	0.0082
VII	30.0	-	35.0	11.0	0.0391	0.9715	0.0265	0.9506	0.0209
VIII	35.0	-	40.0	5.0	0.0178	0.9893	0.0172	0.9679	0.0214
IX	40.0	-	45.0	3.0	0.0107	1.0	0.0112	0.9791	0.0209
				281.0	1.0				

Source : Author elaboration

- Base on table 26 above, the maximum difference is 0.0377 and this result below the critical value (D_α) = 0.0811.
- Hypothesis :$F_0(x)$ = follow the exponential distribution

  - H_0: the distribution of ship time between arrivals F(x) is the same as $F_0(x)$.
  - H_1: the distribution of ship time between arrivals F(x) is not the same as $F_0(x)$.

If the value of D $\leq$ the critical value (D_α), H_0 is accepted. It means the ship time between arrival data follow an exponential distribution.

The diagram of cumulative probability distribution and cumulative density distribution (specified distribution) can be shown at figure 17 below.

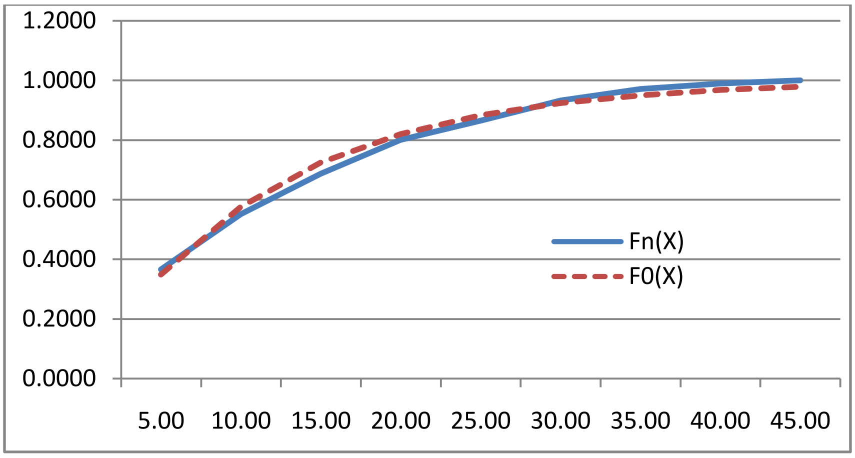

Figure 17. Cumulative Distribution Ship Time between Arrivals
Source : Author elaboration

Using the same way, the measurement of a good fit test for service time can be done. The result of cumulative distribution of service time can be shown in table 27.

Table 27. Distribution Function of Service Time

Class	*Interval*			*Empirical Distribution*			Specified Distribution		Different
				Frequency	*Probability*	Cum Prob. $F_n(X)$	*Probability*	Cum Prob. $F_0(X)$	D
I	0.00	-	1.95	155.0	0.5496	0.5496	0.5435	0.5435	0.0062
II	1.95	-	3.90	88.0	0.3121	0.8617	0.2481	0.7916	**0.0701**
III	3.90	-	5.84	18.0	0.0638	0.9255	0.1133	0.9048	0.0207
IV	5.84	-	7.79	10.0	0.0355	0.9610	0.0517	0.9566	0.0044
V	7.79	-	9.74	2.0	0.0071	0.9681	0.0236	0.9802	0.0121
VI	9.74	-	11.69	5.0	0.0177	0.9858	0.0108	0.9909	0.0051
VII	11.69	-	13.64	0.0	0.0000	0.9858	0.0049	0.9959	0.0101
VIII	13.64	-	15.58	2.0	0.0071	0.9929	0.0022	0.9981	0.0052
IX	15.58	-	17.53	0.0	0.0000	0.9929	0.0010	0.9991	0.0062
X	17.53	-	19.48	2.0	0.0071	1.0	0.0005	0.9996	0.0004
				282.0	1.0				

Source : Author elaboration

Base on table 27 above, the maximum of absolute difference is 0.0701 and this result also below of the critical value (D_α) = 0.0811. It means the cumulative distribution of service time follow the exponential distribution.

The diagram of cumulative probability distribution and cumulative density distribution (specified distribution) can be shown at figure 18 below.

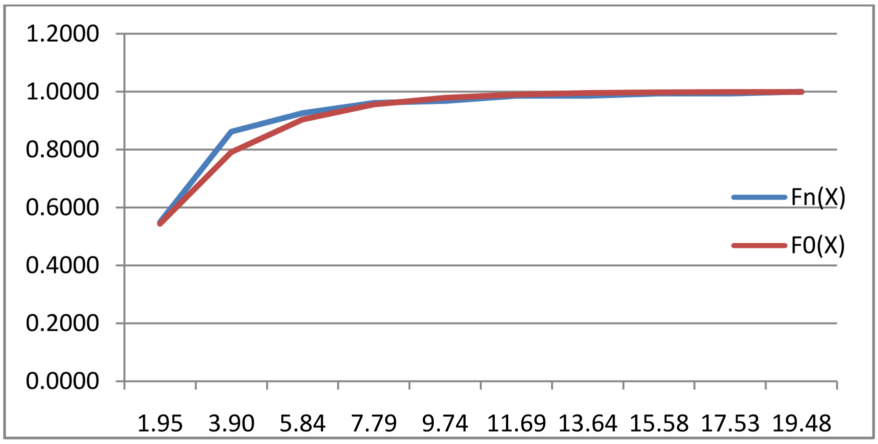

Figure 18. Cumulative Distribution of Service Time
Source : Author elaboration

The result of data move per Call (MPC) test can be shown in table 28 below.

