FINAL PROJECT – TI 141501

# INVENTORY CONTROL SYSTEM IMPROVEMENT FOR EMPTY CONTAINER IN PT SALAM PACIFIC INDONESIA LINES (PT SPIL)

DIDIN DWI NOVIANTO
NRP. 2513 100 154

Supervisor
Prof. Ir. I Nyoman Pujawan, M.Eng., Ph.D., CSCP
NIP. 19691231 199412 1076

DEPARTMENT OF INDUSTRIAL ENGINEERING
Faculty of Industrial Technology
Institut Teknologi Sepuluh Nopember
Surabaya 2017

## APPROVAL SHEET

# INVENTORY CONTROL SYSTEM IMPROVEMENT FOR EMPTY CONTAINER IN PT SALAM PACIFIC INDONESIA LINES (PT SPIL)

## FINAL PROJECT

Is Proposed as a Requisite to Graduate in Industrial Engineering Major and to
Achieve a Bachelor Degree in Department of Industrial Engineering
Faculty of Industrial Technology
Institut Teknologi Sepuluh Nopember
Surabaya

Authored by:
**DIDIN DWI NOVIANTO**
**NRP. 2513 100 154**

Approved by,
Final Project Supervisor

**Prof. Ir. I Nyoman Pujawan, M.Eng., Ph.D., CSCP**
**NIP. 196912311994121076**

KEMENTERIAN RISET, TEKNOLOGI, DAN PENDIDIKAN TINGGI
INSTITUT TEKNOLOGI SEPULUH NOPEMBER
FAKULTAS TEKNOLOGI INDUSTRI
DEPARTEMEN TEKNIK INDUSTRI

**SURABAYA, JULY 2017**

# INVENTORY CONTROL SYSTEM IMPROVEMENT FOR EMPTY CONTAINER IN PT SALAM PACIFIC INDONESIA LINES (PT SPIL)

Name : Didin Dwi Novianto
Student ID : 2513 100 154
Supervisor : Prof. Ir. I Nyoman Pujawan, M.Eng., Ph.D., CSCP

## ABSTRACT

As an archipelago country, sea transportation plays a vital role in Indonesia. This condition challenges Indonesia's companies which offer sea transportation service to fulfill customer needs yet still maintain profit maximization. Shipping lines companies are examples of sea transportation service companies. PT Salam Pacific Indonesia Lines (SPIL) is one of the Indonesian private shipping lines company which operates at least 25 ports with 3 homebases across Indonesia. In PT SPIL, the sub-division of Container Inventory Control (CIC) has the responsibility to control and manage all containers, including empty container inventory level, in ports and homebases. In other words, CIC needs to balance the empty container inventory level among ports and homebases in order to minimize the possibility of empty container overstock and shortage. The current empty container inventory control system in PT SPIL is centralized in homebases, so there is no exact calculation for determining inventory parameter in ports. This research is focused on improving the performance of the current inventory control system in PT SPIL by proposing a discrete event simulation model of empty container Reorder Point (ROP), in which uncertain empty container demand and lead time, empty container inventory level and reorder costs, as well as initial ROP using exact formula are used as input variables. Using Arena simulation software, initial ROP in 5 ports (Banjarmasin, Jayapura, Samarinda, Timika, and Ternate) and 1 homebase (Surabaya) is evaluated in 10 scenarios. Those scenarios are justified using 2 response variables, average inventory level and total empty container reorder costs. It is expected that recommended ROP will affect in low inventory level as well as total reorder costs. By considering those factors, after a year simulation, the recommended ROP scenario for Homebase Surabaya, Port Banjarmasin, Port Jayapura, Port Samarinda, Port Timika, and Port Ternate are consecutively 500 units, 133 units, 63 units, 94 units, 8 units, and 7 units. Compared to the initial scenario, the average inventory level reduction ranges from 22.66% to 89.39% with the biggest empty container reorder costs reduction of 100%.

**Keywords:** Inventory Control System, Empty Container Management, Reorder Point, Discrete Event Simulation

**(This page is intentionally left blank)**

# ACKNOWLEDGEMENT

*Alhamdulillah*, praise to Allah SWT, by whose grace, guidance, and blessing the author to successfully accomplish this final project entitled "Inventory Control System Improvement for Empty Container in PT SPIL". This final project is composed as a requisite to achieve a Bachelor degree in Industrial Engineering Department, Institut Teknologi Sepuluh Nopember. Along the study processes, many parties have involved giving their uncountable supports and prayers to the author. Here, the author would like to express the most sincere gratitude to:

1. Bapak Tukino and Mamah Nurgiati (almh.), the beloved father and mother.
2. Erik, Kiki, Hana, and Ardany, as the author's brothers and sisters.
3. Prof. I Nyoman Pujawan, as the final project supervisor.
4. Mr. Zach, Mr. Rizky, Mr. Reza, and Ms. Fia of PT SPIL, as the external supervisors.
5. Prof. Suparno, Prof. Iwan Vanany, Dr. Niniet Arvietrida, as the final project proposal and final defense examiners.
6. Dr. Nurhadi Siswanto and Yudha Andrian Saputra, S.T., MBA, as the head and secretary of Industrial Engineering Department.
7. Arief Rahman, S.T., M.Sc., as the guardian lecturer.
8. LSCM and QMIPA laboratory lecturers, assistants, alumni, and friends.
9. Kementerian Riset Teknologi dan Pendidikan Tinggi Republik Indonesia, as Bidikmisi scholarship provider.
10. And also dearest Cyprium, students of Industrial Engineering 2013.

The author recognizes that this research is still far from perfection. Therefore, constructive suggestions and critics will be highly appreciated. May this research contribute to both academic and practical world for the better future.

Surabaya, July 2017

Author

(This page is intentionally left blank)

# TABLE OF CONTENTS

**(This page is intentionally left blank)**

# LIST OF TABLES

**(This page is intentionally left blank)**

# LIST OF FIGURES

**(This page is intentionally left blank)**

# CHAPTER 1
# INTRODUCTION

Introduction is essential in introducing the initial stages of research. This chapter consists of research background, problem formulation, objectives, benefits, research scope, and report outline.

## 1.1 Research Background

The demand of any good is increasing rapidly increasing along with the growth of population as well as people's need. The growth of logistic activities is also increasing accordingly. Therefore, logistic activity must be planned effectively so that demand is efficiently fulfilled in financial aspects.

Bahagia, Sandee, and Meeuws (2013) stated that there are 3 types of costs which contribute the most to the total logistics costs. They are transportation costs, inventory costs, and administration costs consecutively. Transportation is an essential part in the economic development of any area. It brings together raw materials for production of marketable commodities and distributes the products of industry to the marketplace. One of the transportation carrier modes is water transportation, including oceangoing, inland, and coastal ships. (Arnold, Chapman & Clive, 2008)

In Indonesia, water transportation, particularly sea transportation, is an important transportation since Indonesia is an archipelago country whose area mostly covered by waterways/seaways. This condition challenges Indonesia's companies which provide sea transportation service, such as shipping lines companies, to fulfill customer needs yet still keep on profit maximization.

PT Salam Pacific Indonesia Lines (SPIL) is one of the Indonesian private shipping lines company which operates at least 25 ports with 3 homebases across Indonesia. PT SPIL has a vision to be the best shipping lines company by providing quality services, such as sea freight distribution using several types of containers, for supporting the development of world trade. PT SPIL owns about 42,000 containers in total for both 20 feet and 40 feet size. The demand of container is taken when partners/customers book empty container that will be stuffed/loaded with their goods. In general, the cycle of empty container can be seen in Figure 1.1

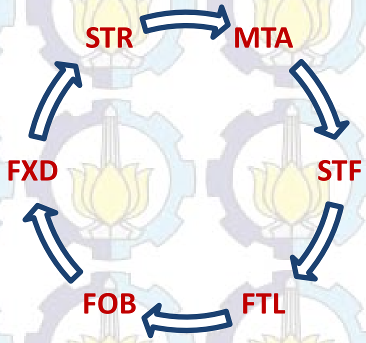



Figure 1. 1 Container Cycle in PT SPIL

Notes:

- MTA : Empty To Available, empty container is ready to be booked/sold to customer.
- STF : Stuffing/Loading, customer good is loaded into the empty container.
- FTL : Full To Load, full container is ready to be loaded to ship.
- FOB : Full On Board, full container is on board to the destination ports / homebases.
- FXD : Full Discharge, full container is discharged from the ship to the depo.
- STR : Stripping/, customer good is unloaded from the container.

In PT SPIL, the sub-division of Container Inventory Control (CIC) has the responsibility to control and manage all containers, including empty container inventory level, in ports and homebases. In other words, CIC needs to balance the empty container inventory level among ports and homebases in order to minimize the possibility of empty container overstock and shortage.

The recent condition remains that the 2016 sales realization of 20 feet empty container in ports and homebase is vary one to each other (see Figure 1.2). It can be inferred that demand of empty container, especially for outer Java areas, is fluctuated at any time. Meanwhile the demand of empty container in ports are not as many as empty container demand in homebases.

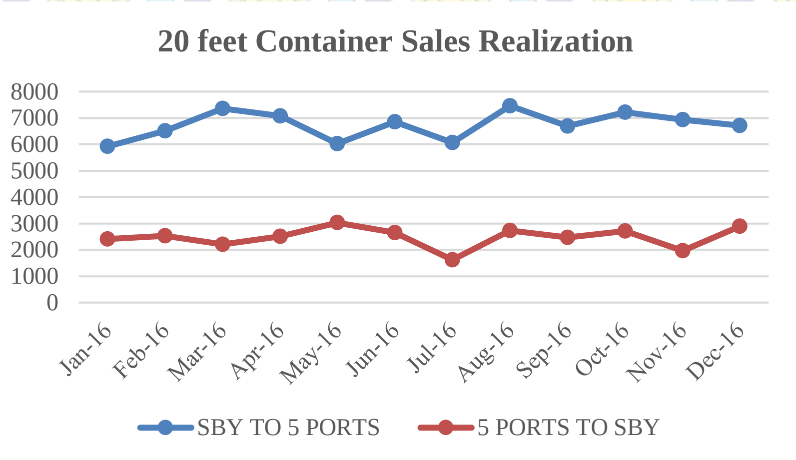



Figure 1. 2 Sales Realization of 20 feet Container

The current empty container inventory control system in PT SPIL is centralized in homebases, so there is no exact calculation for determining minimum inventory in ports. Ports can hold empty containers as long as they want and ship the empty container back to homebases whenever they want. One of the considerations to hold empty container in ports is due to the costs to ship back is quite high. In contrast, homebases cannot ask ports to ship the empty container back due to no exact inventory parameter. This condition often leads to imbalance inventory level that can cause overstock in ports and shortage in homebases. In further, this condition will cause lower service level that can cause lost sales/customer.

According to the Figure 1.3, it can be inferred that for the beginning 3 months on 2017, the empty container position breakdown in ports is slightly different to the position breakdown in 2 homebases. Therefore it is necessary to find the minimum inventory of empty container in both ports and homebases to minimize the possibility of container shortage while maintaining acceptable service level. Minimum inventory can be deliberated by determining Reorder Point (ROP) of empty container. By determining ROP, once inventory level has reached ROP or below ROP, ports need to reorder empty container from inventory pool in homebases to bring the inventory level above its ROP and vice versa.

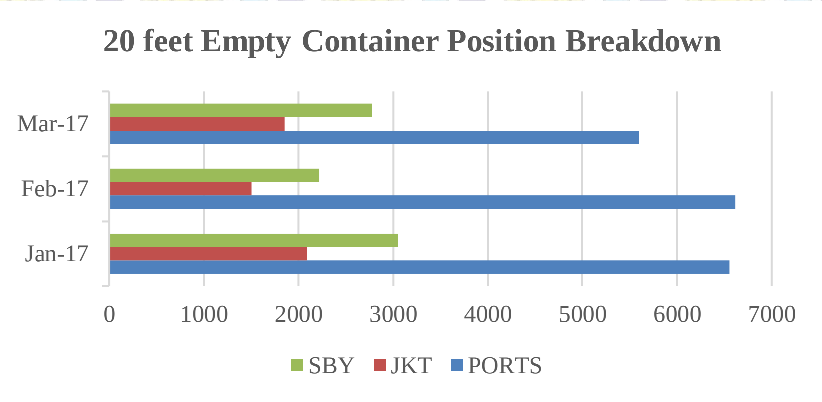



Figure 1. 3 Position Breakdown of 20 feet Empty Container

This research is focused on improving the performance of current inventory control system in PT SPIL by proposing a discrete event simulation model of recommended ROP, in which empty container demand, lead time, empty container inventory level, and initial ROP are used as input variables. Empty container reorder costs, or costs that are affected when empty containers are ordered as many as reorder size from inventory pool whenever inventory level reaches ROP value or below, is also used as input variable. Some uncertainties in empty container demand rate and lead time are considered in this research in order to make the model valid, since those uncertainties are what characterizing maritime distribution problems. The simulation model also consider incoming empty container from homebases/ports, which is dependent on container demand and lead time. Therefore, a discrete event simulation model is chosen in this research. In the model, ROP is utilized as the control variable, while average inventory level and total reorder costs are as response variables. Prior to the simulation process, the value of initial ROP will be evaluated in some scenarios which will give the result of recommended ROP by considering those two response variables.

## 1.2 Problem Formulation

According to the research background explained above, this research is designed to determine the recommended ROP using discrete event simulation and its impacts on operational performance of PT SPIL, particularly in inventory availability and empty container reorder costs.

## 1.3 Research Objectives

This research has several objectives which are as follow.

1. To develop a simulation model of empty container ROP both in ports and homebase.
2. To analyze how recommended ROP affect average inventory level and empty container reorder costs

## 1.4 Research Benefits

These following benefits are expected to be obtained from this research, those are as follow.

1. Constructing the best strategy of empty container inventory control.
2. Reducing the possibility of empty container imbalance stock with acceptable inventory level and reorder costs, both in ports and homebase.

## 1.5 Research Scope

The scope of this research is defined by scope of study and assumptions.

### *1.5.1 Scope of Study*

Several scope of study defined for this research are as follow.

1. 20 feet containers are evaluated in this research.
2. Only 5 ports and 1 homebase of PT SPIL are considered (Banjarmasin, Samarinda, Jayapura, Ternate, Timika, and Surabaya).
3. Only container direct shipping, homebase – port – homebase, is considered.
4. Data used in this research is within the year of 2016.

### *1.5.2 Assumptions*

Several assumptions defined for this research are as follow.

1. Homebase Surabaya is as the inventory pool. Therefore, lead time to reorder empty container is fixed.
2. Containers have high reliability, so repairing process is not considered.
3. Number of empty container reordered is independent to stock availability in Homebase Surabaya.
4. Empty container reorder size is as same as Reorder Point (ROP) value.

## 1.6 Report Outline

This report outline is written in order to show the big picture of the research. A brief explanation of report outline is described as follows.

CHAPTER 1: INTRODUCTION

Introduction is essential in introducing the initial stages of research. This chapter consists of research background, problem formulation, objectives, benefits, research scope, and report outline.

CHAPTER 2: LITERATURE REVIEW

This chapter explains several relevant theories and concepts based on reliable literatures in order to support research comprehension. Some theories and concepts used for this research are empty container management, empty container previous research, inventory, inventory control system, container inventory control in PT SPIL, and simulation.

CHAPTER 3: RESEARCH METHODOLOGY

Research methodology will guide the research processes systematically. It consists of the overview of the structured framework, presented in a flowchart then followed by the description of each phase.

CHAPTER 4: DATA COLLECTION AND PROCESSING

This chapter includes all processes including data collection, data processing, model building, model verification and validation, model replication number, scenario generation, and simulation output.

CHAPTER 5: ANALYSIS AND INTERPRETATION

Results of simulation and all scenarios generated in previous chapter are analyzed and interpreted in the fifth chapter. The analysis and interpretation will lead to conclusions and recommendations for next chapter.

CHAPTER 6: CONCLUSION AND RECOMMENDATION

The last chapter gives conclusions which answer the research objectives. Recommendations are also provided for the research topic and further research.

(This page is intentionally left blank)

# CHAPTER 2
# LITERATURE REVIEW

This chapter explains several relevant theories and concepts based on reliable literatures in order to support research comprehension. Some theories and concepts used for this research are empty container management, empty container previous research, inventory, inventory control system, container inventory control in PT SPIL, and simulation.

## 2.1 Empty Container Management

Quang-Vinh, Won-Young & Kopfer (2011) stated that empty containers are important logistical resources in the light of changes in both domestic and international logistics environment. Ideally, empty containers must be positioned from surplus areas to shortage areas periodically and shipping companies have inventory policies to allocate empty containers to minimize the imbalance condition. Mostly, they reposition empty containers among hub areas, ports and depots. Therefore,, the efficient management of empty containers becomes a source of competitive advantage for shipping companies to improve their customer-service levels and productivity.

Figure 2.1 shows an inland transportation network. Shipping companies have inland depots to store empty containers and to provide them for transportation of freights across/to terminals, depots, and customer locations. Due to the imbalance in trade, some ports accumulate a large number of empty containers, while other ports are often faced with a shortage of empty containers. The imbalance problem often occurs across depots in an inland transport system.

To solve the imbalance problem, Quang-Vinh, Won-Young & Kopfer (2011) proposed three options. Firstly, shipping companies may regularly place orders for empty containers from overseas ports. After repositioning from overseas and arrival at the terminal, the empty containers will be shipped among the inland depots. Secondly, empty containers can be repositioned between depots. Though both the overseas replenishment and inland repositioning of empty containers are undertaken, shortage may still occur. In that case, shipping companies can lease empty containers to make up the shortage at once, but the leased empty containers must be sent back to the leasing companies after a specified period.

A large number of empty containers can be repositioned from overseas ports with moderate prices; however, it requires a long replenishment lead-time and may overstock the depots. Otherwise, repositioning empty containers between depots with shorter lead-time is more flexible to cope with the fluctuation of demands, but this plan has higher transportation costs. Therefore, to reduce expenditure and to be more responsive to customer demands, the challenge for shipping companies is to successfully allocate empty containers between multi-depots and to lease a minimum number of empty containers from leasing companies. However in this research, empty containers leasing is neglected

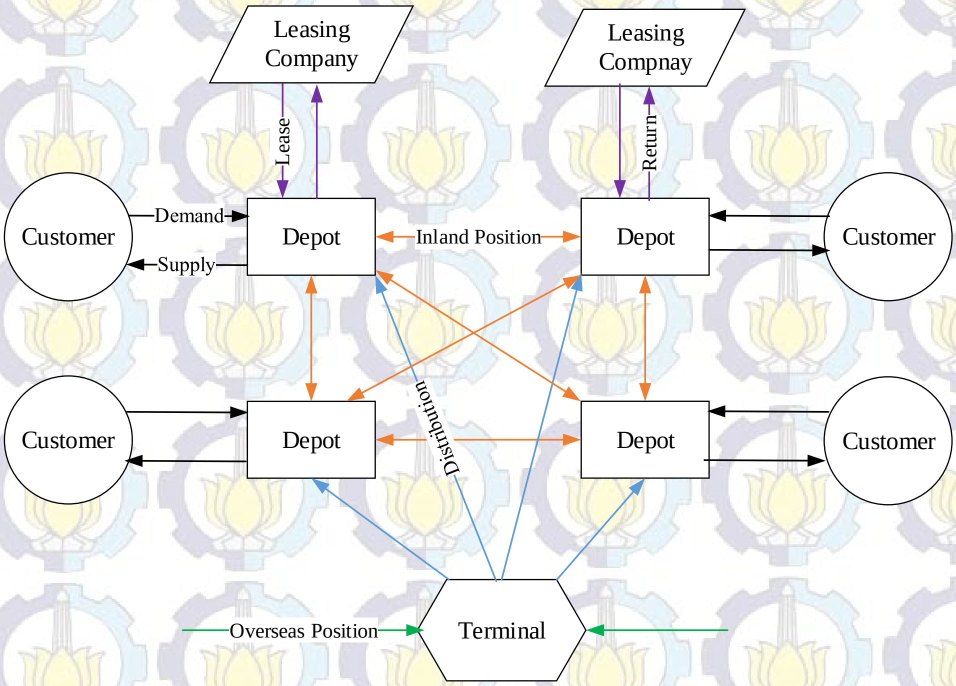



Figure 2. 1 Inland Transportation System for Empty Containers (Quang-Vinh, Won-Young & Kopfer, 2011)

## 2.2 Previous Research on Empty Container

Accordingly, there are a number of previous works in the literature to solve the problem of empty container allocation. One of the earliest papers presenting network models for empty container management was written by White (1972). However, the problem received little attention until the end of the 1980s. Braekers, Janssens, and Caris (2011) then provided a comprehensive state of art solution to the problem after reviewing the different approaches. Table 2.1 presents a classification of the existing research based on whether the authors consider deterministic or stochastic/fuzzy data or whether they study the empty container management problem at the global (i.e. multi-port) or local (i.e. inland) level.

It can be inferred that the majority of the approaches deal with the empty container repositioning problem on a global level and take into account the uncertainty in the demand and supply of empty containers. A model involving both a domestic and a foreign shipping company was studied by Boros, Lei, Zhao, and Zhong (2008). They developed mathematical models and algorithms to support a collaborative planning and scheduling of container operations for supply chain logistics. (Furio, et al. 2013).

Related to the explanation above, this research is classified as single-port level due direct shipping from homebase to port and vice versa. It is using uncertainty approach due to its uncertain demand and lead time.

Table 2. 1 Empty Container Research Classification

| | Deterministic Approach | Uncertainty Approach |
|---|---|---|
| **Multi-port Level** | Di Francesco, Manca, Olivo, and Zuddas (2006) | Cheung and Chen (1998) |
| | Wang and Wang (2007) | Shen and Khoong (1995) |
| | Shintani, Imai, Nishimura, and Papadimitriou (2007) | Di Francesco, Crainic, and Zuddas (2009), Di Francesco, Lai, and Zuddas (2013) |
| | Bandeira, Becker, and Borenstein (2009) | Dong and Song (2009) |
| | Hajeeh and Behbehani (2011) | Wang and Tang (2010) |
| | | Chou et al. (2010) |
| | | Song and Dong (2011a, 2011b) |
| **Single-port Level** | White (1972) | Crainic et al. (1993) |
| | Dejax and Crainic (1987) | Song and Zhang (2010) |
| | Crainic et al. (1989) | |
| | Choong et al. (2002) | |
| | Boros et al. (2008) | |
| | Braekers et al. (2013) | |

Source: (Furio, et al. 2013)

## 2.3 Inventory

Inventory is defined as available material, or other tangible assets, stock on hand, which can be calculated and measured in a specific period of time (Tersine, 1994). Inventory control and management are common problems faced by various organizations in economic sector. Generally, inventory exists in manufacturers, wholesalers, retailers, distributors, hospitals, and many others. Inventory occurs due to uncertainty, location differences, and economical motives (Pujawan, 2010).

Tersine (1994) stated that inventory has several key functions in fulfilling company's needs, including:

1. Minimize the risk of raw materials, or any other desired goods, delivery lateness which could disturb production process.
2. Minimize the risk of accepting low quality raw materials, or any other goods, which have been ordered.

3. Minimize the risk of inflation.
4. Minimize the risk of stock out that leads to lost sales.
5. Maintain customer's goodwill (opportunity costs).
6. Increase customer service level, since availability of product gets higher.
7. Can be allocated to stock seasonal raw material so that company will not suffer from raw material scarcity in market.

According to Ballou (2004), there are three main costs that influence the decision of inventory control system, such as procurement costs, carrying costs, and stock out costs. Those costs are correlated one to each other and Figure 2.1 exhibits the relationship among them.

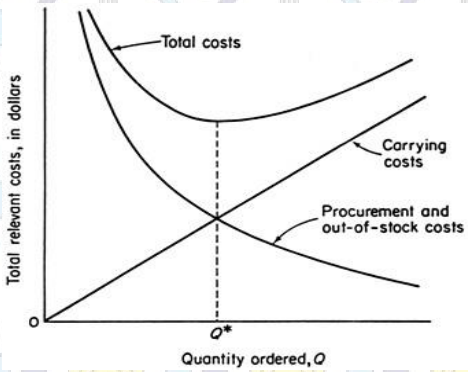



Figure 2. 2 Inventory Costs Trade-Off (Ballou, 2004)

a. Procurement Costs

When an order is placed, there are several relevant costs related to procurement costs, such as: setup order costs, delivery costs, and order costs. Transportation costs can be categorized inside or outside procurement costs, subject to each company. Costs included in procurement costs are mostly fixed and not sensitive to order size. However, such costs as material handling costs and transportation costs is not fixed because it depends of the order size.

b. Carrying Costs

There are four costs categories included in carrying costs, which are: space costs, capital costs, inventory service costs, and inventory risk costs. Each category is explained such as follows.

- Space Costs

  When company uses outsource warehouse, space costs are measured based on materials weight and/or volume in certain period of time. In case the company solely owns the warehouse, space costs captures operational activity in the warehouse.

- Capital Costs

  Capital costs occur because of goods value. Even though the costs are intangible and very subjective compared to other carrying costs, capital costs are responsible for more than 80% of the total inventory costs (Ballou, 2004). To some extent, capital costs are relatively difficult to be measured and several approaches (e.g. hurdle rate or average return on investment) are implemented to calculate this.

- Inventory Service Costs

  Insurance and tax are covered in inventory service costs. Insurance is an attempt to protect goods in warehouse from combustion, natural disaster, and robbery. On the other hand, tax is little part of the total costs in which company is responsible to pay for.

- Inventory Risk Costs

  Costs associated with deterioration, shrinkage (theft), damage, or obsolescence make up the final category of carrying costs (Ballou, 2004). Inventory risk costs value is estimated from expenditure burdened to company to rework the goods as a means to make them functioned and can be used for production process or sold to customers.

c. Stock Out Costs

Stock out costs can be distinguished into two different terminologies, which are lost sales and back order. Lost sales terminology used when customers cannot obtain their desired good in a point of time and they decided not to wait until when it is available. On the contrary, back order is a condition when customers do not mind to long for goods availability. In such case, sales is not lost but only postponed. As a result of it, several additional transportation costs and inventory costs might be found.

## 2.4 Inventory Control System

Determining several fundamentals in inventory control system is essential. Those fundamentals such as: how often the inventory control has to be monitored, replenishment time, and order size (Silver & Peterson, 1998). In general, there are two inventory control system are often used in practice, those are continuous review and periodic review.

### *2.4.1 Continuous Review (s, S System)*

Continuous review system, also referred to perpetual system and fixed-order-quantity system, has an approach to continuously track and check inventory level. One example of continuous review system is (*s*, *S*) system or min-max system. This policy stated that order up to a level S (so order quantity is S-Inventory Position) whenever inventory position drops below s (Reorder Point). In continuous review system, when demand and lead-time are uncertain, safety stock is added as a hedge against stock out. The advantage of continuous review is the ability to address the situation where demand is high yet the disadvantage is variable order quantity.

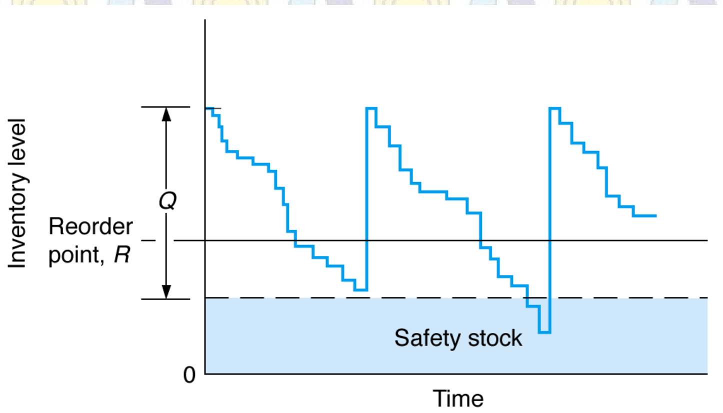



Figure 2. 3 Continuous Review Inventory Control Systems

(Russel and Taylor, 2000)

Here are the inventory profiles in continuous review (Tersine, 1994):

$$Q^* = \sqrt{\frac{2\mu k}{h}} \quad (2.1)$$

$$SS = Z\sqrt{(\sigma_d)^2 L + (\sigma_L)^2 d^2} \quad \text{(when demand and lead time are stochastic)} \quad (2.2.1)$$

$$SS = Z\,\sigma_d\sqrt{L} \quad \text{(when demand is stochastic)} \quad (2.2.2)$$

$$D_L = d \times L \quad (2.3)$$

$$ROP = SS + D_L \quad (2.4)$$

Where,

$Q^*$ = optimum order size

$\mu$ = average annual demand

k = order cost per lot

h = holding cost per unit per year

SS = safety stock

Z = normsiv of service level

$\sigma_d$ = standard deviation of daily demand

$\sigma_L$ = standard deviation of lead time

$D_L$ = average demand during lead time

d = average demand per period

L = average lead time of replenishment

ROP = reorder point

### *2.4.2 Periodic Review*

Periodic review, also referred to as a fixed-time-period system, defines that inventory status tracked at regular periodic intervals and reorder was made to raise the inventory level to the point of a predefined (Russel and Taylor, 2000). In other words, order size is flexible and placed every specified period of time.

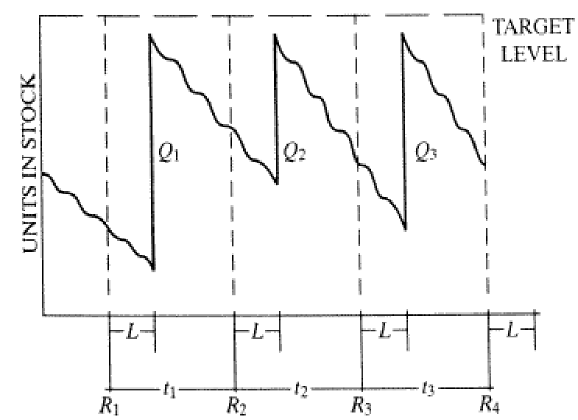



Figure 2. 4 Periodic Review Inventory Control Systems
(Russel and Taylor, 2000)

Below are the inventory profiles in periodic review (Tersine, 1994):

$$T^* = \sqrt{\frac{2k}{h\mu}} \quad (2.5)$$

$$SS = Z\sqrt{(\sigma_d)^2(T + L) + (\sigma_L)^2 d^2} \quad (2.6)$$

$D_{T+L}$ = d (T + L) (2.7)

OUL = SS + $D_{T+L}$ (2.8)

Where,

$T^*$ = optimum review interval

$D_{T+L}$ = average demand during T+L

OUL = order up to level

In periodic system, the inventory level is not necessarily monitored at all time, so it leads to less or even no record keeping required. In contrast, the main drawback is limited direct control. This typically results in larger inventory levels for a periodic inventory system compared to continuous system to guard against unexpected stock outs early in the fixed period.

## 2.5 Container Inventory Control in PT SPIL

As a leading shipping lines company in Indonesia, PT SPIL has to manage its customer-service level very well by fulfilling customer demand of empty container precisely. In fulfilling customer demand, which the demand is lumpy and has no trend/pattern, the sub-division of Container Inventory Control (CIC) has important role to plan and control the inventory of empty container owned by PT SPIL.

In term of container inventory control, PT SPIL has several special characteristics that differs this company from the others such as PT SPIL doesn't have leasing policy and container reposition among ports is rarely happened. In other words, homebases of PT SPIL play significant role to supply empty containers to the ports and expect ports to ship empty container back to the homebase in order to avoid shortage.

Recently, CIC manages empty container inventory by controlling inventory level in daily basis. For example, today's inventory level of empty container ($I_t$ ) is coming from total inventory level at the day before ($I_{t-1}$), incoming container at present ($Incoming\ MT_t$), and incoming order from inventory pool ($Incoming\ Order_t$). Then it is subtracted by present empty container demand ($Demand_t$). Equation 2.5 below refers to the inventory calculation.

$$I_t = I_{t-1} + (Incoming\ MT_t) + (Incoming\ Order_t) - Demand_t \qquad (2.5)$$

## 2.6 Simulation

Simulation refers to a broad collection of methods and application to mimic the behavior of real systems, usually on a computer with appropriate software (Kelton, et al. 2006). Recently, simulation method is more popular and powerful than the development of the technology computer and software. Simulation is used to form a complex system which is difficult to model or cannot be modelled as mathematical formulation. Simulation model is designed to be used for system studying by conducting experiments to achieve the desired objectives/performance measurements.

The main advantages of using simulation model is its ability to deal with complicated models of correspondingly complicated systems. It is also more cost effective than conducting the real simulation process. Simulation has flexibility and ease of use so then it will generate quick and valid decision making. However, because many real systems are affected by uncontrollable and random inputs, it will generate random output too. So running a stochastic simulation once may generate different output in the next experiment. Even simulation output may be uncertain, it can be done with quantify and reduce the uncertainty yet still consider the valid representation of the system.

### *2.6.1 Simulation Model*

Simulation involves systems and models, just like most of the methods. Kelton, et al. (2006) classified simulation in three classification, such as.

1. Static and Dynamic

   In static models, time does not play a natural role but it does in dynamic models. For example, most operational models are dynamic.

2. Continuous and Discrete

   In a continuous model, the state of the system can change continuously over time. While in discrete model, change can occur only at separated points in time.

3. Deterministic and Stochastic

   Models that have no random input are deterministic. Stochastic models, on the other hand, operate with random input. A model can have both deterministic and random inputs in different components.

According to those three classification, this research on empty container inventory control system is classified as dynamic model because the time will have contribution to the system. It is also classified as discrete model because state variables change as an event occurs. In additional, the system has stochastic process. A simulation software called Arena will be used in this research as the simulation tools.

## 2.7 Previous Research

There are several previous research which are in line to this research. Those research are as follow.

Table 2. 2 Comparison of Previous Research and Current Research

| | Previous Research | | | This Research |
|---|---|---|---|---|
| **Year** | 2013 | 2015 | 2016 | 2017 |
| **Type** | Undergraduate Research | Undergraduate Research | Master Research | Undergraduate Research |
| **Author** | Amal Najib | Robertus Willy Gunawan | Edie Triono | Didin Dwi Novianto |
| **Title** | Designing Inventory Control Decision Support System for Empty Containers | Improvement Of Inventory Control Systems For Raw Material In A Make-To-Order Company. | Improvement of Spare Part Inventory Parameter Setting using Monte Carlo Simulation Approach | Inventory Control System Improvement for Empty Container in PT SPIL |
| **Object** | Empty Container | Raw Material | Spare Part | Empty Container |
| **Methods** | (*s*, *S*) Inventory Policy, Visual Basic Application | ABC Analysis, Periodic Review System, Continuous Review System, Monte Carlo Simulation | Monte Carlo Simulation, (*s*, *S*) Inventory Policy | Arena Simulation, Inventory Policy |
| **Output** | Inventory Control Model & Application | Inventory control system, continuous and periodic review system comparison | Optimum Combination of (*s*, *S*) Inventory Model | Recommended ROP |
| **Parameter** | Inventory Level, Repositioning / Leasing Alternative, Costs Factors (Order, Holding, and Leasing Costs) | Total Inventory Costs and Service Level | Service Level and Total Costs | Average Inventory Level and Total Empty Container Reorder Costs |

# CHAPTER 3
# RESEARCH METHODOLOGY

Research methodology will guide the research processes systematically. It consists of the overview of the structured framework, presented in a flowchart then followed by the description of each phase.