Table 28. Distribution Function of Move per Call (MPC)

Class	*Interval*			*Empirical Distribution*			Specified Distribution		Different
				Frequency	*Probability*	Cum Prob. $F_n(X)$	*Probability*	Cum Prob. $F_0(X)$	D
I	0.0	-	416.0	97.0	0.3452	0.3452	0.2803	0.2803	0.0649
II	416.0	-	832.0	55.0	0.1957	0.5409	0.2017	0.4820	0.0589
III	832.0	-	1248.0	29.0	0.1032	0.6441	0.1452	0.6272	0.0170
IV	1248.0	-	1664.0	36.0	0.1281	0.7722	0.1045	0.7317	0.0406
V	1664.0	-	2080.0	30.0	0.1068	0.8790	0.0752	0.8069	0.0721
VI	2080.0	-	2496.0	17.0	0.0605	0.9395	0.0541	0.8610	**0.0785**
VII	2496.0	-	2912.0	7.0	0.0249	0.9644	0.0390	0.9000	0.0645
VIII	2912.0	-	3328.0	7.0	0.0249	0.9893	0.0280	0.9280	0.0613
IX	3328.0	-	3744.0	2.0	0.0071	0.9964	0.0202	0.9482	0.0483
IX	3744.0	-	4160.0	1.0	0.0036	1	0.0145	0.9627	0.0373
				281.0	1				

Source : Author elaboration

Base on table 28, the maximum of absolute difference is 0.0785 and this result also below of the critical value (D_α) = 0.0811 . It means the cumulative distribution of service time follow the exponential distribution.

When the cumulative distribution follows exponential distribution, it means ship time between arrivals and service time have a poison distribution. Hence, the queuing model can use M/M/s for analyzing the ship pattern in the terminal.

5.3. Evaluating of Ship Queuing at Berth and Yard Capacity

In this sub chapter, ship queuing will be evaluated based on ship service data year 2012. In the previous sub chapter, service time and time between arrivals have been tested by frequency distribution test which have results as poison distribution. M/M/s model will be implemented to evaluate ship queuing model. According facilities data, there are two berths available at Tanjung Priok car terminal, but only one berth is used for berthing activity serving the Ro-Ro vessel, another one is almost never be used because the depth and length do not meet the ship requirements. According this condition, M/M/1 can be used as the ship queuing model because there is only one server (berth) to serve ship berthing.

5.3.1.Ship Arrival Rate (λ)

According table 5, the average of ship time between arrivals at Tanjung Priok car Terminal is 11.63 hour with 282 ship calls. This condition reflects condition of ship arrival rate per year.

5.3.2. Berth service rate

Ship service time or usually called Berth Time (BT) consists of Berth Working Time (BWT) and Non Operation Time (NOT). BWT is time which is allocated for working to serve ship in the berth. NOT is the time which is allocated for does not work in the BT periods. The example of NOT such as loading/unloading preparation which is assumed 30 minutes, time for loading/unloading which depends on the number of gang deployed per berth and time required for ship un-berthing preparation which is assumed 30 minutes. Cargoes consist of car, bus/truck and heavy cargoes. The cycle time of service for a whole cargo is average 2.48 minutes per gang. Hence, berth productivity is

60/2.48 = 24moves per gang per hour. Base on table 7, move per call 1,265 moves and by using 1 gang worker, the time required for loading/unloading is 1,265 units / 24 moves = 53.7 hour. By adding the time for preparation before and after loading/unloading operation thus the ship service time at a berth is 54.7 hours or the ship service rate ($\boldsymbol{\mu}$) is (365 x 24 hour) / 53.7 hour = 163 ships per year. The service rates will be different if the terminal deploys difference composition of gang workers. More number of gang workers will reduce the ship service time and in turn it will increase the ship service rate. With the same calculation, table 29 will show the ship service time and ship service rate with different number of gang worker.

Table 29. Ship Service Rate by Various Number of Gang Workers

		GANG WORKER						
	Units	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Gang Productivity	Per Hour	24	24	24	24	24	24	24
Move per Call	Units	1,265	1,265	1,265	1,265	1,265	1,265	1,265
Preparation Time	Hour	1	1	1	1	1	1	1
Ship Service Time	Hour	54	27	19	14	12	10	9
Ship Service Rate ($\boldsymbol{\mu}$)	**Calls**	**163**	**320**	**472**	**618**	**759**	**895**	**1,027**

Source : Author elaboration

5.3.3. Berth Utilization

Queuing model M/M/1 can be used to evaluate ships behavior in the terminal. By assumption 1 berth to serve ship in the terminal and average gang worker allocation is four gangs. In the following calculation is as an example of ship characteristics in the queuing model at berth which is served by four gang workers.

a. Utilization rate for each berth

$$\rho = \frac{\lambda}{\mu} = \frac{282}{618} = 0.4564$$

b. Probability of berth idling

$Po = 1 - \frac{\lambda}{\mu}$ = 1 - $\frac{282}{618}$ = 0.5436

c. Average number ship in the terminal

$L = \frac{\rho}{1-\rho}$ $= = \frac{0.4564}{1-0.4564}$ = 0.839539

d. Average number ship in the queue

$Lq = L - \rho$ =0.839539 – 0.4564 = 0.383154

e. The mean response time is the Average time a ship spends in the terminal $W = \frac{1}{\mu-\lambda}$ = $W = \frac{1}{618-282}$ = 0.002977 year or 26.08 hour.

f. Average time a ship spends in the queue

$Wq = \frac{Lq}{\lambda} = \frac{0.383154}{282}$ = 0.001359 year or 11.90 hour.

The different allocation of gang workers will bring impact on a difference result of service rate. The calculation of queuing model by different service rate can use the same way which is shown in the table 30 below.

Table 30. Characteristics of Queuing Model for Various Service

Number of berths	**k=**	1	1	1	**1**	1
Arrival rate (ships /year)	λ=	282	282	282	**282**	282
Gang Workers Allocation per ship		1	2	3	**4**	5
Service rate of berth (ships /year)	μ=	163	320	472	**618**	759
Average utilization	ρ=	172.90%	88.06%	59.78%	**45.64%**	37.15%
Probability system is empty	Po=	-0.7290	0.1194	0.4022	**0.5436**	0.6285
Average number of ships in the port	L=	-2.3718	7.3738	1.4862	**0.8395**	0.5912
Average number of ships in the queue	Lq=	-4.1008	6.4932	0.8884	**0.3832**	0.2197
Average time in the port	W= (years)	-0.0084	0.0261	0.0053	**0.0030**	0.0021
	W= (hours)	-73.6773	229.0572	46.1678	**26.0793**	18.3652
Average waiting time in the queue	Wq= (years)	-0.0145	0.0230	0.0032	**0.0014**	0.0008
	Wq= (hours)	-127.3857	201.7031	27.5983	**11.9022**	6.8235

Source : Author elaboration

Table 30 above shows that the more gang workers allocated deployed to serve loading/unloading activities will reduce ship berthing time and in turn, it will increase capacity to serve ship in berth per year. In this case, allocating average 4 gang workers will change service rate of berth to be 618 calls and it will reduce average berth utilization to be 45.64%. It means there is the increasing the probability to serve ship become 54.36%. Furthermore, the decreasing of average utilization will leverage a decreasing of average ship waiting time in the berth because berth idling increase and hence the probability to serve every ship call on time will increase.