The research methodology flowchart is given as follows

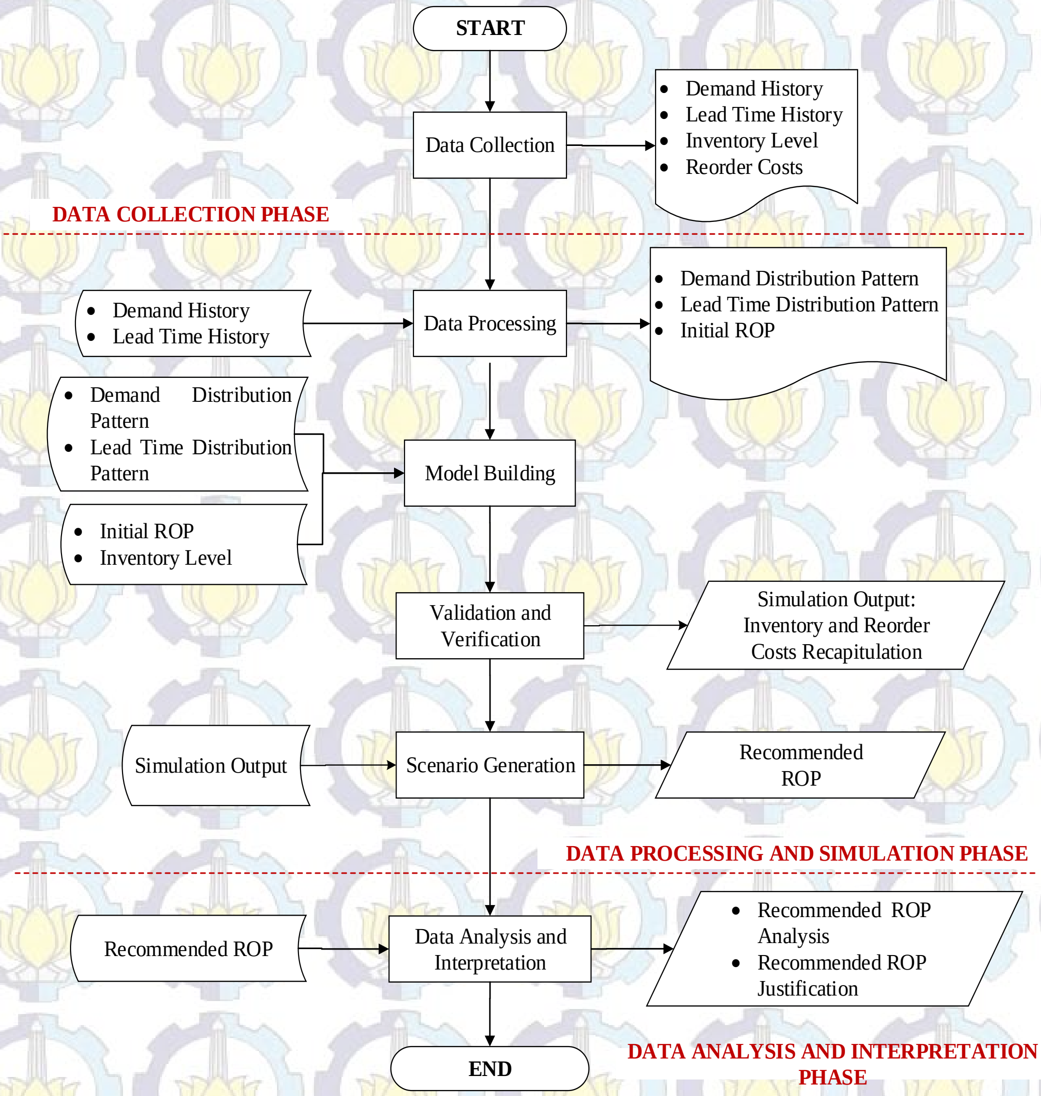



Figure 3. 1 Research Methodology Flowchart

## 3.1 Data Collection Phase

In this phase, data used for the research are being collected. Data were retrieved from PT Salam Pacific Lines Indonesia (SPIL) Surabaya. Data collected are both primary and secondary data. Data collected from PT SPIL are sales realization data, ship activities logs, inventory data, container reorder costs worksheet, and container movement scheme.

## 3.2 Data Processing and Simulation Phase

The output obtained from the previous phase is then processed and being simulated to find the recommended ROP afterwards. At the end, the simulation and costs recapitulation output are being analyzed and interpreted.

### *3.2.1 Data Processing*

In data processing, there are 2 groups of the processed data. The first group are sales realization data which represent container demand distribution and lead time which is retrieved from ship activities logs. Those data will be processed to determine the initial ROP using formulas explained in Equation 2.1 – 2.4. The second one is container demand and lead time which will be fit each distribution pattern using Input Analyzer in Arena software. Those data will be the input parameter in Arena simulation. The last one is empty container reorder costs calculation.

### *3.2.2 Model Building*

After obtaining all input parameters required to build the simulation model, the next step is model building itself. Before building using software Arena, a conceptual model is being built first so that it can represent the real/existing condition. The conceptual model in this research is a flowchart of container delivery cycle from empty to empty in ports and homebase, as presented in Figure 3.2. The simulation model is expected to accommodate the uncertainties in container demand and lead time. To do so, model needs to be validated and verified afterwards.

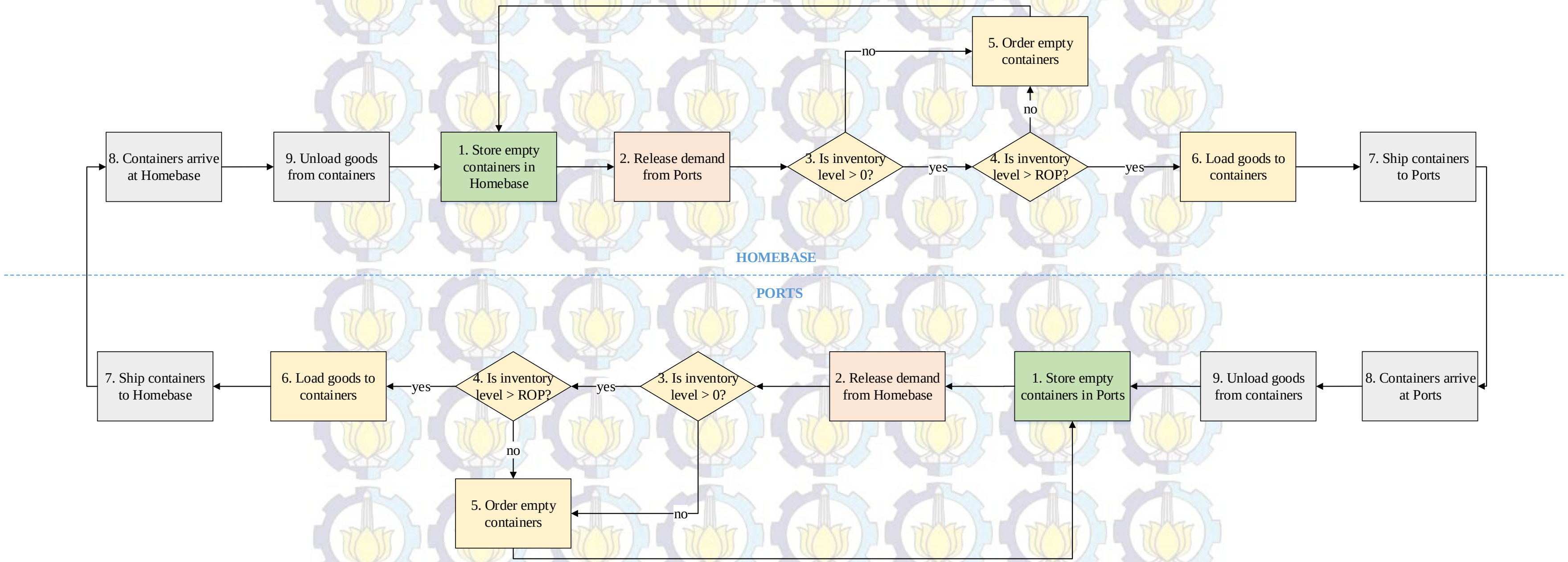



Figure 3. 2 Container Delivery Cycle

### *3.2.3 Model Verification and Validation*

The aim of model verification is to ensure that model built is following the system’s logic. The verification in 2 steps. The first one is done by using trace and debug facilities in Arena software. It is to ensure that there is no error occurred in software system. The second step of verification is called system’s logic verification. It is done to ensure that model follows correct logic and flow process. This model will be verified according to its parameter.

After verification process is done, model needs to be validated in order to ensure that the simulation model represents the actual system. Since this simulation model mostly deals with inventory information, inventory level in some periods in month of January and February 2016 will be the validation parameter.

### *3.2.4 Scenario Generation*

The output of verified and validated model is then processed in Process Analyzer in Arena software by adding and reducing initial ROP value with certain number (scenarios). From that process, some new ROP values will be retrieved which need to be compared one to each other so it results a recommended value of ROP. The comparison or response parameters are average inventory level and total reorder costs. It is expected that recommended ROP will response to small inventory level and reorder costs.

## 3.3 Data Analysis and Interpretation Phase

This last phase mainly focuses on output analysis and interpretation. This analysis will analyze and interpret the recommended value of ROP and how they affect stock availability as well as total reorder costs for each ports and homebase. After all, this research will give recommendation based on the simulation output.

# CHAPTER 4
# DATA COLLECTION AND PROCESSING

This chapter includes all processes including data collection, data processing, model building, model verification and validation, model replication number, scenario generation, and simulation output.

## 4.1 Data Collection

As previously mentioned, several data are collected to describe the existing performance of company's inventory control system and to obtain several input parameters in order to generate the scenarios. Several data to collect are sales realization data, ship activities logs, inventory level data, reorder costs worksheet, and container movement scheme.

### *4.1.1 Container Sales Realization Data*

Demand of empty container in each ports and homebase is represented in sales realization data. These data will be used to generate demand into daily basis in a year. Data are retrieved from CIC system, which are converted into daily basis using such a distribution that later on will be used as one of the parameter in initial ROP calculation and simulation inputs.

### *4.1.2 Ship Activities Logs*

From the container shipping activities of the company, lead time of the container from empty to empty can be recorded. Specifically, lead time is divided into loading/stuffing time, on board time/reorder time, and unloading/stripping time. According to the current condition, stuffing and stripping time follow random distribution (uncertain lead time) while on board time can be classified as fixed time since it is one of the company performance indicators. Hence stuffing and stripping time are represented into distributed data. Along with demand, lead time is the other parameter in initial ROP calculation and simulation inputs.

### *4.1.3 Container Inventory Level Data*

Inventory level data plays important role in this simulation since they are used as input in simulation model and as validation parameter. Moreover, inventory level is also used as response variable along with reorder costs to find the recommended ROP. The data for initial inventory level in each ports and homebase can be seen in Table A.8, Appendix A.

### *4.1.4 Empty Container Reorder Costs Worksheet*

Another important data to collect is the worksheet of container reorder costs since costs is one of the response variables. Reorder costs are costs that are affected when inventory level of empty container is not sufficient or laid below the ROP. In that condition, order will be taken as much as the reorder size, which is then converted into reorder costs.

From the worksheet, reorder costs component can be broken down. The container reorder costs consists of Terminal Handling Charges (THC), freight costs, and administration. THC and freight costs are variable costs since THC depends on each terminal port and freight costs depend on the distance covered by ship. Meanwhile administration costs are assumed to be fixed costs for each container unit ordered.

### *4.1.5 Container Movement Scheme*

The movement of the container is started when empty container is available to be loaded/stuffed with customer goods. So, when demand is taken into an order, system will check whether inventory level of empty container is sufficient or not. If no, system will reorder as much as reorder size, if yes system will check whether inventory level is less than ROP or not. If inventory is less than ROP, system will reorder again. In this process, reorder costs are also considered by converting number of reorder size into total reorder costs.

After being checked, empty container is being stuffed and assigned to each destination ports or homebase. There will be 2 lead times at those points, such as stuffing time and on board time. Each ports and homebase has each lead time. Then full container will arrive to the destination and stripping/unloading process is taken in a period of lead time before container is available (empty container) to be loaded/stuffed again.

## 4.2 Data Processing

After all necessary data has been collected, data are then processed to picture the existing condition which then will be used for the simulation inputs. From the data explained in the previous subchapter, the processed data are container demand distribution pattern, lead time distribution pattern, initial ROP, and reorder costs calculation.

### *4.2.1 Container Demand Distribution Pattern*

The first data to be processed is container demand distribution pattern. Since demand in both ports and homebase is recorded in monthly basis and it is fluctuating, a goodness fit test will be performed to define what distribution best describe the pattern. As seen in the Table 4.1, triangular distribution is used for capture the daily demand of empty container both in ports and homebase. An example of SBY-SDA route distribution fitting display from Input Analyzer in Arena is presented in Figure 4.1. The other data can be seen Table 4.1. The detail of container daily demand can be seen in Table A.1, Appendix A.

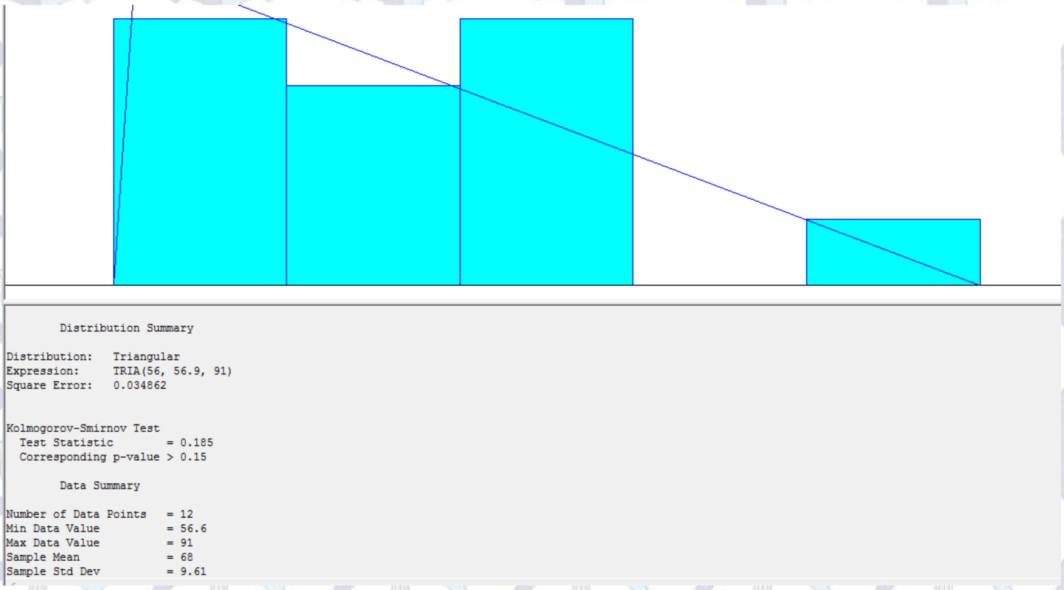



Figure 4. 1 Daily Container Demand Distribution Fitting of SBY-SDA Route

Table 4. 1 Recapitulation of Daily Container Demand Distribution

| Route | Expression (daily unit) |
|---|---|
| BMS-SBY | TRIA(36,49,63) |
| JYP-SBY | TRIA(3,10,15) |
| SDA-SBY | TRIA(9,15,22) |
| TIM-SBY | TRIA(1,1,2) |
| TTE-SBY | TRIA(1,1,2) |
| SBY-BMS | TRIA(58,69,79) |
| SBY-JYP | TRIA(23,36,45) |
| SBY-SDA | TRIA(57,68,91) |
| SBY-TIM | TRIA(19,27,35) |
| SBY-TTE | TRIA(9,13,16) |

### *4.2.2 Container Lead Time Distribution Pattern*

As mentioned before, container lead time consists of 3 data, stuffing time, on board time, and stripping time. Following the behavior of the container demand rate explained before, stuffing and stripping time are using triangular distribution as well. An example of distribution fitting display of stuffing route JYP-SBY from Input Analyzer in Arena is presented in Figure 4.2. The other data can be seen Table 4.2. While the detail of container lead time can be seen in Table A.3 - A.7, Appendix A.

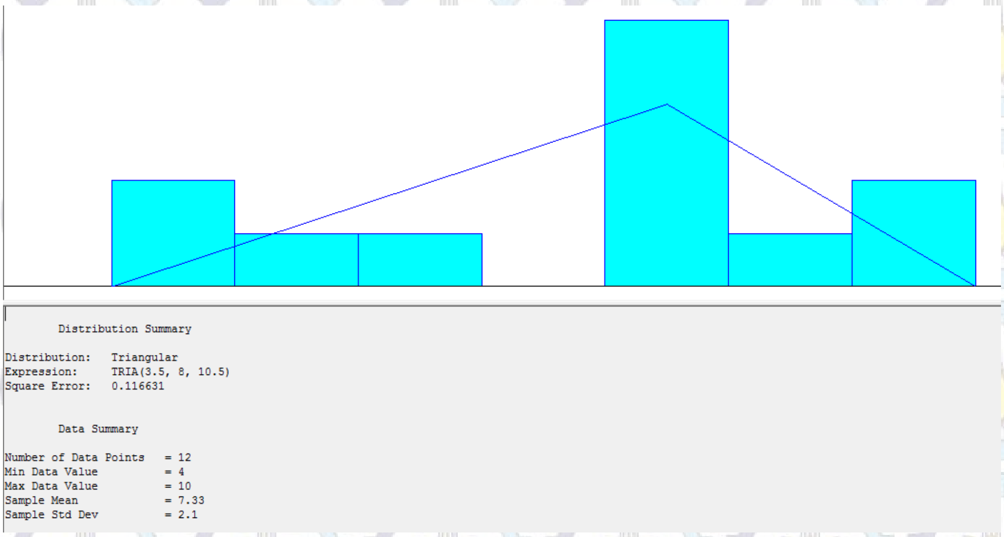



Figure 4. 2 Container Lead Time Distribution Fitting of JYP-SBY Route (Stuffing)

Table 4. 2 Recapitulation of Container Lead Time Distribution

| Route | Expression (day) | | |
|---|---|---|---|
| | Stuffing | On Board / Reorder Time | Stripping |
| SBY-BMS | TRIA(1,4,5) | 2 | TRIA(1,2,6) |
| SBY-JYP | TRIA(4,8,9) | 10 | TRIA(2,5,8) |
| SBY-SDA | TRIA(3,5,9) | 4 | TRIA(2,2,6) |
| SBY-TIM | TRIA(3,6,9) | 9 | TRIA(4,5,8) |
| SBY-TTE | TRIA(5,5,8) | 8 | TRIA(5,7,9) |
| BMS-SBY | TRIA(2,3,5) | 2 | TRIA(1,5,9) |
| JYP-SBY | TRIA(4,8,10) | 10 | TRIA(2,5,10) |
| SDA-SBY | TRIA(3,5,9) | 4 | TRIA(2,3,7) |
| TIM-SBY | TRIA(3,7,9) | 9 | TRIA(5,6,10) |
| TTE-SBY | TRIA(4,6,8) | 8 | TRIA(5,7,9) |
| SBY-SBY | - | 1 | - |

According to the table above, on board time can be defined as reorder time since reordering empty container doesn't need to have stuffing and stripping process. Note that route SBY-SBY doesn't have stuffing and stripping time due to condition that Surabaya is utilized as inventory pool. Therefore, lead time is occurred only for on board /reorder time.

### *4.2.3 Initial ROP Calculation*

In this research, Reorder Point (ROP) is a point to reorder empty container when inventory level isn't sufficient to fulfill the future demand. According to the Equation 2.4 – 2.6, ROP considers 2 important parameters, demand and lead time. Accordingly, ROP calculation in this research considers stochastic/uncertain demand and lead time.

Due to the condition that there is no exact inventory parameter in ports, initial ROP calculation is used as scenario 0 in this simulation. It is then justified by the company whether initial ROP is feasible or not. While in homebase, company has a kind of safety stock point to hold empty container. This point is then also justified by the company to be used as initial ROP. Below is the calculation example of the initial ROP of BMS-SBY route according to the Equation 2.4 – 2.6. The rest of the calculation result is presented in Table 4.5. While the calculation inputs are presented in Table 4.3 and 4.4.

$$SS = Z\sqrt{(\sigma_d)^2 L + (\sigma_L)^2 d^2} \tag{2.4}$$

$$SS_{BMS} = 1.645\sqrt{(8.8)^2 \times 9.08 + (1.56)^2 \times 49^2} \approx 134 units$$

$$DL = d \times L \tag{2.5}$$

$$DL_{BMS} = 49 \times 9.08 \approx 449 \; units$$

$$ROP = SS + DL \tag{2.6}$$

$$ROP_{BMS} = 134 + 449 \approx 583 \; units$$

Where,

SS = safety stock

Z = normsiv of service level (1.645)

$D_L$ = average demand during lead time

$\sigma_d$ = standard deviation of daily demand (see Table A.2, Appendix A for detail)

$\sigma_L$ = standard deviation of lead time (see Table A.3 – A.7, Appendix A for detail)

d = average demand per period (see Table A.2 Appendix A for detail)

L = average lead time of replenishment (see Table A.3 – A.7, Appendix A for detail)

ROP = Reorder Point

Table 4. 3 Container Daily Demand for BMS-SBY Route

| MONTH | BMS-SBY CONTAINER DAILY DEMAND (unit) |
|---|---|
| Jan | 43 |
| Feb | 41 |
| Mar | 43 |
| Apr | 51 |
| May | 52 |
| Jun | 36 |
| Jul | 37 |
| Aug | 56 |
| Sep | 61 |
| Oct | 63 |
| Nov | 50 |
| Dec | 59 |
| **Average** | **49** |
| **Std. Dev** | **8.8** |

Table 4. 4 Container Lead Time for BMS-SBY Route

| MONTH | BMS SBY | | | |
|---|---|---|---|---|
| | STF (day) | ON BOARD (day) | STR (day) | Total (day) |
| Jan | 4 | 2 | 1 | 7 |
| Feb | 3 | 2 | 3 | 8 |
| Mar | 2 | 2 | 4 | 8 |
| Apr | 4 | 2 | 2 | 8 |
| May | 4 | 2 | 2 | 8 |
| Jun | 3 | 2 | 5 | 10 |
| Jul | 3 | 2 | 5 | 10 |
| Aug | 5 | 2 | 6 | 13 |
| Sep | 2 | 2 | 5 | 9 |
| Oct | 3 | 2 | 5 | 10 |
| Nov | 5 | 2 | 2 | 9 |
| Dec | 5 | 2 | 2 | 9 |
| **Average** | 3.58 | 2.00 | 3.50 | **9.08** |
| **Std. Dev** | 1.08 | 0.00 | 1.68 | **1.56** |

Table 4. 5 Recapitulation of Initial ROP Calculation

| Route | Z | Daily Demand Average | Demand Standard Dev. | Lead Time Average | Lead Time Standard Dev. | Parameter | |
|---|---|---|---|---|---|---|---|
| | | | | | | Safety Stock | Reorder Point |
| | % | unit container | unit container | day | Day | unit container | unit container |
| SBY-BMS | 95 | 70 | 6.6 | 8.58 | 1.44 | 1000 | 2000 |
| SBY-JYP | 95 | 36 | 6.3 | 21.83 | 1.99 | | |
| SBY-SDA | 95 | 68 | 9.2 | 13.33 | 2.57 | | |

Table 4.5 Recapitulation of Initial ROP Calculation (con't)

| Route | Z | Daily Demand Average | Demand Standard Dev. | Lead Time Average | Lead Time Standard Dev. | Parameter | |
|---|---|---|---|---|---|---|---|
| | | | | | | Safety Stock | Reorder Point |
| | % | unit container | unit container | day | Day | unit container | unit container |
| SBY-TIM | 95 | 27 | 4.1 | 17.42 | 3.4 | | |
| SBY-TTE | 95 | 13 | 2.2 | 24.75 | 1.66 | | |
| BMS-SBY | 95 | 49 | 8.8 | 9.08 | 1.56 | 134 | 583 |
| JYP-SBY | 95 | 10 | 3.4 | 23 | 2.8 | 55 | 293 |
| SDA-SBY | 95 | 15 | 3.6 | 14.5 | 3 | 79 | 304 |
| TIM-SBY | 95 | 1 | 0.2 | 18.08 | 2.81 | 5 | 26 |
| TTE-SBY | 95 | 1 | 0.3 | 25.33 | 1.87 | 5 | 43 |

### *4.2.4 Empty Container Reorder Costs Calculation*

After determining all the simulation inputs, another important step to be done is calculating empty container reorder costs. The empty container reorder costs consists of Terminal Handling Charges (THC), freight costs based on each destination, and administration costs. On the other hand, the total reorder costs are depicted from the total reorder size multiply by container reorder costs. The mathematical expression used to calculate Reorder Costs (ROC) as well as the calculation example for Port BMS are as follow.

$$Container\ ROC = THC + Freight\ Cost + Administration\ Cost \qquad (4.1)$$

$$Container\ ROC_{BMS} = 484{,}000 + 405{,}000 + 10{,}000 = Rp\ 899{,}000,-$$

The recapitulation of reorder costs is presented in table below.

Table 4. 6 Empty Container Reorder Costs Recapitulation

| Ports/Homebase | THC | Freight Costs | Administration | Reorder Costs |
|---|---|---|---|---|
| | unit container | unit container | unit container | unit container |
| SBY | Rp 825,000.- | Rp - | Rp 10,000.- | Rp 835,000.- |
| BMS | Rp 484,000.- | Rp 405,000.- | Rp 10,000.- | Rp 899,000.- |
| JYP | Rp 500,000.- | Rp 825,000.- | Rp 10,000.- | Rp 1,335,000.- |
| SDA | Rp 795,000.- | Rp 475,000.- | Rp 10,000.- | Rp 1,280,000.- |
| TIM | Rp 825,000.- | Rp 750,000.- | Rp 10,000.- | Rp 1,585,000.- |
| TTE | Rp 261,000.- | Rp 585,000.- | Rp 10,000.- | Rp 856,000.- |

Source: PT SPIL Surabaya and Kitrans Logistics (2017)

According to the table above, the freight costs of Homebase Surabaya remains zero because Surabaya is as the inventory pool. Therefore, freight costs are not considered in this condition. Meanwhile freight costs for each port are transportation costs from the inventory pool (Surabaya) to its destination ports.

## 4.3 Model Building

After obtaining all the input parameters to simulate the system, the next step is to build a simulation model using Arena software based on the movement of empty container in ports and homebase. The conceptual model of simulation has been presented in Figure 3.2 Chapter 3. In general, model is devided into ports model and homebase sub-model. Those sub-models mainly consist of 3 modules, such as demand generation module, inventory level and ROP checking module, and container shipping and stripping module. The integration of sub-models is only occurred between ports and homebase.

### *4.3.1 Container Demand Generation Module*

The container movement model starts with demand generation from each ports and homebase. The demand follows such a distribution that is already mentioned before. Homebase Surabaya accommodates 5 demand from each port, while ports only accommodate demand from Surabaya, as presented in the Figure 4.4 and 4.5. After demand being generated, container inventory level has to be checked before assigned to its destination ports or homebase. Figure 4.3 is the conceptual model of container demand generation module which is obtained from container delivery cycle in Chapter 3.

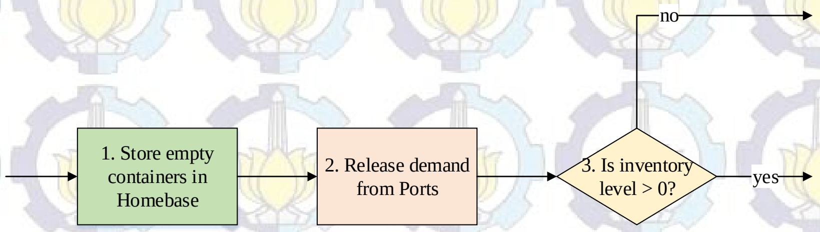



Figure 4. 3 Container Demand Generation Conceptual Model

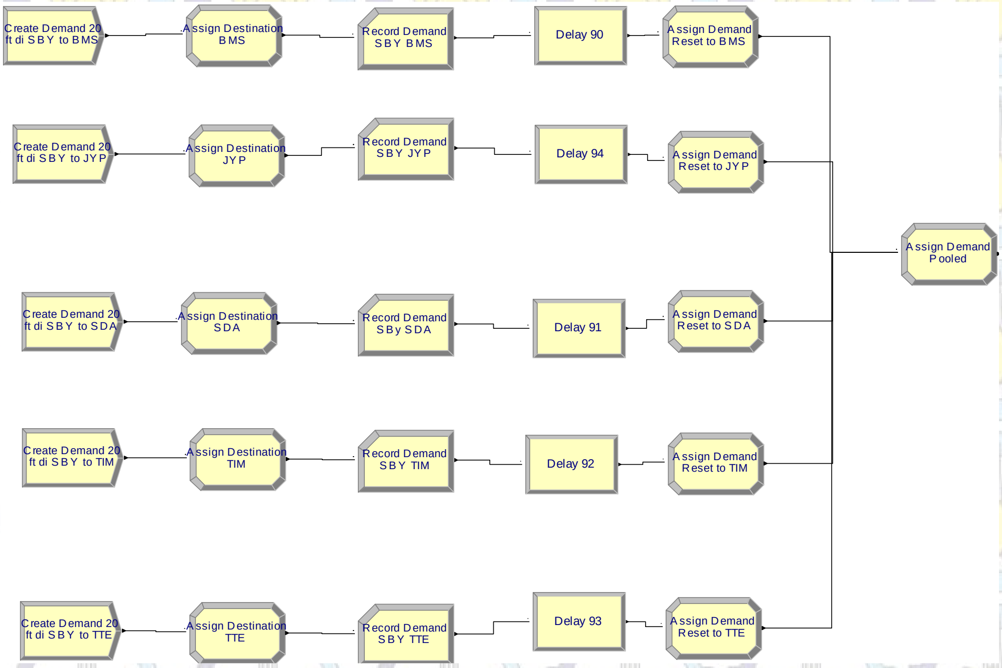



Figure 4. 4 Container Demand Generation Module in Homebase

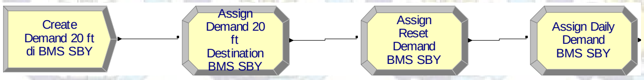



Figure 4. 5 Container Demand Generation Module in Ports

### *4.3.2 Inventory Level and ROP Checking Module*

The demand then being checked into 2 conditions. First, to check whether inventory level is sufficient or not to fulfill the demand. If it is not sufficient or less than zero, order will be taken and released in a period of reorder lead time. Inventory level checking is also used whenever container stockout is occurred. The reorder size is as same as the ROP value. The reorder size is then converted into reorder costs. Inventory level will be updated whenever order is received. On the other hand, when inventory level is sufficient, it will go to the second check, ROP checking. The concept of ROP checking is typical as the concept of inventory level checking. It is to ensure that inventory level is more than or equal to the ROP. Reorder costs is also considered in this process. The value of ROP, reorder size, and inventory level are stated as variables. The step then goes to the first inventory update, which update inventory level based on fulfilled demand and ordered empty container. After that, loading/stuffing process will take into account with a distributed period of lead time. This module is presented in Figure 4.7 and 4.8. While the conceptual model is in Figure 4.6.

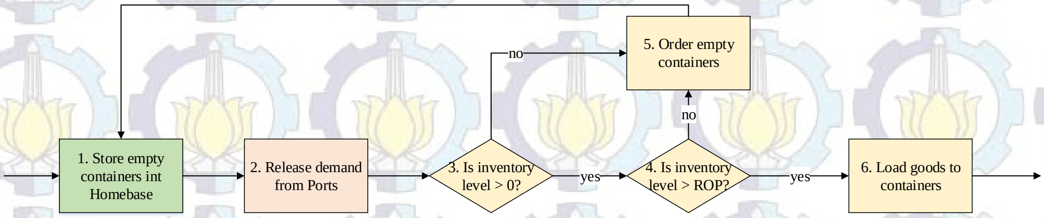



Figure 4. 6 Inventory Level and ROP Checking Conceptual Model

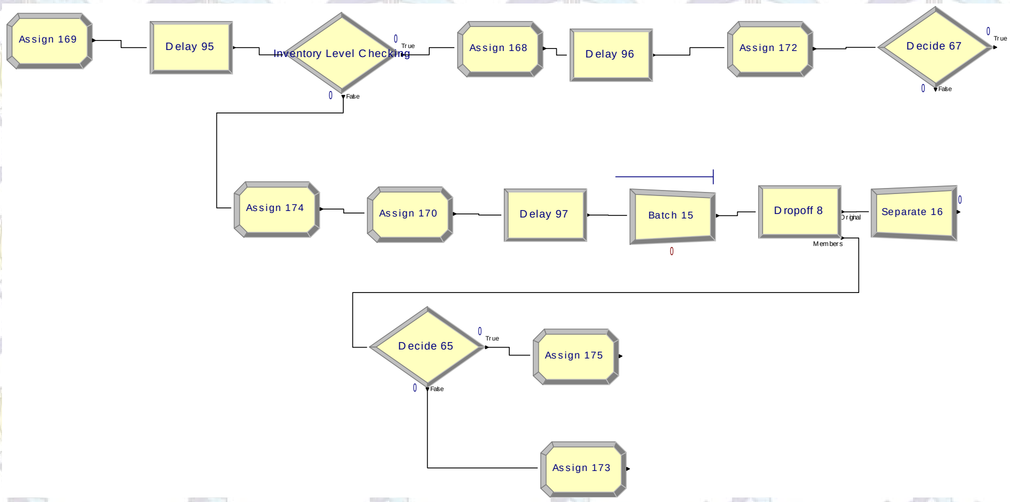



Figure 4. 7 Inventory Level Checking Module in Homebase and Ports

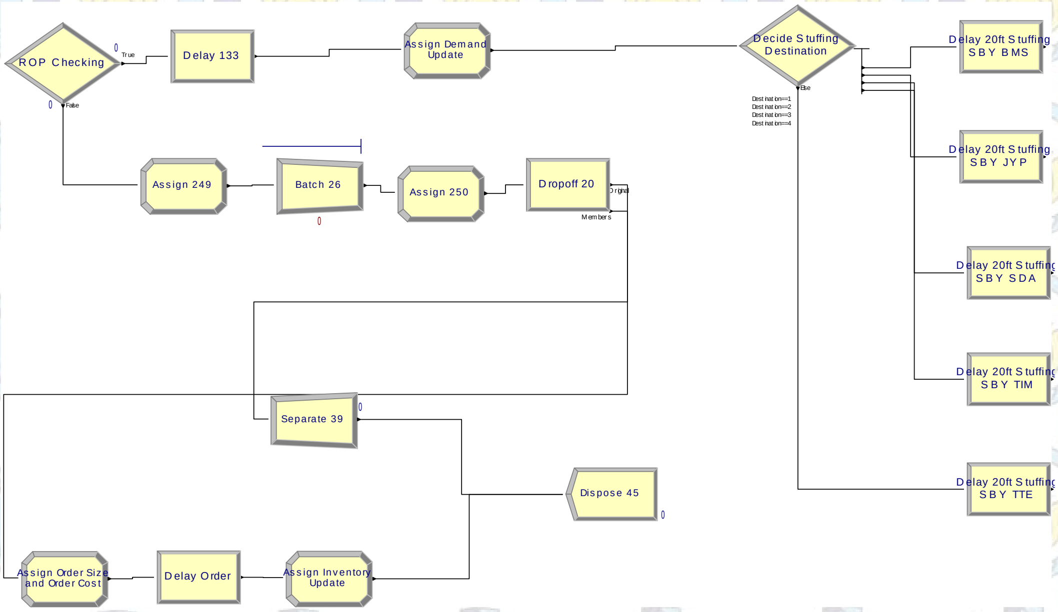



Figure 4. 8 ROP Checking Module in Homebase and Ports

### *4.3.3 Container Shipping and Unloading/Stripping Module*

After stuffing process is done, then container is being shipped to the destination ports or homebase with fixed period of lead time. The next process will be taken in destination ports or homebase. Container is unloaded/stripped following distributed period of lead time. After being unloaded, container will remain into condition of empty container. Inventory level of empty container is then updated afterwards. Since this model can be classified as closed-loop model, the cycle will be started from container demand generation again. This container shipping and unloading/stripping module is presented in Figure 4.10 and 4.11 respectively. While the conceptual model can be seen in Figure 4.9.