5.3.4. Berth Capacity

Considering the average ship call per year as much 282 calls, deploying one gang worker in every service will reduce ship service rate. Thus, the terminal need more berth to serve 282 calls. On the other hand, deploying more than one gang workers will enhance ship service rate per year. If ship service rate ($\boldsymbol{\mu}$)> average ship calls, the terminal does not need to expand its berth.

According table 8, the average allocation of gang workers is 4.22 = 4 gang. It means the service rate per year will grow become 618 ship calls per year which is more than average ship calls per year (618 ($\boldsymbol{\mu}$)> 288). Using this assumption, berth capacity more than average ship calls per year.

Considering ship forecasting data which is estimated in the previous cub chapter, table 31 will show the comparison of berth capacity (Service rate of berth in ships /year) and ships call (arrival rates) in the future years (until 2020) with average four gang workers allocation to serve each ship berthing. Furthermore, the changes of arrival rate will change the characteristics of ship at berth behavior as follow:

Table 31. Queuing Model Characteristics with 4 Gang Workers per Year

Annotation	Unit	Year				
		2013	2015	2017	2019	2020
Number of berths	k=	1	1	1	1	1
Forecasting of arrival rate (ships /year)	λ=	255	264	272	281	285
Service rate of berth (ships /year)	μ=	618	618	618	618	618
Average utilization	ρ=	41.27%	42.73%	44.02%	45.48%	46.12%
Probability system is empty	Po=	0.6	0.6	0.6	0.5	0.5
Average number of ships in the port	L=	0.7	0.7	0.8	0.8	0.9
Average number of ships in the queue	Lq=	0.290	0.319	0.346	0.379	0.395
Average time in the port	W= (years)	0.003	0.003	0.003	0.003	0.003
	W= (hours)	24.1	24.8	25.3	26.0	26.3
Average waiting time in the queue	Wq= (years)	0.001	0.001	0.001	0.001	0.001
	Wq= (hours)	9.96	10.58	11.15	11.82	12.14

Source : Author elaboration

In 2013, where the arrival rate 255 ships, service rate of berth 618 and the average berth utilization only 41.27% and then, in 2020, ship arrival rate increase to 285 ships and the berth still utilization increase only to 46.12 %. Average number of ships in the queue 0.290 in 2012 and it increase to 0.395 in 2020. It indicates that berth still enough to serve ships call in a whole that year until 2020 where the number of ships in queue below 0.5 (equivalent 0). The capacity of berth still more than ship arrival in a whole year as can be shown in figure 19.

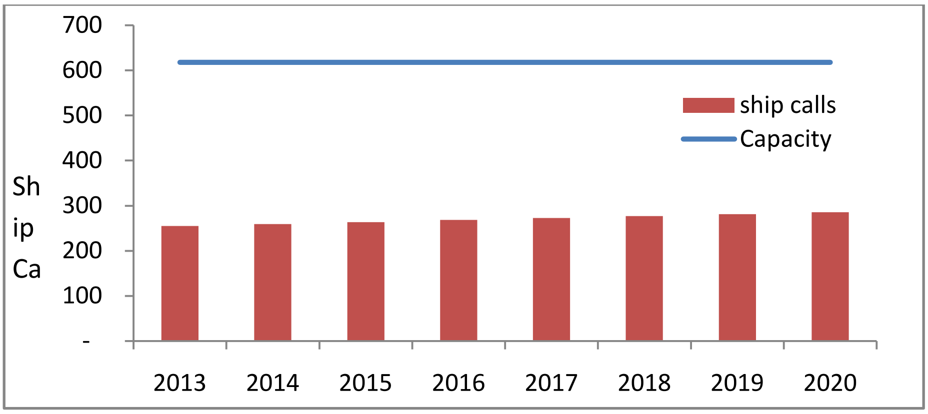

Figure 19. Comparison of Berth Capacity and Ship Arrivals
Source : Author elaboration

On the other hand, berthing operation will require the additional LOA of ship around 30 meters for rear ramp door and cargo maneuvers. Average Length overall (LOA) is 178,75 = 179 meter or 209 (after additional space) and the longest LOA is 208 meter or 238 meter (after additional space) with 41 cases (15% from total ship calls). Where, length of berth is 220 meter. Technically, 41 ships can be berthed with over stake to the neighbor terminal (PT.DKP) as long as the depth of basin met the ship draft requirement.

The analysis above ignored ship pattern of ships arrive to the port and only describe the average condition to compare the number of berth availability and number of ship in a whole year. In the fact, ships arrive in the same time and it shows as a shortage of berth to serve ship arrival on time. To eliminate this condition, terminal management should organize an effective ship planning by imposing berthing window contract to the ship company. It organizes and allocating a particular time to the ship for berthing. First in/First Out (FIFO) service methods should be implemented to reduce conflict among ship companies and terminal management.

5.3.5. Proper Throughput Capacity

Proper throughput capacity is handling capacity to cope with incoming cargoes with no congestion which leads to the port with competitive edge (Daniel moon, 2013). It reflects an optimal throughput can be handled in the terminal per year. The lower proper throughput capacity is recommended for maintaining the better service quality. Handling capacity between the quay and the yard is different and if yard utilization exceeds a critical point quay handling capacity will affected accordingly. The proper throughput capacity can be measured by comparing the maximum throughput via berth and yard in a whole year. In this case, the maximum berth throughput and yard throughput calculation can be done as follow:

Berth Throughput = service rate per year * average MPC

Berth throughput $_{2012}$ = 618 * 1,265 = 781,770 units.

On the other hand, yard capacity per year was counted by considering some assumption as follow:

- Average yard capacity per Hectare is 581 CEU (the calculation can be shown in table 32 in the next sub chapter)
- The percentage of truck, giant truck, forklift, excavator and dozer use the similar assumption with 2012 where car is 95% and 0.5% for other cargoes.
- Dwelling time of car 6 days, dwelling time other vehicle except car 9 days.
- Utilization of yard similar with effective yard: 70%.
- Service days 365 days
- Peaking factor 1.34

According assumption above, yard capacity can be calculated as follow:

$$\text{Yard throughput } 2012 = \frac{Tgs*H*U.*K}{DT*PF}*\frac{1}{U'},$$

Yard throughput 2012

$$= \left(\left(\frac{(15.5 * 581) * 1 * 0.7 * 365}{6 * 1.34} * 0.95 \right) + \left(\frac{(15.5 * 581) * 1 * 0.7 * 365}{9 * 1.34} * 0.05 \right) \right) * \frac{1}{0.7}$$

= 402,018 CEU.

Due to yard throughput (402,018)< berth throughput (781,770), the proper throughput is only 402,018 CEU of cargoes. It means yard capacity needs a special attention to avoid congestion in the port.

5.3.6. Yard Capacity

Yard capacity is a maximum throughput can be stored by a certain yard area. In this study, the annual yard terminal capacity will expressed in terms of car equivalent unit (CEU) which is deployed 12 m^2 per CEU.The major objective related to yard capacity includes maximum utilization of existing capacity, creation of additional facility to meet future requirements in line with the growth of cargo throughput.

Before calculate yard capacity, it is important to measure effective yard per hectare storage area. As known before, total area in Tanjung Priok Car terminal around 13.5 ha and it consists of office building, Car wash, Warehouse, storage area, service point and stall carrier. Total storage areas around 15.5 Ha (include car parking building) consist of block a, b, c, e, f, buffer area and car park building 5 floors which is can be shown in table 32 below.

Table 32. Storage Yard Capacity per Ha

Block	Width (Ha)	Block Capacity	Capacity/Ha
Block A	1.2 Ha	720	600
Block B	0.7 Ha	420	570
Block C	1 Ha	600	550
Block E	4.9 Ha	2,352	550

Block F	2.1 Ha	1.260	600
Buffer Area	1 Ha	600	600
Car Parking Building	1 Ha, 5 floor	3,000	600
Total	**15.5 Ha**	**8.952**	
Average			**581**

Source : Author elaboration

According table 32, the average capacity of storage yard is 581 per Ha. 1 ground slot car equivalent unit is 11.8 ≈ 12 m^2. Effective area per hectare = 581 * 12 = 6,977 m^2or equivalent with 70% (6,977 m^2 / 10,000 m^2). Hence, 30% of storage area per hectare is allocated for aisle way between cars. It is important to support car maneuver for loading/unloading and car shifting among yards.

According Dally formula, yard capacity can be calculated as follow:

$$Required\ Tgs = \frac{CCcar * DT * PF}{H * U * K} + \frac{\frac{CCbus}{truck} * DT * PF}{H * U * K} + \frac{CCgiant\ truck * DT * PF}{H * U * K} + \frac{CCforklift * DT * PF}{H * U * K} + \frac{CCexcavator * DT * PF}{H * U * K} + \frac{CCdozer * DT * PF}{H * U * K}$$

Where Tgs is totalground slot needed to stack cargo in the storage yard, H is average stacking height, CC is cargo throughput in year consist of car, bus/truck and heavy cargoes. It would be counted with CEU base where 1 truck/bus equivalent with 2.72 CEU, 1 giant truck equivalent by 4.21CEU, forklift equivalent 0.99 = 1 CEU, excavator equivalent by 3.33 CEU, and dozer equivalent by 1.69 CEU. Reflect on cargo throughputs composition in year 2012, the proportion of vehicle can be assumed as follow:

- Truck/bus = 5,998/(5,998+604) = 91% from total bus/truck throughput
- Giant Truck = 604 / (5,998 + 604) = 9% from total bus/truck throughput
- Forklift = 6,067 / (6,067+ 4,962 + 42) = 54.8% from total heavy cargoes throughput
- Excavator = 4,962 / (6,067+ 4,962 + 42) = 44.8% from total heavy cargoes throughput
- Dozer = 42 / (6,067+ 4,962 + 42) = 0.4% from total heavy cargoes throughput

U is land utilization ratio and it is similar with effective area (70%) as already discussed before. Another space (separation area) is allocated to operational reserve such as aisle way and turning cycle areas, K is service days (365 days), DT is dwelling time and PF is peaking factor which has been calculated in the previous chapter around 1.34.

Even though the formula above usually used for container calculation, it could be used at Ro-Ro terminal, of course with some specific adjustments such as stacking height (H) always be counted by 1 because car, truck or excavator could not be stacked more than one.In this case, 1 car equivalent unit (CEU) deployed 12 m^2.According terminal experience, dwelling time of car around 6 days, Bus/truck and heavy cargoes is 9 days. Bus/truck and heavy cargoes spent more time in the terminal because the importers do not have buffer yard to stack their cargo out of terminal hence, they prefer to stack their cargo in the terminal yard and pay the progressive storage fee. Cargo throughput 2012 in equivalent with Car Equivalent Unit (CEU) can be calculated as follow:

Cccar2012		= 341,409 CEU
Ccbus/truck2012	= 5,998 * 2.72	= 16,287 CEU
Ccgiant truck2012	= 604 *4.21	= 2,554 CEU
Ccforklift2012	= 6,067 * 1	= 6,067 CEU
Ccexcavator2012	= 4,962 * 3.33	= 16,520 CEU
Ccdozer2012	= 42 * 1.69	= 71 CEU
Total CEU2012	= 4,962 * 3.33	= 382,898 CEU

In following, the required of yard capacity 2012 can be calculated as follow:

$$Required\ Tgs = \frac{341{,}409 * 6 * 1.34}{1 * 0.7 * 365} + \frac{(382{,}898 - 341{,}409) * 9 * 1.34}{1 * 0.7 * 365}$$

$Required\ Tgs\ = 10{,}743 + 1{,}958$= 12,702 CEU.

$$Required\ yard\ (Ha) = \frac{12{,}702\ CEU\ *\ 12\ m2}{10{,}000} = 15.24\ Ha$$

On the other hand base on previous data, the storage yard existing only 15.5 Ha . It means, in 2012 there is a surplus yard area only 0.76 Ha CEU or 0.76/15.5 = 2% from total yard available. It is a dangerous situation where yard occupancy almost close with 100% and it is feared congestion on the yard.