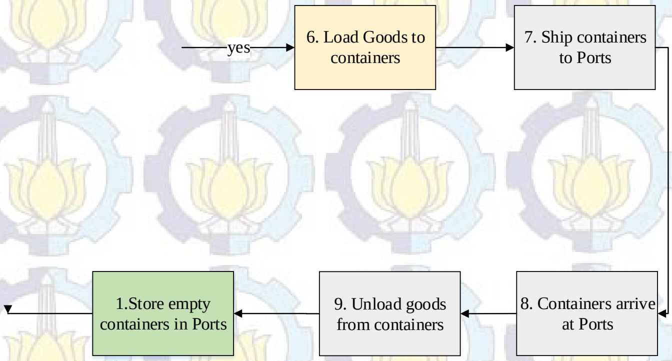


Figure 4. 9 Container Shipping and Stripping Conceptual Model

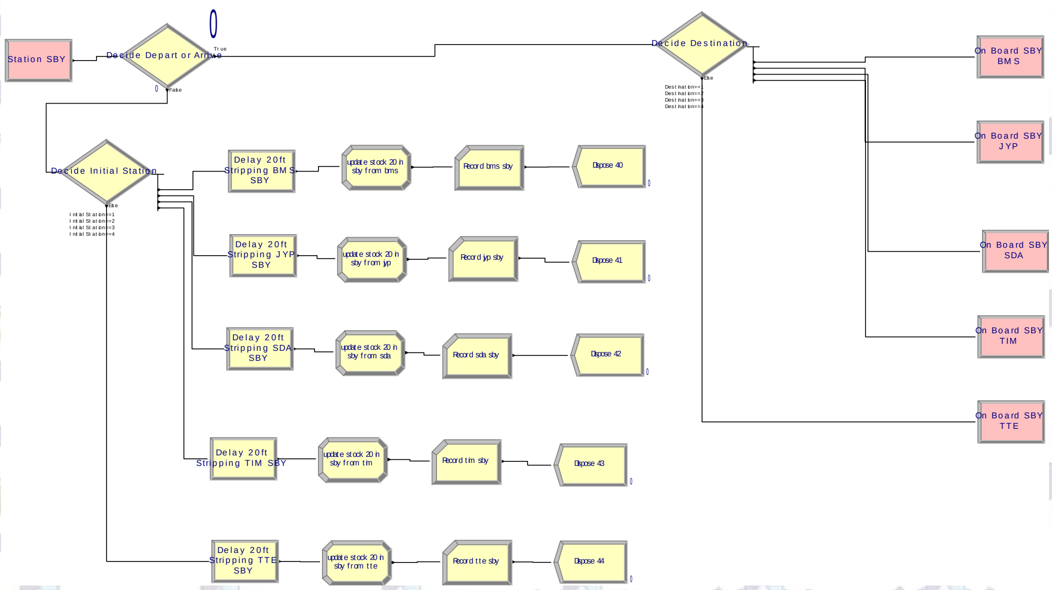


Figure 4. 10 Container Shipping and Unloading Module in Homebase

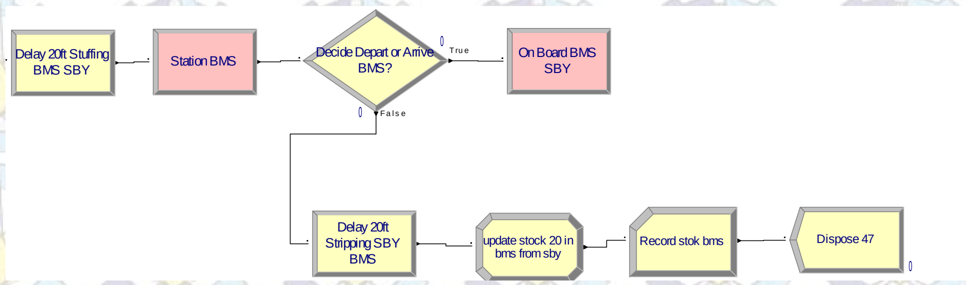


Figure 4. 11 Container Shipping and Unloading Module in Ports

## 4.4 Model Verification and Validation

After building the simulation model, the next important step is to verify and validate the model to ensure the model follows its logical design and fits the real/existing system.

### *4.4.1 Model Verification*

Model verification is conducted in two types, such as error checking using trace and debug facility embedded in Arena software and system logic verification.

#### 4.4.1.1 Trace and Debug Verification

This verification type is conducted by pressing F4 button in Arena software. It is aimed to check whether current model is error or not. Below is the figure of the trace and debug verification.

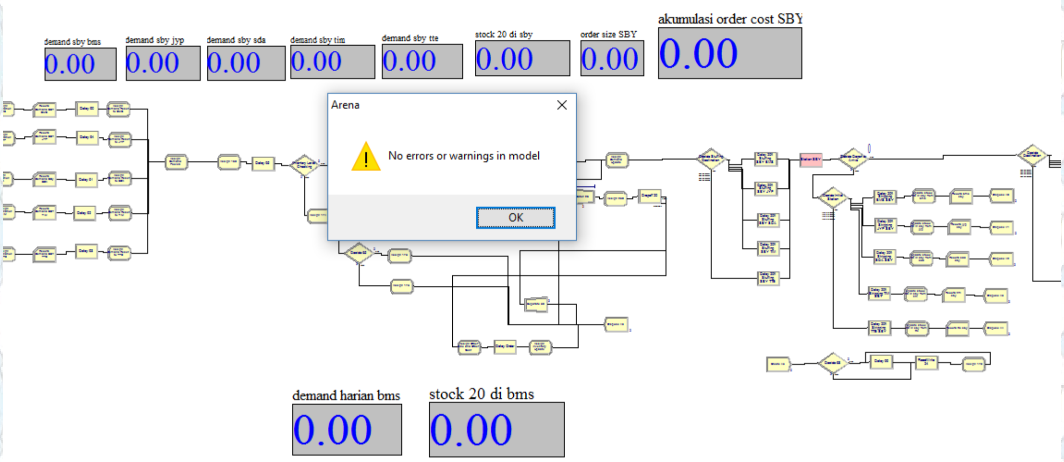



Figure 4. 12 Trace and Debug Verification

Figure above shows that model has no error. Therefore it can go to the system logic verification

#### 4.4.1.2 System Logic Verification

System logic verification is another important aspect of discrete event simulation. It is done to ensure that model follows correct logic and flow process.

This model will be verified according to its parameter, such as inventory level and reorder costs.

1. Inventory Level Verification

Inventory level in both ports and homebase follows such a flow or formula mentioned before in Chapter 2. For example, today's inventory level of empty container ($I_t$) is coming from total inventory level at the day before ($I_{t-1}$), incoming container at present ($Incoming\ MT_t$), and incoming order ($Incoming\ Order_t$). Then it is subtracted by present empty container demand ($Demand_t$). Equation 2.5 below refers to the inventory calculation. Therefore this model has to be verified in order to able to update the inventory level in correct way. The formula of inventory level (I) is as follow.

$$I_t = I_{t-1} + (Incoming\ MT_t) + (Incoming\ Order_t) - Demand_t \quad (2.5)$$

To verify this parameter, some outputs need to be derived from the simulation in a certain period of time. Model will be run in 60 days and Homebase Surabaya is taken as a sample. The reorder size is as much as initial ROP, 2000 units, and empty container reorder lead time is 1 day. Below is the recapitulation of the outputs that need to be verified, where (I) is Inventory and (MT) is empty container.

Table 4. 7 Inventory Level Verification of Homebase Surabaya

| t | Simulation I | Demand | Incoming MT | Reorder | Incoming Order | Actual I | Verification |
|---|---|---|---|---|---|---|---|
| 0 | 501 | 0 | 0 | 2000 | | 501 | verified |
| 1 | 305 | 196 | 0 | 2000 | | 305 | verified |
| 2 | 2099 | 206 | 0 | | 2000 | 2099 | verified |
| 3 | 3876 | 223 | 0 | | 2000 | 3876 | verified |
| 4 | 3679 | 197 | 0 | | | 3679 | verified |
| 5 | 3465 | 214 | 0 | | | 3465 | verified |
| 6 | 3259 | 206 | 0 | | | 3259 | verified |
| 7 | 3065 | 194 | 0 | | | 3065 | verified |
| 8 | 2863 | 202 | 0 | | | 2863 | verified |
| 9 | 2663 | 209 | 9 | | | 2663 | verified |

Table 4. 7 Inventory Level Verification of Homebase Surabaya (con't)

| t | Simulation I | Demand | Incoming MT | Reorder | Incoming Order | Actual I | Verification |
|---|---|---|---|---|---|---|---|
| 10 | 2467 | 209 | 13 | | | 2467 | verified |
| 11 | 2279 | 219 | 31 | | | 2279 | verified |
| 12 | 2137 | 200 | 58 | | | 2137 | verified |
| 13 | 1979 | 199 | 41 | 2000 | | 1979 | verified |
| 14 | 1819 | 215 | 55 | 2000 | | 1819 | verified |
| 15 | 3657 | 219 | 57 | | 2000 | 3657 | verified |
| 16 | 5469 | 222 | 34 | | 2000 | 5469 | verified |
| 17 | 5289 | 226 | 46 | | | 5289 | verified |
| 18 | 5121 | 221 | 53 | | | 5121 | verified |
| 19 | 4973 | 206 | 58 | | | 4973 | verified |
| 20 | 4836 | 212 | 75 | | | 4836 | verified |
| 21 | 4708 | 201 | 73 | | | 4708 | verified |
| 22 | 4572 | 212 | 76 | | | 4572 | verified |
| 23 | 4418 | 216 | 62 | | | 4418 | verified |
| 24 | 4282 | 212 | 76 | | | 4282 | verified |
| 25 | 4121 | 219 | 58 | | | 4121 | verified |
| 26 | 3996 | 204 | 79 | | | 3996 | verified |
| 27 | 3855 | 212 | 71 | | | 3855 | verified |
| 28 | 3712 | 220 | 77 | | | 3712 | verified |
| 29 | 3575 | 207 | 70 | | | 3575 | verified |
| 30 | 3440 | 217 | 82 | | | 3440 | verified |
| 31 | 3329 | 200 | 89 | | | 3329 | verified |
| 32 | 3169 | 221 | 61 | | | 3169 | verified |
| 33 | 3023 | 219 | 73 | | | 3023 | verified |
| 34 | 2888 | 207 | 72 | | | 2888 | verified |
| 35 | 2748 | 215 | 75 | | | 2748 | verified |
| 36 | 2620 | 209 | 81 | | | 2620 | verified |
| 37 | 2473 | 226 | 79 | | | 2473 | verified |
| 38 | 2363 | 189 | 79 | | | 2363 | verified |
| 39 | 2216 | 224 | 77 | | | 2216 | verified |
| 40 | 2102 | 201 | 87 | | | 2102 | verified |
| 41 | 1937 | 221 | 56 | 2000 | | 1937 | verified |
| 42 | 1808 | 201 | 72 | 2000 | | 1808 | verified |
| 43 | 3671 | 226 | 89 | | 2000 | 3671 | verified |
| 44 | 5509 | 232 | 70 | | 2000 | 5509 | verified |
| 45 | 5368 | 202 | 61 | | | 5368 | verified |
| 46 | 5213 | 220 | 65 | | | 5213 | verified |
| 47 | 5072 | 210 | 69 | | | 5072 | verified |
| 48 | 4905 | 236 | 69 | | | 4905 | verified |

Table 4. 7 Inventory Level Verification of Homebase Surabaya (con't)

| t | Simulation I | Demand | Incoming MT | Reorder | Incoming Order | Actual I | Verification |
|---|---|---|---|---|---|---|---|
| 49 | 4756 | 221 | 72 | | | 4756 | verified |
| 50 | 4604 | 215 | 63 | | | 4604 | verified |
| 51 | 4467 | 210 | 73 | | | 4467 | verified |
| 52 | 4319 | 222 | 74 | | | 4319 | verified |
| 53 | 4187 | 218 | 86 | | | 4187 | verified |
| 54 | 4048 | 222 | 83 | | | 4048 | verified |
| 55 | 3928 | 206 | 86 | | | 3928 | verified |
| 56 | 3796 | 213 | 81 | | | 3796 | verified |
| 57 | 3655 | 208 | 67 | | | 3655 | verified |
| 58 | 3497 | 234 | 76 | | | 3497 | verified |
| 59 | 3339 | 236 | 78 | | | 3339 | verified |
| 60 | 3216 | 208 | 85 | | | 3216 | verified |

From the table above, it can be inferred that all inventory level during 60 days is well verified and follow the system logic.

2. Reorder Costs Verification

The next verification is to verify reorder costs. The system remains that every reorder costs taken will be multiplied by unit reorder costs. Reorder is taken whenever inventory level is below the ROP. Let Homebase Surabaya be the sample. The unit reorder costs is as much as Rp835,000.- per container, while the reorder size is as much as ROP, 2000 units. So reorder costs accumulation should be Rp1,670,000,000.- Below is the figure of the simulation model which capture the logic of reorder costs calculation.

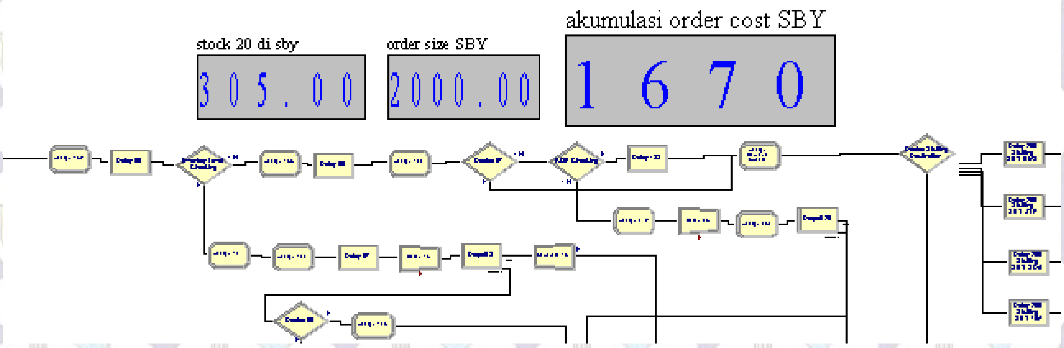



Figure 4. 13 Reorder Costs Verification of Homebase Surabaya

Since the result of manual calculation is as same as the simulation result, it can be inferred that model is verified.

### *4.4.2 Model Validation*

After verification process is done, model needs to be validated in order to ensure that the simulation model represents the actual system. Since this simulation model mostly deals with inventory information, inventory level in some periods in month of January and February 2016 will be the validation parameter. Simulation will be run for only 60 days. In number, there are only 9 inventory level data from the existing/actual system. Therefore t-test is chosen with additional assumption of unequal variances. Reports of t-test for each ports and homebase are processed using Data Analysis in Microsoft Excel with 95% of confidence level. Below are the tables of the validation parameter and statistical t-test result for each port and homebase. The rest of the validation parameter table can be seen in Table B.1 – B.2, Appendix B.

Table 4. 8 Model Validation Parameter Table

| | **Inventory Level in SBY (unit)** | | **Inventory Level in BMS (unit)** | |
|---|---|---|---|---|
| Day | Simulation | Actual | Simulation | Actual |
| 3 | 3876 | 3484 | 605 | 838 |
| 10 | 2467 | 3588 | 851 | 1223 |
| 24 | 4282 | 3785 | 914 | 425 |
| 31 | 3329 | 3052 | 984 | 238 |
| 32 | 3169 | 2732 | 1010 | 568 |
| 39 | 2216 | 2353 | 1117 | 1283 |
| 45 | 5368 | 2667 | 1226 | 310 |
| 52 | 4319 | 2968 | 1260 | 938 |
| 59 | 3339 | 2219 | 1322 | 1083 |

Table 4. 9 T-Test Recapitulation Table

| t-Test: Two-Sample Assuming Unequal Variances | | | | |
|---|---|---|---|---|
| | **Surabaya (SBY)** | | **Banjarmasin (BMS)** | |
| | *Simulation* | *Actual* | *Simulation* | *Actual* |
| Mean | 3596.111111 | 2983.111111 | 1032.111111 | 766.9444444 |
| Variance | 963802.1111 | 301083.6111 | 51593.36111 | 156598.0903 |
| Observations | 9 | 9 | 9 | 9 |
| Hypothesized Mean Difference | 0 | | 0 | |
| Df | 13 | | 13 | |
| **t Stat** | **1.635144297** | | **1.743446952** | |
| P(T<=t) one-tail | 0.062994292 | | 0.052420205 | |
| t Critical one-tail | 1.770933396 | | 1.770933396 | |
| P(T<=t) two-tail | 0.125988583 | | 0.104840409 | |
| **t Critical two-tail** | **2.160368656** | | **2.160368656** | |
| | **Jayapura (JYP)** | | **Samarinda (SDA)** | |
| | *Simulation* | *Actual* | *Simulation* | *Actual* |
| Mean | 2159.333333 | 1786.944444 | 2055.666667 | 1301.333333 |
| Variance | 2960407.5 | 81455.90278 | 964836 | 258376 |
| Observations | 9 | 9 | 9 | 9 |
| Hypothesized Mean Difference | 0 | | 0 | |
| Df | 8 | | 12 | |
| **t Stat** | **0.640542743** | | **2.046132188** | |
| P(T<=t) one-tail | 0.269864699 | | 0.03165119 | |
| t Critical one-tail | 1.859548038 | | 1.782287556 | |
| P(T<=t) two-tail | 0.539729397 | | 0.063302381 | |
| **t Critical two-tail** | **2.306004135** | | **2.17881283** | |
| | **Timika (TIM)** | | **Ternate (TTE)** | |
| | *Simulation* | *Actual* | *Simulation* | *Actual* |
| Mean | 681.5555556 | 653.1111111 | 290.3333333 | 221.5555556 |
| Variance | 89938.27778 | 9164.361111 | 17267 | 1998.777778 |
| Observations | 9 | 9 | 9 | 9 |
| Hypothesized Mean Difference | 0 | | 0 | |
| Df | 10 | | 10 | |
| **t Stat** | **0.271066658** | | **1.486538361** | |
| P(T<=t) one-tail | 0.395926421 | | 0.083984897 | |
| t Critical one-tail | 1.812461123 | | 1.812461123 | |
| P(T<=t) two-tail | 0.791852842 | | 0.167969795 | |
| **t Critical two-tail** | **2.228138852** | | **2.228138852** | |

According to the tables above, t-stat values are needed to be compared with t-critical two-tail values. For validation purposes, t-stat values have to be laid in between t-critical two-tail values. Looking at the table above, it is implying that under 95% confidence level, there is no significant difference between simulation output and actual data for all ports and homebase. Simulation model is considered to be valid and can be analyzed further.

## 4.5 Model Replication Number

Replication number of the simulation model needs to be defined correctly in order to accommodate the random output of the simulation, since there are some uncertainties considered in this simulation. The process of defining replication number is first by simulating the model with approximate number of replication, then calculating the minimum required number of replication using some formulas. Below is the table of incoming container of Homebase Surabaya that is already simulated with 5 replications for a year period (360 days).

Table 4. 10 Incoming Container Replication of Homebase Surabaya

| Replication | Incoming Container SBY (unit) |
|---|---|
| 1 | 25793 |
| 2 | 25602 |
| 3 | 25789 |
| 4 | 25681 |
| 5 | 25381 |
| **Average** | **25649** |
| **StDev.** | **170** |

In order to ensure that 5 replications is sufficient, the minimum required number of replication has to be calculated using formulas as follows (Law and Kelton, 2000).

$$n' \approx \left(\frac{Z_{a/2} \times s}{h_w}\right)^2 \quad (4.3)$$

$$h_w = \beta = \left(t_{n-1,1-\alpha/2}\right) \cdot \frac{s}{\sqrt{n_0}} \quad (4.4)$$

Where,

$h_w$ = half width

α = error (5%)
s = standard deviation of replications
$n_0$ = initial number of replications
n' = minimum number of replications required
$\left(t_{n-1,1-\alpha/2}\right)$ = student t distribution (2.77)

$$h_w = \beta = 2.77 \frac{170}{\sqrt{5}} = 210.6$$

$$n' \approx \left(\frac{1.96 \times 170}{210.6}\right)^2 = 3\ replications$$

According to the result above, it can be inferred that number of minimum replication required is 3 replications. Therefore 5 replications used at the beginning is sufficient.

## 4.6 Scenario Generation

This research is aimed to develop an inventory control system by determining its recommended ROP. Initial ROP is used as initial scenario (scenario 0). Those number are then being evaluated by reducing and adding to some certain number until they reach recommended number, considering average inventory and total reorder costs.

For each port and homebase, the additional and reduction numbers are based on empirical and company judgement. The ranges are 7% - 12% of the ROP value. As the example, Scenario 1 – 9 in Homebase Surabaya are generated from 10% reduction of its initial ROP, while Scenario 10 is from the 10% additional of its initial ROP. Other ports will follow the same rule but using different percentage. The change of ROP in each port and homebase will also lead to the change of reorder size, which will be as same as ROP value. Therefore each port and homebase have different additional and reduction number of ROP and reorder size as well. Moreover the combination number for each scenario in each port and homebase are independent one to each other. The relation only occurs between homebase and each port.

The scenario generation processes are done in Process Analyzer in Arena software. It is expected that recommended ROP will lead to low inventory level as well as total reorder costs. Below is the list of scenarios used.

Table 4. 11 List of Simulation Scenarios

| Scenario | ROP (unit) | | | | | |
|---|---|---|---|---|---|---|
| | **SBY** | **BMS** | **JYP** | **SDA** | **TIM** | **TTE** |
| Scenario 0 | 2000 | 583 | 293 | 304 | 26 | 43 |
| Scenario 1 | 1800 | 533 | 253 | 284 | 24 | 38 |
| Scenario 2 | 1600 | 483 | 213 | 264 | 22 | 33 |
| Scenario 3 | 1500 | 433 | 193 | 244 | 20 | 28 |
| Scenario 4 | 1400 | 383 | 173 | 224 | 18 | 23 |
| Scenario 5 | 1200 | 333 | 153 | 204 | 16 | 18 |
| Scenario 6 | 1000 | 283 | 133 | 184 | 14 | 13 |
| Scenario 7 | 800 | 233 | 93 | 144 | 12 | 11 |
| Scenario 8 | 600 | 183 | 73 | 104 | 10 | 9 |
| Scenario 9 | 500 | 133 | 63 | 94 | 8 | 7 |
| Scenario 10 | 2200 | 623 | 333 | 324 | 28 | 48 |

## 4.7 Simulation Output

The initial system and the scenarios are being simulated for 360 days. The replication length is 5 replications for each scenario. There are 2 parameters to evaluate the ROP of the system, such as average inventory level and total reorder costs in a whole year. Simulation output will be derived to each ports and homebase. Below are tables of simulation output from Process Analyzer in Arena software and output recapitulation for homebase and each ports respectively.

| | Scenario Properties | | | | Controls | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | S | Name | Program File | Reps | ROP Samarinda | ROP Timika | ROP Ternate | ROP Surabaya | ROP Jayapura | ROP Banjarmasin |
| 1 | | Scenario 10 | 11 : Model3b | 5 | 324 | 28 | 48 | 2200 | 333 | 623 |
| 2 | | Scenario 0 | 11 : Model3b | 5 | 304 | 26 | 43 | 2000 | 293 | 583 |
| 3 | | Scenario 1 | 11 : Model3b | 5 | 284 | 24 | 38 | 1800 | 253 | 533 |
| 4 | | Scenario 2 | 11 : Model3b | 5 | 264 | 22 | 33 | 1600 | 213 | 483 |
| 5 | | Scenario 3 | 11 : Model3b | 5 | 244 | 20 | 28 | 1500 | 193 | 433 |
| 6 | | Scenario 4 | 11 : Model3b | 5 | 224 | 18 | 23 | 1400 | 173 | 383 |
| 7 | | Scenario 5 | 11 : Model3b | 5 | 204 | 16 | 18 | 1200 | 153 | 333 |
| 8 | | Scenario 6 | 11 : Model3b | 5 | 184 | 14 | 13 | 1000 | 133 | 283 |
| 9 | | Scenario 7 | 11 : Model3b | 5 | 144 | 12 | 11 | 800 | 93 | 233 |
| 10 | | Scenario 8 | 11 : Model3b | 5 | 104 | 10 | 9 | 600 | 73 | 183 |
| 11 | | Scenario 9 | 11 : Model3b | 5 | 94 | 8 | 7 | 500 | 63 | 133 |

Figure 4. 14 Simulation Process Analyzer Interface

Table 4. 12 Simulation Output Recapitulation of Homebase Surabaya

| Scenario | ROP (unit) | Average Inventory Level (unit) | Total Reorder Costs |
|---|---|---|---|
| Scenario 0 | 2000 | 3641 | Rp 45,758,000,000 |
| Scenario 1 | 1800 | 3374 | Rp 44,488,800,000 |
| Scenario 2 | 1600 | 3510 | Rp 45,156,800,000 |
| Scenario 3 | 1500 | 3597 | Rp 45,090,000,000 |
| Scenario 4 | 1400 | 3102 | Rp 44,422,000,000 |
| Scenario 5 | 1200 | 2518 | Rp 44,088,000,000 |
| Scenario 6 | 1000 | 1504 | Rp 43,253,000,000 |
| Scenario 7 | 800 | 795 | Rp 42,885,600,000 |
| Scenario 8 | 600 | 974 | Rp 42,985,800,000 |
| Scenario 9 | 500 | 714 | Rp 42,668,500,000 |
| Scenario 10 | 2200 | 2619 | Rp 44,088,000,000 |

Table 4. 13 Simulation Output Recapitulation for Port Banjarmasin

| Scenario | ROP (unit) | Average Inventory Level (unit) | Total Reorder Costs |
|---|---|---|---|
| Scenario 0 | 583 | 5945 | Rp 1,048,234,000 |
| Scenario 1 | 533 | 5478 | Rp 958,334,000 |
| Scenario 2 | 483 | 5181 | Rp 868,434,000 |
| Scenario 3 | 433 | 4999 | Rp 778,534,000 |
| Scenario 4 | 383 | 5150 | Rp 1,101,814,400 |
| Scenario 5 | 333 | 5277 | Rp 1,496,835,000 |
| Scenario 6 | 283 | 4376 | Rp 1,272,085,000 |
| Scenario 7 | 233 | 3357 | Rp 1,047,335,000 |
| Scenario 8 | 183 | 1766 | Rp 822,585,000 |
| Scenario 9 | 133 | 631 | Rp 765,228,800 |
| Scenario 10 | 623 | 6043 | Rp 1,120,154,000 |

Table 4. 14 Simulation Output Recapitulation of Port Jayapura

| Scenario | ROP (unit) | Average Inventory Level (unit) | Total Reorder Costs |
|---|---|---|---|
| Scenario 0 | 293 | 10589 | Rp 3,598,626,000 |
| Scenario 1 | 253 | 8580 | Rp 1,013,265,000 |
| Scenario 2 | 213 | 7750 | Rp - |
| Scenario 3 | 193 | 7620 | Rp - |
| Scenario 4 | 173 | 7541 | Rp - |
| Scenario 5 | 153 | 7361 | Rp - |
| Scenario 6 | 133 | 7086 | Rp - |
| Scenario 7 | 93 | 6713 | Rp - |
| Scenario 8 | 73 | 5997 | Rp - |

Table 4. 14 Simulation Output Recapitulation of Port Jayapura (con't)

| Scenario | ROP (unit) | Average Inventory Level (unit) | Total Reorder Costs |
|---|---|---|---|
| Scenario 9 | 63 | 5499 | Rp - |
| Scenario 10 | 333 | 11612 | Rp 4,890,105,000 |

Table 4. 15 Simulation Output Recapitulation for Port Samarinda

| Scenario | ROP (unit) | Average Inventory Level (unit) | Total Reorder Costs |
|---|---|---|---|
| Scenario 0 | 304 | 18948 | Rp 1,945,600,000 |
| Scenario 1 | 284 | 18582 | Rp 1,817,600,000 |
| Scenario 2 | 264 | 18364 | Rp 1,689,600,000 |
| Scenario 3 | 244 | 18061 | Rp 1,561,600,000 |
| Scenario 4 | 224 | 17871 | Rp 1,433,600,000 |
| Scenario 5 | 204 | 17329 | Rp 1,305,600,000 |
| Scenario 6 | 184 | 16722 | Rp 1,177,600,000 |
| Scenario 7 | 144 | 15628 | Rp 921,600,000 |
| Scenario 8 | 104 | 14029 | Rp 665,600,000 |
| Scenario 9 | 94 | 12787 | Rp 601,600,000 |
| Scenario 10 | 324 | 19239 | Rp 2,073,600,000 |

Table 4. 16 Simulation Output Recapitulation of Port Timika

| Scenario | ROP (unit) | Average Inventory Level (unit) | Total Reorder Costs |
|---|---|---|---|
| Scenario 0 | 26 | 8346 | Rp - |
| Scenario 1 | 24 | 8249 | Rp - |
| Scenario 2 | 22 | 8133 | Rp - |
| Scenario 3 | 20 | 8114 | Rp - |
| Scenario 4 | 18 | 8041 | Rp - |
| Scenario 5 | 16 | 7830 | Rp - |
| Scenario 6 | 14 | 7685 | Rp - |
| Scenario 7 | 12 | 7410 | Rp - |
| Scenario 8 | 10 | 6858 | Rp - |
| Scenario 9 | 8 | 6455 | Rp - |
| Scenario 10 | 28 | 8307 | Rp - |

Table 4. 17 Simulation Output Recapitulation of Port Ternate

| Scenario | ROP (unit) | Average Inventory Level (unit) | Total Reorder Costs |
|---|---|---|---|
| Scenario 0 | 43 | 3628 | Rp - |
| Scenario 1 | 38 | 3578 | Rp - |
| Scenario 2 | 33 | 3559 | Rp - |
| Scenario 3 | 28 | 3522 | Rp - |
| Scenario 4 | 23 | 3495 | Rp - |
| Scenario 5 | 18 | 3423 | Rp - |
| Scenario 6 | 13 | 3315 | Rp - |
| Scenario 7 | 11 | 3184 | Rp - |
| Scenario 8 | 9 | 2955 | Rp - |
| Scenario 9 | 7 | 2748 | Rp - |
| Scenario 10 | 48 | 3643 | Rp - |

(This page is intentionally left blank)

# CHAPTER 5
# ANALYSIS AND INTERPRETATION

Results of simulation and all scenarios generated in previous chapter are analyzed and interpreted in the fifth chapter. The analysis and interpretation will lead to conclusions and recommendations for next chapter.

## 5.1 Inventory Control System for Homebase Surabaya (SBY)

Homebase Surabaya plays a significant role in inventory control system for the whole company since there is no exact inventory parameter in ports. Therefore it is necessary to find the recommended value of ROP. The current condition remains that Surabaya defined its ROP and reorder size as many as 2,000 container unit. After being simulated for a year, it results in 3641 units of average inventory level and Rp 45,088,000,000.- of reorder costs.

**Table 4.12** in previous chapter recapitulates all simulation scenario results in Homebase Surabaya in terms of its average inventory level and total reorder costs. While total reorder costs (vertical) against the average inventory level (horizontal) is presented in Figure 5.1.

According to the comparison in **Table 4.12**, it can be inferred that bigger ROP will result in bigger inventory level and reorder costs as well. Although there are some points which are in contrast. In other words, the change of ROP in Homebase Surabaya is less sensitive to the inventory level and total reorder costs. However the gap between them is not significant. It is due to the condition that bigger ROP leads the reorder size as well. So when inventory level reaches the point below ROP, system will reorder empty container as many as its ROP. The fact that Homebase Surabaya has the biggest container demand among all ports also affect total reorder costs because it reorders empty container frequently. Therefore among other ports, Homebase Surabaya has relatively small inventory level yet high total reorder costs.

To justify the best/recommended scenario with the recommended value of ROP considering average inventory level and total reorder costs, Figure 5.1 is presented to compare total reorder costs and inventory level. According to Figure 5.1, it can be concluded that among other scenarios, Scenario 9 fits the best with Homebase Surabaya with the value of ROP is as many as 500 units. Comparing to the current scenario, company is able to save as much as Rp 3,089,500,000.- of reorder costs. The average inventory reduction is as many as 2927 units or equal to 80.39%.

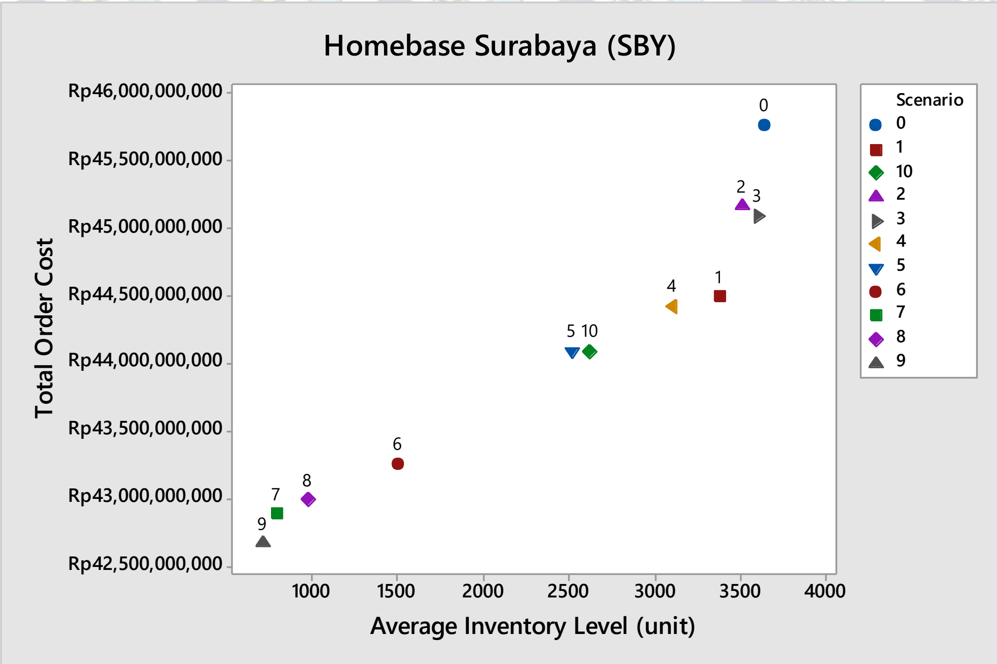



Figure 5. 1 Scatterplot of Average Inventory Level and Total Reorder Costs in SBY

## 5.2 Inventory Control System for Port Banjarmasin (BMS)

Currently, Port Banjarmasin doesn't have exact inventory parameter to order/ship empty container back to the homebase. Therefore it is necessary to find the recommended value of ROP. Since there is no current ROP in Banjarmasin, initial ROP calculated using exact formula is used as initial scenario. It remains that Banjarmasin defined its ROP and reorder size as many as 583 container units. After being simulated for a year, it results in 5945 units of average inventory level and Rp 1,120,154,000.- of reorder costs.

**Table 4.13** in previous chapter recapitulates all simulation scenario results in Port Banjarmasin in terms of its average inventory level and total reorder costs. While total reorder costs (vertical) against the average inventory level (horizontal) is presented in Figure 5.2.

According to the comparison in **Table 4.13**, it can be inferred that all points are fluctuated. In other words, the change of ROP in Port Banjarmasin is not sensitive to the inventory level and total reorder costs. However, the smallest ROP gives smallest average inventory level and reorder costs. So when inventory level reaches the point below ROP, system will reorder empty container as many as its ROP. The fact that Port Banjarmasin has the 2nd biggest container demand after Homebase Surabaya also affect total reorder costs because this port reorders empty container frequently. Typical to the Homebase Surabaya, Port Banjarmasin has relatively small inventory level yet high total reorder costs.

According to Figure 5.2, it can be concluded that Scenario 9 fits the best with Port Banjarmasin with the value of ROP is as many as 133 units. Comparing to the initial scenario, company is able to save as much as Rp 283,005,200.- of reorder costs. The average inventory reduction is as many as 5314 units or equal to 89.39%.

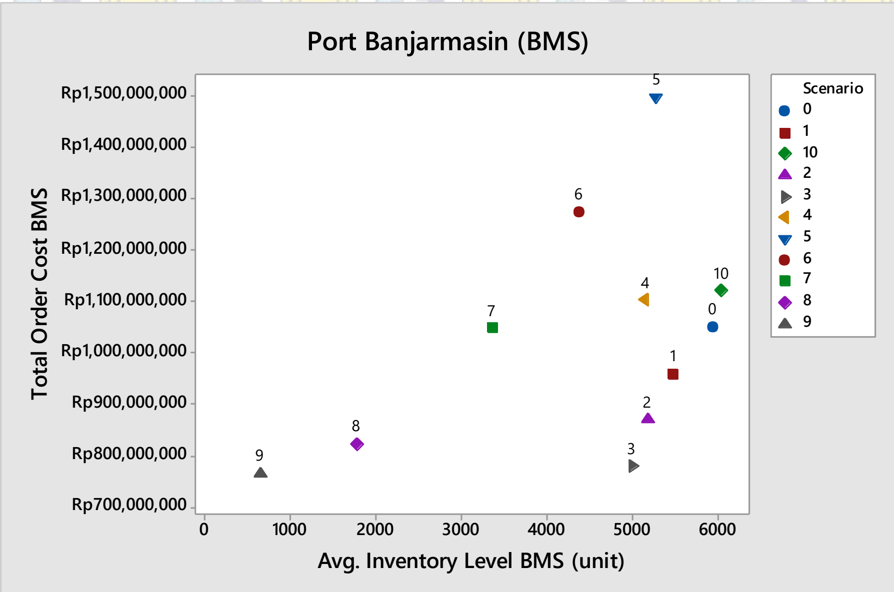



Figure 5. 2 Scatterplot of Average Inventory Level and Total Reorder Costs in BMS

## 5.3 Inventory Control System for Port Jayapura (JYP)

Port Jayapura also doesn’t have any inventory parameter. In this simulation, Port Jayapura is using initial ROP as many as 293 container units. After being simulated, it results in 10589 units of average inventory level and Rp 3,598,626,000.- of reorder costs.