For the further evaluation, the comparison between yard capacity and cargo throughput forecasting can be calculated with similar way from 2013 until 2020 with same assumption such as sub chapter 5.3.5. Based on these assumptions, the storage yard surplus/shortage in the future can be shown in table 33 below.

Table 33. Surplus/Shortage Slot in Car Equivalent Units Base

CARGOES	2013	2014	2015	2016	2017	2018	2019	2020
1.Car	311,130	349,201	387,272	425,343	463,413	501,484	539,555	577,626

2.Bus/Truck in	4,065	4,416	4,767	5,119	5,470	5,821	6,172	6,523
2.a.Bus/Truck (91%)	3,699	4,019	4,338	4,658	4,977	5,297	5,616	5,936
2.b. Bus/Truck in CEU (2.ax CEU truck)	10,045	10,913	11,781	12,648	13,516	14,383	15,251	16,119
2.c. Giant Trk (9%)	366	397	429	461	492	524	555	587
2.d. Giant Trk in CEU (2.c x CEU Gtrk)	1,541	1,674	1,807	1,940	2,074	2,207	2,340	2,473
3.Heavy cargoes	9,322	10,046	10,770	11,494	12,218	12,942	13,666	14,390
3.a.Forklift (54.8%)	5,108	5,505	5,902	6,299	6,695	7,092	7,489	7,886
3.b.Forklift in CEU (3.a x CEU forklift)	5,108	5,505	5,902	6,299	6,695	7,092	7,489	7,886
3.c.Excavtor (44.8%)	4,176	4,501	4,825	5,149	5,474	5,798	6,122	6,447
3.d.Excavator in CEU (3.c x CEU exacavtr)	13,904	14,984	16,064	17,144	18,224	19,303	20,383	21,463
3.e. Dozer (0.4%)	37	40	43	46	49	52	55	58
3.f. Dozer in CEU (3.e x CEU dozer)	63	68	73	77	82	87	92	97
4. Total CEU	341,792	382,345	422,898	463,451	504,004	544,557	585,110	625,663
5.Service Day	365	365	365	365	365	365	365	365
6.Peaking factor	1.34	1.34	1.34	1.34	1.34	1.34	1.34	1.34
7.a.Dweling Time car	6	6	6	6	6	6	6	6
7.b. Dwelling time truck &HC	9	9	9	9	9	9	9	9
8.Utilization	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
9.Required Slot	11,238	12,553	13,868	15,183	16,499	17,814	19,129	20,444
10.Required Yard (Ha)	13.49	15.06	16.64	18.22	19.80	21.38	22.95	24.53
11.Existing yard (Ha) =(Required slot x 12) /10,000	15.5	15.5	15.5	15.5	15.5	15.5	15.5	15.5
12.Surplus/Shortage Yard (Ha)	2	0.4	(1.1)	(2.7)	(4.3)	(5.9)	(7.5)	(9.0)

Source : Author elaboration

The calculation above shows a surplus or shortage slot until 2020. Base on a decreasing cargoes throughput forecasting in 2013 where the terminal still has surplus area 2 Ha. But, in line with the increasing cargoes throughput in 2015, there is shortage storage of yard area -1.1 Ha and it continues until 2020 which is the shortage increase until -9 Ha. For more clearly, the storage yard surplus/shortage can be shown in figure20 below.

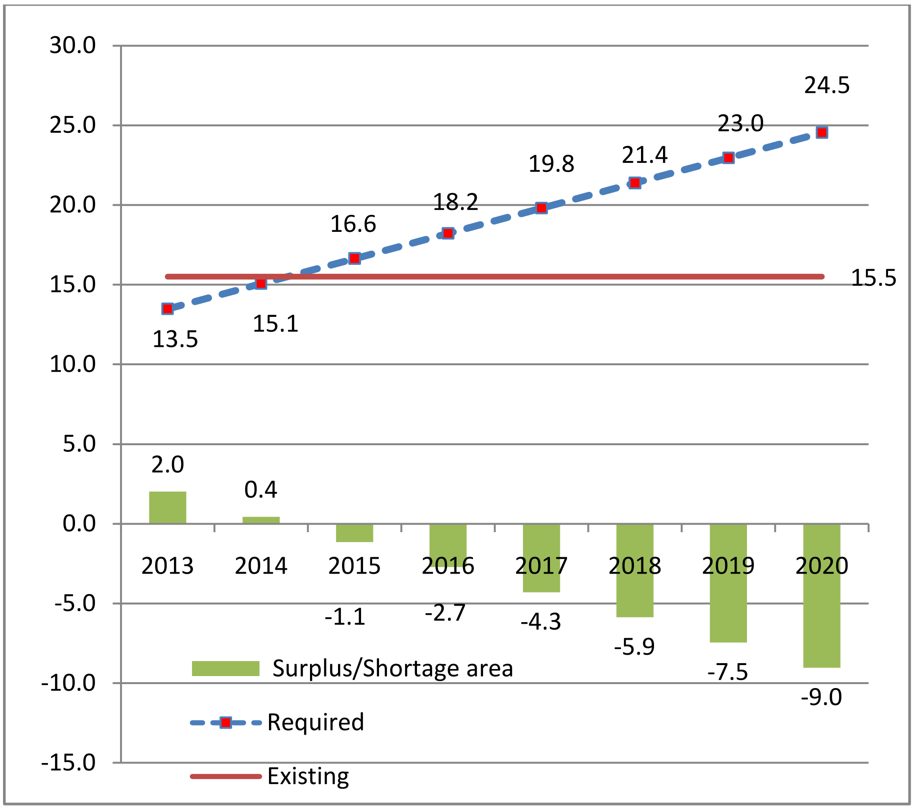

Figure 20. Surplus/shortage Area 2013 – 2020 (in Ha)
Source : Author elaboration

This dangerous situation should be considered by terminal management seriously to avoid congestion in the yard operation which in turn,it will influence loading/unloading productivity.

Expanding yard capacity requires considerable time which is consisting of planning, procuring, and construction. It need time around 1 – 2 years. In the planning steps, terminal management should consider the speed development technique because terminal only has 2 year before the shortage yard storage occurs without reduce existing capacity. There are two options to solve this problem such as:

a. Reducing dwelling time in the terminal

Reducing dwelling time in the terminal will increase yard capacity. For the example, Base on throughput forecasting data 2013 – 2020, reducing dwelling of car from 6 days to be 5 days and dwelling time truck/bus and heavy cargoes from 9 days to 1 8 days will reduce slot requirement around 16% as can be shown in table 34 below.

Table 34. Percentage of Reducing Slot Requirement because of Reducing Dwelling Time

Simulation	Year							
	2013	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Dwelling Time								
- Car	6	6	6	6	6	6	6	6
- Bus/truck and HC	9	9	9	9	9	9	9	9
Required Slot	11,238	12,553	13,868	15,183	16,499	17,814	19,129	20,444
Required yard (Ha)	13.5	15.1	16.6	18.2	19.8	21.4	23.0	24.5
Existing yard	15.5	15.5	15.5	15.5	15.5	15.5	15.5	15.5
Surplus/Shortage Yard (Ha)	2	0	**(1)**	(3)	(4)	(6)	(7)	(9)
Dwelling Time								
- Car	5	5	5	5	5	5	5	5
- Bus/truck and HC	8	8	8	8	8	8	8	8
Required Slot	9,445	10,548	11,650	12,753	13,855	14,958	16,060	17,163
Required yard (Ha)	11.3	12.7	14.0	15.3	16.6	17.9	19.3	20.6
Existing yard	15.5	15.5	15.5	15.5	15.5	15.5	15.5	15.5
Surplus/Shortage Yard (Ha)	4	3	2	0	**(1)**	(2)	(4)	(5)
Reducing slot requirement	**1,793**	**2,005**	**2,218**	**2,431**	**2,643**	**2,856**	**3,069**	**3,281**
% reducing	**16%**	**16%**	**16%**	**16%**	**16%**	**16%**	**16%**	**16%**

Source : Author elaboration

In this case, a reduction 1 days of dwelling time will increase yard capacity significantly. It will change the shortage of storage yard from 2015 to be 2017. The yard capacity will increase significantly.

b. Extended storage yard

The extending storage yard can be planned by acquired 12 Ha PT. Dock Koja Bahari (DKB) IIIarea. This choice is better than developed a new car park building which is reducing yard capacity in the construction periods and it will leverage congestion in the terminal.

Chapter 6. Conclusion and Recommendations

Information of terminal capacity is very important for terminal management to cope with congestion in the terminal. Proper throughput capacity can become an indicator to measure terminal capacity. In this case, the evaluation has been limited only for berth and yard. Base on previous evaluation, this thesis will create some conclusion and recommendation as follows:

6.1. Conclusions

a. There is a decreasing cargoes throughput forecasting in 2013 but it will rebound in the next year until 2020. It caused by too high cargo throughputs in 2012 and a decreasing of Indonesia GDP in 2013.
b. Considering the presence of the vessel LOA more than 220 m around15% from total ship calls, it can be overcome by doing overstake operation to the neighboring terminals.
c. Base on ship calls behavior, there is a large berth capacity in this terminal. Berth capacity can handle around 618 ship calls per year compare with only average 285 ship calls in 2020. In other words, berth capacity is larger than ship calls per year. Nevertheless, the same time ship arrival still brings a problem in the berth service because it will leverage waiting time.
d. The more allocation of gang worker will increase ship productivity and in turn will increase ship calls frequency.
e. Due to different type of cargo, the yard capacity counted base on car equivalent unit (CEU). Since yard throughput below of berth capacity, it can be an indicator to measure proper throughput capacity.
f. By 5 days car dwelling time and 9 days bus/truck and heavy cargoes dwelling time, the shortage of storage/yard capacity will start in 2015 and it is become a crucial problem for this terminal which is must be coped urgently.
g. Pushing down the dwelling time 1 point (from 6 to 5 days for car and from 9 to 8 days for bus, truck and heavy cargoes) will increase yard capacity 16% and it will move back the yard area shortage from 2015 to be 2017. This strategy will give time to the terminal to construct its yard area.

6.2. Recommendations

6.2.1. For Terminal Management

a. To cope the same time ship arrivals, terminal management can make a coordination with ship company by determining window berthing contract where it will allocates the particular time to the particular ship for berthing in the terminal.
b. Creating an agreement with the neighbor terminal to overstake ship berthing which is having berth length requirementover 220 m.
c. Until 2020, terminal no need to extend the number of berth, but if necessary can extend the length of berth from 220 m to be 250 m to cope ship over 220 m length.
d. The terminal needs an additional yard capacity by two ways :
   - In the short run, the terminal should push down dwelling time. This strategy can be implemented by coordination with cargo owner and imposing progressive tariff.
   - In the long run, Extending yard area about 9 Ha or more to overcomea rapid cargoes increasing until 2020. The extending of yard is better than develop car park building because it does not reduce yard capacity during construction periods. The yard extending can be done by acquiring PT DKB III in the west of terminal. The consideration of this choice is PT. DKB III is not full operated so it rather easy to acquire this docking terminal.

6.2.2. For academic purpose

Base on gang worker allocation, the increasing of gang worker allocation will enhance level of service until the optimal productivity limit. Beyond the limit, the law of diminishing return will occurred. So, it should be analyzed in further research.