**Table 4.14** in previous chapter recapitulates all simulation scenario results in Port Jayapura in terms of its average inventory level and total reorder costs. While total reorder costs (vertical) against the average inventory level (horizontal) is presented in Figure 5.3.

According to the comparison in Table **4.14**, it can be inferred that, typical to the previous analysis, bigger ROP will result in bigger inventory level and reorder costs as well. It is due to the condition that bigger ROP leads the reorder size as well. So when inventory level reaches the point below ROP, system will reorder empty container as many as its ROP. Note that reorder costs remain 0 in Scenario 2 until Scenario 9. It means that the inventory level is able to cover the fluctuated demand from Homebase Surabaya without reordering empty container. Consequently, this port holds more empty containers compared to the previous homebase and port. It also can be concluded that the change of ROP in Port Jayapura is not sensitive to the total reorder costs.

According to Figure 5.3, it can be concluded that Scenario 9 fits the best with Port Jayapura with the value of ROP is as many as 63 units. Comparing to the initial scenario, company is able to save as much as Rp 3,598,626,000.- of empty container reorder costs. The average inventory reduction is as many as 5090 units or equal to 48.07%.

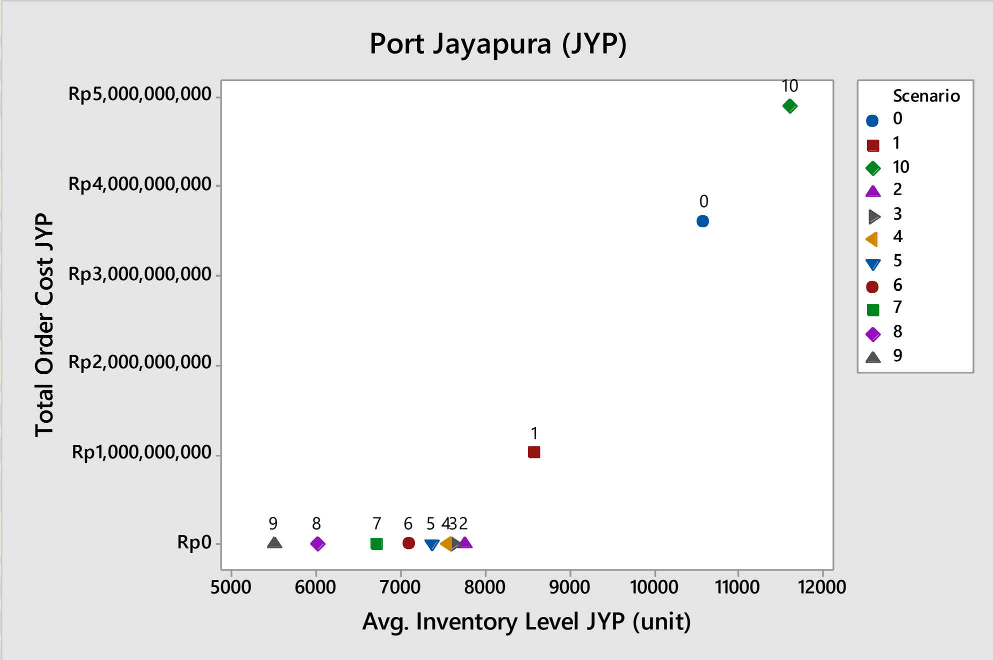



Figure 5. 3 Scatterplot of Average Inventory Level and Total Reorder Costs in JYP

## 5.4 Inventory Control System for Port Samarinda (SDA)

As same as the other ports, Port Samarinda doesn't have any inventory parameter. In this simulation, Port Samarinda is using initial ROP as many as 304 container units. After being simulated for a year, it results in 18948 units of average inventory level and Rp 1,945,600,000.- of reorder costs.

**Table 4.15** in previous chapter recapitulates all simulation scenario results in Port Jayapura in terms of its average inventory level and total reorder costs. While total reorder costs (vertical) against the average inventory level (horizontal) is presented in Figure 5.3.

According to the comparison in Table **4.15**, it can be inferred that, typical to the previous analysis, bigger ROP will result in bigger inventory level and reorder costs as well. It is due to the condition that bigger ROP leads the reorder size as well. So when inventory level reaches the point below ROP, system will reorder empty container as many as its ROP. In fact, Port Samarinda holds the largest number of empty containers among others, although there still be reduction from both average inventory level and total reorder costs. It means that the demand of empty container from Homebase Surabaya is slightly imbalance to the demand of empty container from this port. Therefore, this port still reorders empty container couple times and holds the reorders and incoming containers as inventory as well.

According to Figure 5.4, it can be concluded that Scenario 9 fits the best with Port Samarinda with the value of ROP is as many as 94 units. Comparing to the initial scenario, company is able to save as much as Rp 1,344,000,000.- of empty container reorder costs. The average inventory reduction is as many as 6161 units or equal to 32.52%. It also can be concluded that the change of ROP in Port Samarinda is sensitive to the inventory level and total reorder costs.

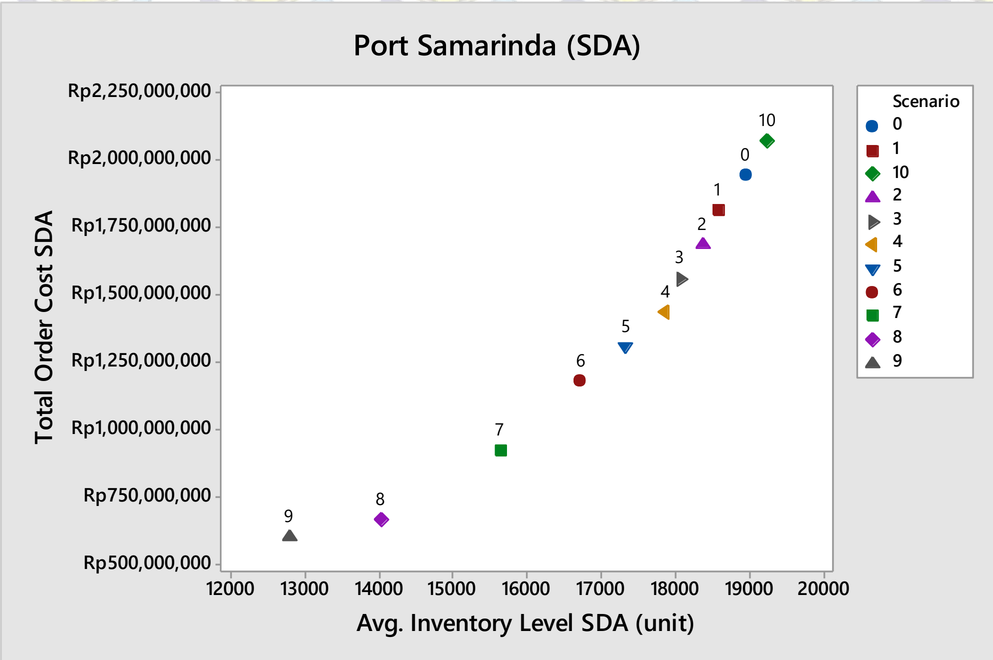



Figure 5. 4 Scatterplot of Average Inventory Level and Total Reorder Costs in SDA

## 5.5 Inventory Control System for Port Timika (TIM)

Recently, Port Timika doesn't have any inventory parameter, as same as other ports. In this simulation, Port Timika is using ROP as much as 26 container units as the initial ROP. After being simulated, it results in 8346 units of average inventory level and 0 reorder costs.

**Table 4.16** in previous chapter recapitulates all simulation scenario results in Port Jayapura in terms of its average inventory level and total reorder costs. While total reorder costs (vertical) against the average inventory level (horizontal) is presented in Figure 5.3.

According to the comparison in **Table 4.16**, it can be inferred that, typical to the previous analysis, bigger ROP will result in bigger inventory level and reorder costs as well. A major different is the fact that the total reorder costs for all scenarios remains 0. As stated in Port Jayapura, this condition means that the inventory level is able to cover the fluctuated demand from Homebase Surabaya without reordering any empty container. Moreover, the demand from homebase is slightly imbalance to the demand from this port. Consequently, this port holds more empty containers compared to the previous homebase and ports.

According to Figure 5.5, it can be concluded that Scenario 9 fits the best with Port Timika with the value of ROP is as many as 8 units. Comparing to the initial scenario, company does not need to reorder any empty container in all scenarios. However, the average inventory reduction is as many as 1891 units or equal to 22.66%. It also can be concluded that the change of ROP in Port Timika is not sensitive to the total reorder costs.

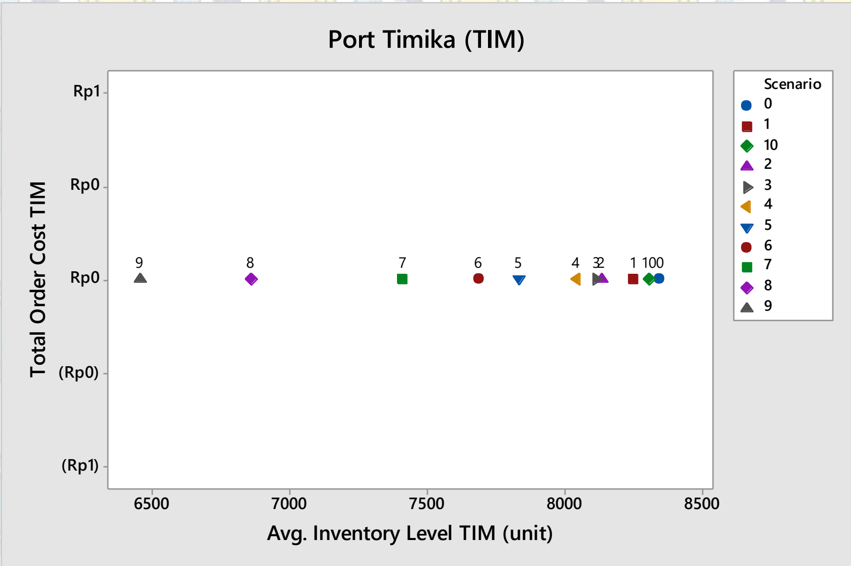



Figure 5. 5 Scatterplot of Average Inventory Level and Total Reorder Costs in TIM

## 5.6 Inventory Control System for Port Ternate (TTE)

The last port to be analyzed and interpreted is Ternate. Recently, Port Ternate doesn’t have any inventory parameter, as same as other ports. In this simulation, Port Ternate is using ROP as much as 43 container units as the initial ROP. After being simulated, it results in 3628 units of average inventory level and 0 reorder costs.

**Table 4.17** in previous chapter recapitulates all simulation scenario results in Port Jayapura in terms of its average inventory level and total reorder costs. While total reorder costs (vertical) against the average inventory level (horizontal) is presented in Figure 5.3.

According to the comparison in **Table 4.17**, it can be inferred that bigger ROP will result in bigger inventory level and reorder costs as well. The behavior of this port is typically as the same as Port Timika. The fact that the total reorder costs for all scenarios remains 0. As stated before, this condition means that the inventory level is able to cover the fluctuated demand from Homebase Surabaya without reordering any empty container. Moreover, the demand from homebase is slightly imbalance to the demand from this port. Consequently, this port holds more empty containers compared to the previous homebase and ports.

According to Figure 5.6, it can be concluded that Scenario 9 fits the best with Port Ternate with the value of ROP is as many as 7 units. Comparing to the initial scenario, company does not need to reorder any empty container in all scenarios. However, the average inventory reduction is as many as 880 units or equal to 24.26%. It also can be concluded that the change of ROP in Port Ternate is not sensitive to the total reorder costs.

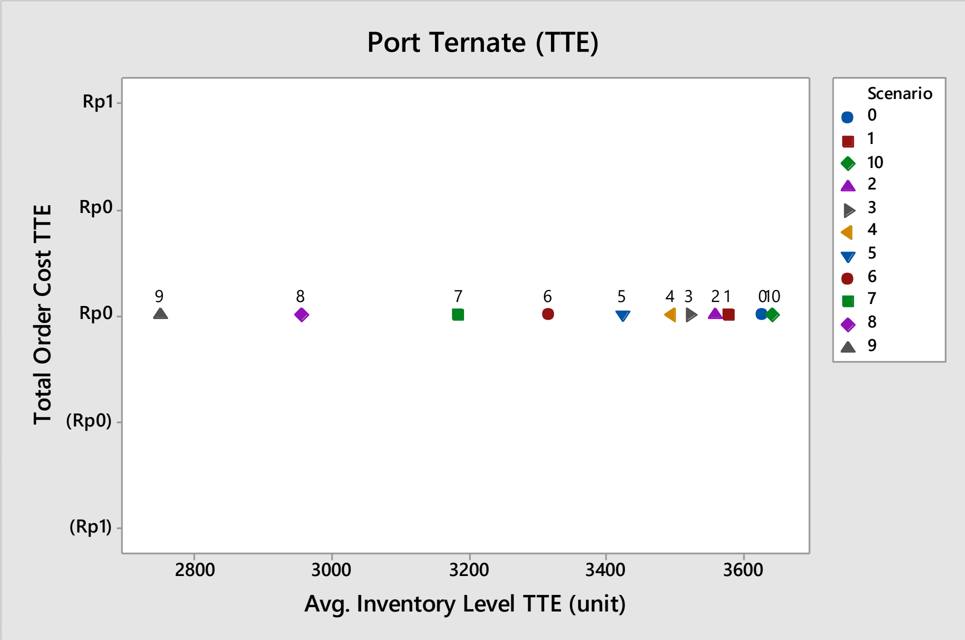



Figure 5. 6 Scatterplot of Average Inventory Level and Total Reorder Costs in TTE

## 5.7 Average Inventory Level and Reorder Costs Reduction Comparison

In reorder to be able find the recommended inventory parameter (ROP), all scenarios both in ports and homebase are already analyzed and interpreted. Below is the recapitulation table of the recommended ROP.

Table 5. 1 Recommended Scenario Recapitulation Table

| Ports | Chosen ROP (unit) | Average Inventory Level (unit) | Inventory Level Reduction | Total Reorder Cost | Reorder Cost Reduction |
|---|---|---|---|---|---|
| SBY | 500 | 714 | 80.39% | Rp 42,668,500,000.00 | 6.75% |
| BMS | 133 | 631 | 89.39% | Rp 765,228,800.00 | 27% |
| JYP | 63 | 5499 | 48.07% | Rp - | 100% |
| SDA | 94 | 12787 | 32.52% | Rp 601,600,000.00 | 69.08% |
| TIM | 8 | 6455 | 22.66% | Rp - | 0% |
| TTE | 7 | 2748 | 24.26% | Rp - | 0% |

According to the table above, it can be inferred that the smaller the ROP will result at smaller average inventory level and total reorder costs as well. However, Port Jayapura, Samarinda, Timika, and Ternate hold more empty containers compared to Homebase Surabaya and Port Banjarmasin. It is due to the imbalance demand of empty container. Those 4 ports receive more empty containers rather than deliver empty container to the homebase. As the tradeoffs, reorder costs for Port Jayapura, Timika, and Ternate remains 0 because the inventory level is always laid above the ROP. In other words, there are some ports and/or homebase which are not sensitive to the change of ROP considering average inventory level and total reorder costs.

# CHAPTER 6
# CONCLUSION AND RECOMMENDATION

The last chapter gives conclusions which answer the research objectives. Recommendations are also provided for the research topic and further research.

## 6.1 Conclusion

Conclusions of this research are as follow.

1. The model developed in this research has been able to evaluate the performance of empty container inventory control system in PT SPIL by accommodating some uncertainties in container demand and lead time. Several scenarios have been generated in order to evaluate the initial scenario which is obtained from the exact formula calculation. Other aspects are also captured by this model such as inventory level and ROP checking, incoming container, container reorder costs calculation, and container reorder time. By considering all those aspects, the recommended scenario of ROP for each port and homebase can be developed.
2. There are total 10 scenarios that have been evaluated in this research to determine the best scenario for recommended ROP. The recommended ROP according to this model and compared with the initial scenario for Surabaya, Banjarmasin, Jayapura, Samarinda, Timika, and Ternate are consecutively 500 units with 80.39% of inventory level reduction and 6.75% of reorder costs reduction, 133 units with 89.39% of inventory level reduction and 27% of reorder costs reduction, 63 units with 48.07% of inventory level reduction and 100% of reorder costs reduction, 94 units with 32.52% of inventory level reduction and 69.08% of reorder costs reduction, 84 units with 22.66% of inventory level reduction and 0% of reorder costs reduction, and 7 units with 24.26% of inventory level reduction and 0% of reorder costs reduction.

## 6.2 Recommendation

Recommendations for this and the next research are as follow.

1. Develop the model by considering wider scope of ports and homebases so it can capture company business process better.
2. Develop the model by combining 40 feet container with multiple shipping destinations.

# REFERENCES


Arief, M. M. (2014). *An Integrated Shipment Planning and Storage Capacity: A Simulation Study*. Surabaya: Industrial Engineering ITS

Arnold, J. R. T., Chapman, S. N., & Clive, L. M. (2008). *Introduction to Materials Management (6th Ed.)*. USA: Pearson Prentice Hall

Bahagia, I. S., Sandee, H., & Meeuws, R. (2013). *State of Logistics Indonesia 2013*. Washington DC: World Bank.

Ballou, R., H., (2004). *Business Logistics/Supply Chain Management (5th ed.)*. Englewood Cliffs: Prentice Hall, Inc.

Christiansen, M., Fagerholt, K., Nygreen, B., & Ronen, D. (2007). *Chapter 4 Maritime Transportation*. 14, 189-284

Furio, S., Andres, C., Adenso-Diaz., & Lozano, S. (2013). *Optimization of Empty Container Movements using Street-Turn: Application to Valencia Hinterland.* Computers and Industrial Engineering Journal 66 (2013) 909-917

Gunawan, R. W. (2015). *Improvement Of Inventory Control Systems For Raw Material In A Make-To-Order Company*. Surabaya: Industrial Engineering ITS

Kelton, D. W., Sadowski, R., & Sturrock, D. T. (2006). *Simulation with Arena*: McGraw Hill Higher Education.