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APPENDICES

Appendix 1. Table t Distribution Critical Value

Source : C. Dougherty, 2002, Introduction to Econometrics, second edition 2002, Oxford University Press, Oxford)

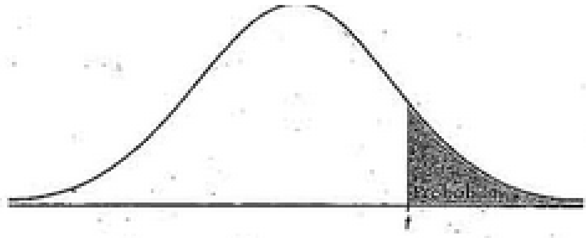

TABLE B: t-DISTRIBUTION CRITICAL VALUES

	Tail probability p											
df	.25	.20	.15	.10	.05	.025	.02	.01	.005	.0025	.001	.0005
1	1.000	1.376	1.963	3.078	6.314	12.71	15.89	31.82	63.66	127.3	318.3	636.6
2	.816	1.061	1.386	1.886	2.920	4.303	4.849	6.965	9.925	14.09	22.33	31.60
3	.765	.978	1.250	1.638	2.353	3.182	3.482	4.541	5.841	7.453	10.21	12.92
4	.741	.941	1.190	1.533	2.132	2.776	2.999	3.747	4.604	5.598	7.173	8.610
5	.727	.920	1.156	1.476	2.015	2.571	2.757	3.365	4.032	4.773	5.893	6.869
6	.718	.906	1.134	1.440	1.943	2.447	2.612	3.143	3.707	4.317	5.208	5.959
7	.711	.896	1.119	1.415	1.895	2.365	2.517	2.998	3.499	4.029	4.785	5.408
8	.706	.889	1.108	1.397	1.860	2.306	2.449	2.896	3.355	3.833	4.501	5.041
9	.703	.883	1.100	1.383	1.833	2.262	2.398	2.821	3.250	3.690	4.297	4.781
10	.700	.879	1.093	1.372	1.812	2.228	2.359	2.764	3.169	3.581	4.144	4.587
11	.697	.876	1.088	1.363	1.796	2.201	2.328	2.718	3.106	3.497	4.025	4.437
12	.695	.873	1.083	1.356	1.782	2.179	2.303	2.681	3.055	3.428	3.930	4.318
13	.694	.870	1.079	1.350	1.771	2.160	2.282	2.650	3.012	3.372	3.852	4.221
14	.692	.868	1.076	1.345	1.761	2.145	2.264	2.624	2.977	3.326	3.787	4.140
15	.691	.866	1.074	1.341	1.753	2.131	2.249	2.602	2.947	3.286	3.733	4.073
16	.690	.865	1.071	1.337	1.746	2.120	2.235	2.583	2.921	3.252	3.686	4.015
17	.689	.863	1.069	1.333	1.740	2.110	2.224	2.567	2.898	3.222	3.646	3.965
18	.688	.862	1.067	1.330	1.734	2.101	2.214	2.552	2.878	3.197	3.611	3.922
19	.688	.861	1.066	1.328	1.729	2.093	2.205	2.539	2.861	3.174	3.579	3.883
20	.687	.860	1.064	1.325	1.725	2.086	2.197	2.528	2.845	3.153	3.552	3.850
21	.686	.859	1.063	1.323	1.721	2.080	2.189	2.518	2.831	3.135	3.527	3.819
22	.686	.858	1.061	1.321	1.717	2.074	2.183	2.508	2.819	3.119	3.505	3.792
23	.685	.858	1.060	1.319	1.714	2.069	2.177	2.500	2.807	3.104	3.485	3.768
24	.685	.857	1.059	1.318	1.711	2.064	2.172	2.492	2.797	3.091	3.467	3.745
25	.684	.856	1.058	1.316	1.708	2.060	2.167	2.485	2.787	3.078	3.450	3.725
26	.684	.856	1.058	1.315	1.706	2.056	2.162	2.479	2.779	3.067	3.435	3.707
27	.684	.855	1.057	1.314	1.703	2.052	2.158	2.473	2.771	3.057	3.421	3.690
28	.683	.855	1.056	1.313	1.701	2.048	2.154	2.467	2.763	3.047	3.408	3.674
29	.683	.854	1.055	1.311	1.699	2.045	2.150	2.462	2.756	3.038	3.396	3.659
30	.683	.854	1.055	1.310	1.697	2.042	2.147	2.457	2.750	3.030	3.385	3.646
40	.681	.851	1.050	1.303	1.684	2.021	2.123	2.423	2.704	2.971	3.307	3.551
50	.679	.849	1.047	1.299	1.676	2.009	2.109	2.403	2.678	2.937	3.261	3.496
60	.679	.848	1.045	1.296	1.671	2.000	2.099	2.390	2.660	2.915	3.232	3.460
80	.678	.846	1.043	1.292	1.664	1.990	2.088	2.374	2.639	2.887	3.195	3.416
100	.677	.845	1.042	1.290	1.660	1.984	2.081	2.364	2.626	2.871	3.174	3.390
1000	.675	.842	1.037	1.282	1.646	1.962	2.056	2.330	2.581	2.813	3.098	3.300
∞	.674	.841	1.036	1.282	1.645	1.960	2.054	2.326	2.576	2.807	3.091	3.291
	50%	60%	70%	80%	90%	95%	96%	98%	99%	99.5%	99.8%	99.9%
	Confidence level C											

Appendix 2. CarForecasting

SUMMARY OUTPUT – Car Forecasting
Independent variable : Truck/Bus and Heavy Cargoes
Equation : -1,403,752.471 – 10.37886529X_{GDP} +12,710.64032 $X_{Population}$

Regression Statistics	
Multiple R	0.804591536
R Square	0.647367539
Adjusted R Square	0.546615408
Standard Error	27982.59141
Observations	10

ANOVA

	df	SS	MS	F	Significance F
Regression	2	10062422159	5031211080	6.425348319	0.026039222
Residual	7	5481177955	783025422.1		
Total	9	15543600115			

	Coefficients	Standard Error	t Stat	P-value
Intercept	-1,403,752.471	1066137.775	-1.316670794	0.229417093
GDP (in Billion USD)	-10.37886529	324.3502698	-0.031998941	0.975366167
Population (in Million)	12,710.64032	9848.704986	1.290590015	0.237835636

Appendix 3. Bus / Truck Forecasting

SUMMARY OUTPUT Bus/Truck Forecasting
Independent Variables : GDP and Population,
equation = $Y_{Bus/Truck}$ = 10,937.8 + (16.69 x X_{GDP}) + (-123.89 x $X_{population}$)

Regression Statistics	
Multiple R	0.90
R Square	0.81
Adjusted R Square	0.76
Standard Error	576.33
Observations	10

ANOVA

	df	SS	MS	F	Significance F
Regression	2.00	10,098,903.81	5,049,451.90	15.20	0.00
Residual	7.00	2,325,116.59	332,159.51		
Total	9.00	12,424,020.40			

	Coefficients	Standard Error	t Stat	P-value
Intercept	10,937.80	21,958.30	0.50	0.63
GDP (in Billion USD)	16.69	6.68	2.50	0.04
Population (in Million)	(123.89)	202.85	(0.61)	0.56

Semester	Car unit	Bus/Truck unit	GDP (in Billion USD)	Population (in Million)
smtr 1 2008	89,554	813	245.10	114.78

smtr 2 2008	90,550	1,851	265.12	115.93
smtr 1 2009	45,610	485	277.84	116.49
smtr 2 2009	57,653	674	261.51	117.66
smtr 1 2010	87,569	1,622	326.45	118.23
smtr 2 2010	100,569	2,585	380.11	119.41
smtr 1 2011	107,369	1,744	377.61	119.99
smtr 2 2011	112,432	3,560	469.23	121.19
smtr 1 2012	157,691	3,835	428.49	121.78
smtr 2 2012	183,718	2,767	430.51	123.00
smtr 1 2013	150,806	1,989	373.83	122.61
smtr 2 2013	160,324	2,077	384.71	123.37
smtr 1 2014	169,842	2,164	395.59	124.12
smtr 2 2014	179,359	2,252	406.47	124.88
smtr 1 2015	188,877	2,340	417.35	125.64
smtr 2 2015	198,395	2,428	428.23	126.40
smtr 1 2016	207,912	2,515	439.11	127.16
smtr 2 2016	217,430	2,603	449.99	127.91
smtr 1 2017	226,948	2,691	460.87	128.67
smtr 2 2017	236,466	2,779	471.76	129.43
smtr 1 2018	245,983	2,867	482.64	130.19
smtr 2 2018	255,501	2,954	493.52	130.94
smtr 1 2019	265,019	3,042	504.40	131.70
smtr 2 2019	274,536	3,130	515.28	132.46
smtr 1 2020	284,054	3,218	526.16	133.22
smtr 2 2020	293,572	3,305	537.04	133.97

Appendix 4. Heavy Cargoes Forecasting

SUMMARY OUTPUT Heavy Cargoes Forecasting

Independent Variables : Coal Production

Equation : Y = -1,618.331715 + 39.98857792 X coal

Regression Statistics	
Multiple R	0.91883949
R Square	0.844266008
Adjusted R Square	0.824799258
Standard Error	746.8827347
Observations	10

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	24193055.04	24193055.04	43.36964558	0.000171957
Residual	8	4462670.556	557833.8195		
Total	9	28655725.6			

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	-1618.33171	856.3092951	-1.88989156	0.095441843
Coal Production (in million tonnes)	39.98857792	6.072157439	6.585563422	0.000171957

Semester	Heavy Cargo unit	Coal Production (in million tonnes)

smtr 1 2008	2,253	90.58
smtr 2 2008	2,973	98.13
smtr 1 2009	678	72.00
smtr 2 2009	2,345	136.01
smtr 1 2010	3,575	124.10
smtr 2 2010	4,332	132.69
smtr 1 2011	4,588	170.32
smtr 2 2011	6,207	199.68
smtr 1 2012	6,222	179.28
smtr 2 2012	4,849	152.72
smtr 1 2013	4,570	154.76
smtr 2 2013	4,751	159.29
smtr 1 2014	4,932	163.82
smtr 2 2014	5,113	168.34
smtr 1 2015	5,294	172.87
smtr 2 2015	5,475	177.40
smtr 1 2016	5,656	181.92
smtr 2 2016	5,837	186.45
smtr 1 2017	6,018	190.98
smtr 2 2017	6,199	195.50
smtr 1 2018	6,380	200.03
smtr 2 2018	6,562	204.55
smtr 1 2019	6,743	209.08
smtr 2 2019	6,924	213.61
smtr 1 2020	7,105	218.13
smtr 2 2020	7,286	222.66

Appendix 5. Ship Call Forecasting

SUMMARY OUTPUT – Ship Call Forecasting

Independent Variable : Truck/Bus and Heavy cargoes

Equation : $Y = 102.9477967 + 0.014402835\ X_{Bus/Truck} - 0.00098924 X_{Heavy\ Cargo}$

Regression Statistics	
Multiple R	0.875448336
R Square	0.766409788
Adjusted R Square	0.699669728
Standard Error	9.556695862
Observations	10

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	2097.586949	1048.793475	11.48350455	0.006160149
Residual	7	639.3130506	91.3304358		
Total	9	2736.9			

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	102.9477967	8.032669807	12.816137	4.08379E-06
Bus/Truck	0.014402835	0.008237829	1.748377448	0.123885941
Heavy Cargo	-0.00098924	0.005424231	0.182374253	0.860458282

Semester	Ship Call	Bus/Truck	Heavy Cargo
	Unit	unit	unit

smtr 1 2008	108	813	2,253
smtr 2 2008	142	1,851	2,973
smtr 1 2009	100	485	678
smtr 2 2009	108	674	2,345
smtr 1 2010	123	1,622	3,575
smtr 2 2010	148	2,585	4,332
smtr 1 2011	129	1,744	4,588
smtr 2 2011	139	3,560	6,207
smtr 1 2012	147	3,835	6,222
smtr 2 2012	135	2,767	4,849
smtr 1 2013	127	1,989	4,570
smtr 2 2013	128	2,077	4,751
smtr 1 2014	129	2,164	4,932
smtr 2 2014	130	2,252	5,113
smtr 1 2015	131	2,340	5,294
smtr 2 2015	132	2,428	5,475
smtr 1 2016	134	2,515	5,656
smtr 2 2016	135	2,603	5,837
smtr 1 2017	136	2,691	6,018
smtr 2 2017	137	2,779	6,199
smtr 1 2018	138	2,867	6,380
smtr 2 2018	139	2,954	6,562
smtr 1 2019	140	3,042	6,743
smtr 2 2019	141	3,130	6,924
smtr 1 2020	142	3,218	7,105
smtr 2 2020	143	3,305	7,286