Najib, A. (2013). *Designing Inventory Control Decision Support System for Empty Containers*. Surabaya: Industrial Engineering ITS

Pujawan, I. N. & Mahendrawati, E. R. (2010). *Supply Chain Management (2nd ed.)*. Surabaya: Guna Widya.

Quang-Vinh, D., Won-Young, Y., & Kopfer, H. (2011). *Positioning Empty Containers under Dependent Demand Process.* Computers and Industrial Engineering Journal 62 (2011) 708-715

Russel, R. H., & Taylor, B. W. (2000). *Operations Management*. USA: Prentice Hall, Inc.

Silver, E. A., & Peterson, R. (1998). *Decision Systems for Inventory Management and Production Planning*. New York: John Wiley and Sons.

Tersine, R. J., (1994). *Principles of Inventory and Material Management (4th ed.)*. USA: Prentice Hall International Edition.

Triono, E., Pujawan, I. N. (2016). *Improvement of Spare Part Inventory Parameter Setting using Monte Carlo Simulation Approach*. Surabaya: Prosiding Seminar Nasional Manajemen Teknologi XXV, ITS Surabaya

# APPENDIX A
# SIMULATION INPUT PARAMETERS

Table A.1 Container Daily Demand in 2016

| Route | Container Daily Demand (unit) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| BMS-SBY | 43 | 41 | 43 | 51 | 52 | 36 | 37 | 56 | 61 | 63 | 50 | 59 |
| JYP-SBY | 3 | 7 | 12 | 10 | 15 | 14 | 6 | 10 | 11 | 11 | 14 | 12 |
| SDA-SBY | 15 | 22 | 16 | 21 | 15 | 15 | 9 | 17 | 12 | 13 | 13 | 17 |
| TIM-SBY | 1 | 1 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| TTE-SBY | 1 | 2 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 2 |
| SBY-BMS | 64 | 58 | 72 | 70 | 66 | 77 | 60 | 79 | 78 | 67 | 74 | 69 |
| SBY-JYP | 41 | 35 | 38 | 36 | 33 | 36 | 23 | 27 | 43 | 45 | 41 | 31 |
| SBY-SDA | 60 | 57 | 73 | 71 | 69 | 91 | 60 | 74 | 63 | 57 | 71 | 70 |
| SBY-TIM | 26 | 27 | 28 | 26 | 26 | 29 | 19 | 19 | 29 | 30 | 35 | 27 |
| SBY-TTE | 15 | 12 | 11 | 16 | 13 | 12 | 9 | 11 | 15 | 15 | 14 | 15 |

Table A.2 Container Daily Demand Average and Standard Deviation in 2016

| Route | Average (unit) | Standard Deviation (unit) |
|---|---|---|
| BMS-SBY | 49 | 9 |
| JYP-SBY | 10 | 4 |
| SDA-SBY | 15 | 4 |
| TIM-SBY | 1 | 0 |
| TTE-SBY | 1 | 0 |
| SBY-BMS | 70 | 7 |
| SBY-JYP | 36 | 7 |
| SBY-SDA | 68 | 10 |
| SBY-TIM | 27 | 4 |
| SBY-TTE | 13 | 2 |

Table A.3 Container Lead Time in 2016

| MONTH | SBY BMS (day) | | | | SBY JYP (day) | | | |
|---|---|---|---|---|---|---|---|---|
| | STF | ON BOARD | STR | Total | STF | ON BOARD | STR | Total |
| Jan | 4 | 2 | 2 | 8 | 8 | 10 | 4 | 22 |
| Feb | 3 | 2 | 3 | 8 | 8 | 10 | 5 | 23 |
| Mar | 2 | 2 | 5 | 9 | 9 | 10 | 6 | 25 |
| Apr | 4 | 2 | 2 | 8 | 8 | 10 | 3 | 21 |
| May | 4 | 2 | 2 | 8 | 7 | 10 | 5 | 22 |
| Jun | 3 | 2 | 3 | 8 | 7 | 10 | 8 | 25 |
| Jul | 3 | 2 | 3 | 8 | 8 | 10 | 3 | 21 |

Table A.3 Container Lead Time in 2016 (con't)

| MONTH | SBY BMS (day) | | | | SBY JYP (day) | | | |
|---|---|---|---|---|---|---|---|---|
| | STF | ON BOARD | STR | Total | STF | ON BOARD | STR | Total |
| Aug | 5 | 2 | 6 | 13 | 5 | 10 | 6 | 21 |
| Sept | 1 | 2 | 5 | 8 | 6 | 10 | 2 | 18 |
| Oct | 1 | 2 | 5 | 8 | 4 | 10 | 6 | 20 |
| Nov | 5 | 2 | 2 | 9 | 8 | 10 | 5 | 23 |
| Dec | 5 | 2 | 1 | 8 | 4 | 10 | 7 | 21 |
| Average | 3.33 | 2.00 | 3.25 | 8.58 | 6.83 | 10.00 | 5.00 | 21.83 |
| Std. Dev | 1.44 | 0.00 | 1.60 | 1.44 | 1.70 | 0.00 | 1.76 | 1.99 |
| Min | 1.00 | 2.00 | 1.00 | 8.00 | 4.00 | 10.00 | 2.00 | 18.00 |
| Max | 5.00 | 2.00 | 6.00 | 13.00 | 9.00 | 10.00 | 8.00 | 25.00 |
| Mode | 4.00 | 2.00 | 2.00 | 8.00 | 8.00 | 10.00 | 5.00 | 21.00 |

Table A.4 Container Lead Time in 2016

| MONTH | SBY SDA (day) | | | | SBY TIM (day) | | | |
|---|---|---|---|---|---|---|---|---|
| | STF | ON BOARD | STR | Total | STF | ON BOARD | STR | Total |
| Jan | 5 | 4 | 3 | 12 | 6 | 9 | 5 | 20 |
| Feb | 4 | 4 | 2 | 10 | 6 | 9 | 5 | 20 |
| Mar | 4 | 4 | 4 | 12 | 7 | 9 | 7 | 23 |
| Apr | 7 | 4 | 4 | 15 | 7 | 9 | 6 | 22 |
| May | 5 | 4 | 5 | 14 | 8 | 9 | 8 | 25 |
| Jun | 6 | 4 | 5 | 15 | 9 | 9 | 5 | 23 |
| Jul | 4 | 4 | 6 | 14 | 6 | 9 | 8 | 23 |
| Aug | 9 | 4 | 6 | 19 | 5 | 9 | 7 | 21 |
| Sep | 5 | 4 | 4 | 13 | 5 | 9 | 8 | 22 |
| Oct | 7 | 4 | 3 | 14 | 4 | 9 | 7 | 20 |
| Nov | 3 | 4 | 2 | 9 | 4 | 9 | 4 | 17 |
| Dec | 7 | 4 | 2 | 13 | 3 | 9 | 4 | 16 |
| Average | 5.50 | 4.00 | 3.83 | 13.33 | 5.83 | 9.00 | 6.17 | 21.00 |
| Std. Dev | 1.73 | 0.00 | 1.47 | 2.57 | 1.75 | 0.00 | 1.53 | 2.59 |
| Min | 3.00 | 4.00 | 2.00 | 9.00 | 3.00 | 9.00 | 4.00 | 16.00 |
| Max | 9.00 | 4.00 | 6.00 | 19.00 | 9.00 | 9.00 | 8.00 | 25.00 |
| Mode | 5.00 | 4.00 | 2.00 | 14.00 | 6.00 | 9.00 | 5.00 | 20.00 |

Table A.5 Container Lead Time in 2016

| MONTH | SDA SBY (day) | | | | TIM SBY (day) | | | |
|---|---|---|---|---|---|---|---|---|
| | STF | ON BOARD | STR | Total | STF | ON BOARD | STR | Total |
| Jan | 5 | 4 | 3 | 12 | 6 | 9 | 5 | 20 |
| Feb | 4 | 4 | 5 | 13 | 6 | 9 | 5 | 20 |
| Mar | 6 | 4 | 6 | 16 | 7 | 9 | 6 | 22 |
| Apr | 7 | 4 | 4 | 15 | 7 | 9 | 6 | 22 |
| May | 5 | 4 | 5 | 14 | 8 | 9 | 8 | 25 |
| Jun | 6 | 4 | 6 | 16 | 9 | 9 | 10 | 28 |
| Jul | 8 | 4 | 7 | 19 | 9 | 9 | 7 | 25 |
| Aug | 9 | 4 | 7 | 20 | 7 | 9 | 8 | 24 |
| Sep | 5 | 4 | 4 | 13 | 7 | 9 | 9 | 25 |
| Oct | 7 | 4 | 3 | 14 | 5 | 9 | 6 | 20 |
| Nov | 3 | 4 | 2 | 9 | 4 | 9 | 6 | 19 |
| Dec | 7 | 4 | 2 | 13 | 3 | 9 | 7 | 19 |
| Average | 6.00 | 4.00 | 4.50 | 14.50 | 6.50 | 9.00 | 6.92 | 22.42 |
| Std. Dev | 1.71 | 0.00 | 1.78 | 3.00 | 1.83 | 0.00 | 1.56 | 2.94 |
| Min | 3.00 | 4.00 | 2.00 | 9.00 | 3.00 | 9.00 | 5.00 | 19.00 |
| Max | 9.00 | 4.00 | 7.00 | 20.00 | 9.00 | 9.00 | 10.00 | 28.00 |
| Mode | 5.00 | 4.00 | 3.00 | 13.00 | 7.00 | 9.00 | 6.00 | 20.00 |

Table A.6 Container Lead Time in 2016

| MONTH | BMS SBY (day) | | | | JYP SBY (day) | | | |
|---|---|---|---|---|---|---|---|---|
| | STF | ON BOARD | STR | Total | STF | ON BOARD | STR | Total |
| Jan | 4 | 2 | 1 | 7 | 8 | 10 | 4 | 22 |
| Feb | 3 | 2 | 3 | 8 | 8 | 10 | 5 | 23 |
| Mar | 2 | 2 | 4 | 8 | 9 | 10 | 6 | 25 |
| Apr | 4 | 2 | 2 | 8 | 8 | 10 | 3 | 21 |
| May | 4 | 2 | 2 | 8 | 10 | 10 | 5 | 25 |
| Jun | 3 | 2 | 5 | 10 | 10 | 10 | 9 | 29 |
| Jul | 3 | 2 | 5 | 10 | 8 | 10 | 3 | 21 |
| Aug | 5 | 2 | 6 | 13 | 5 | 10 | 10 | 25 |
| Sep | 2 | 2 | 5 | 9 | 6 | 10 | 2 | 18 |
| Oct | 3 | 2 | 5 | 10 | 4 | 10 | 9 | 23 |
| Nov | 5 | 2 | 2 | 9 | 8 | 10 | 5 | 23 |
| Dec | 5 | 2 | 2 | 9 | 4 | 10 | 7 | 21 |
| Average | 3.58 | 2.00 | 3.50 | 9.08 | 7.33 | 10.00 | 5.67 | 23.00 |
| Std. Dev | 1.08 | 0.00 | 1.68 | 1.56 | 2.10 | 0.00 | 2.61 | 2.80 |
| Min | 2.00 | 2.00 | 1.00 | 7.00 | 4.00 | 10.00 | 2.00 | 18.00 |
| Max | 5.00 | 2.00 | 6.00 | 13.00 | 10.00 | 10.00 | 10.00 | 29.00 |
| Mode | 3.00 | 2.00 | 2.00 | 8.00 | 8.00 | 10.00 | 5.00 | 23.00 |

Table A.7 Container Lead Time in 2016

| MONTH | SBY TTE (day) | | | | TTE SBY (day) | | | |
|---|---|---|---|---|---|---|---|---|
| | STF | ON BOARD | STR | Total | STF | ON BOARD | STR | Total |
| Jan | 5 | 8 | 9 | 22 | 8 | 8 | 9 | 25 |
| Feb | 7 | 8 | 7 | 22 | 7 | 8 | 7 | 22 |
| Mar | 5 | 8 | 6 | 19 | 7 | 8 | 6 | 21 |
| Apr | 6 | 8 | 5 | 19 | 6 | 8 | 5 | 19 |
| May | 8 | 8 | 7 | 23 | 6 | 8 | 7 | 21 |
| Jun | 8 | 8 | 7 | 23 | 5 | 8 | 9 | 22 |
| Jul | 7 | 8 | 6 | 21 | 6 | 8 | 7 | 21 |
| Aug | 6 | 8 | 8 | 22 | 6 | 8 | 8 | 22 |
| Sep | 5 | 8 | 5 | 18 | 4 | 8 | 6 | 18 |
| Oct | 7 | 8 | 5 | 20 | 7 | 8 | 6 | 21 |
| Nov | 6 | 8 | 7 | 21 | 6 | 8 | 7 | 21 |
| Dec | 5 | 8 | 7 | 20 | 5 | 8 | 7 | 20 |
| Average | 6.25 | 8.00 | 6.58 | 20.83 | 6.08 | 8.00 | 7.00 | 21.08 |
| Std. Dev | 1.14 | 0.00 | 1.24 | 1.64 | 1.08 | 0.00 | 1.21 | 1.73 |
| Min | 5.00 | 8.00 | 5.00 | 18.00 | 4.00 | 8.00 | 5.00 | 18.00 |
| Max | 8.00 | 8.00 | 9.00 | 23.00 | 8.00 | 8.00 | 9.00 | 25.00 |
| Mode | 5.00 | 8.00 | 7.00 | 22.00 | 6.00 | 8.00 | 7.00 | 21.00 |

Table A.8 Empty Container Initial Inventory Level

| Ports | Jan-16 (unit) |
|---|---|
| BMS | 166 |
| JYP | 463 |
| SDA | 106 |
| TIM | 396 |
| TTE | 166 |
| SBY | 501 |

# APPENDIX B

# SIMULATION DATA AND MODEL

Table B.1 Model Validation Parameter Table (cont'd)

| | **Inventory Level in JYP (unit)** | | **Inventory Level in SDA (unit)** | |
|---|---|---|---|---|
| Day | Simulation | Actual | Simulation | Actual |
| 3 | 432 | 2195 | 64 | 132 |
| 10 | 371 | 1730 | 1478 | 1360 |
| 24 | 236 | 2070 | 1660 | 1930 |
| 31 | 1206 | 1955 | 1916 | 1090 |
| 32 | 1523 | 1598 | 1949 | 1350 |
| 39 | 3673 | 1808 | 2312 | 1740 |
| 45 | 3829 | 1763 | 2672 | 1200 |
| 52 | 3992 | 1208 | 3066 | 1500 |
| 59 | 4172 | 1758 | 3384 | 1410 |

Table B.2 Model Validation Parameter Table

| | **Inventory Level in TIM (unit)** | | **Inventory Level in TTE (unit)** | |
|---|---|---|---|---|
| Day | Simulation | Actual | Simulation | Actual |
| 3 | 393 | 590 | 163 | 144 |
| 10 | 386 | 537 | 156 | 192 |
| 24 | 397 | 513 | 169 | 250 |
| 31 | 564 | 696 | 238 | 265 |
| 32 | 585 | 747 | 247 | 277 |
| 39 | 697 | 669 | 302 | 225 |
| 45 | 858 | 606 | 369 | 168 |
| 52 | 1036 | 749 | 447 | 235 |
| 59 | 1218 | 771 | 522 | 238 |

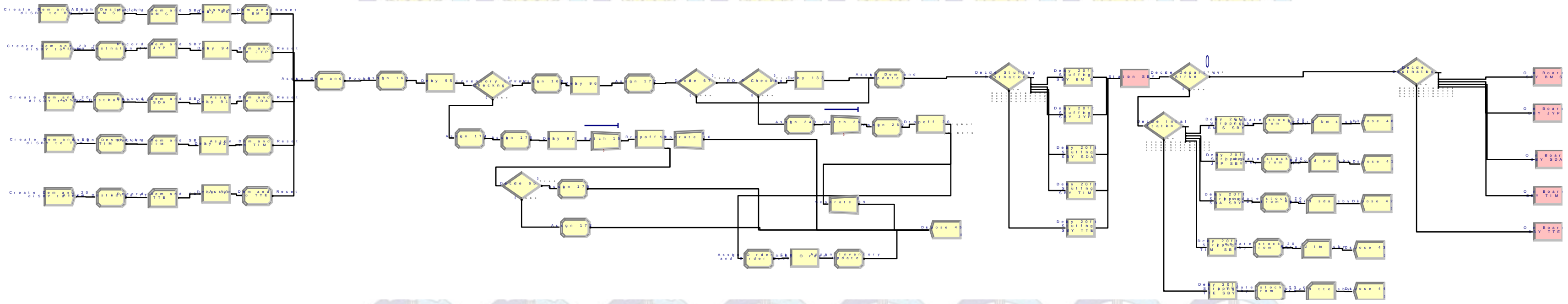


Figure B.1 Homebase Simulation Model

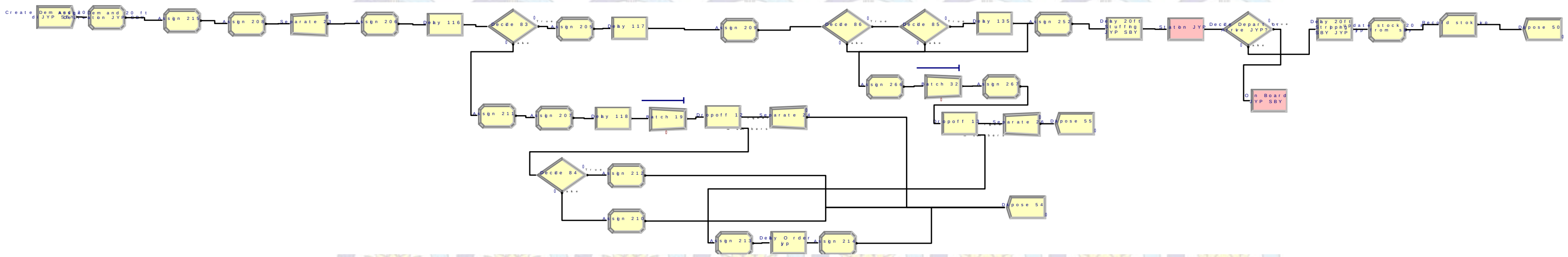
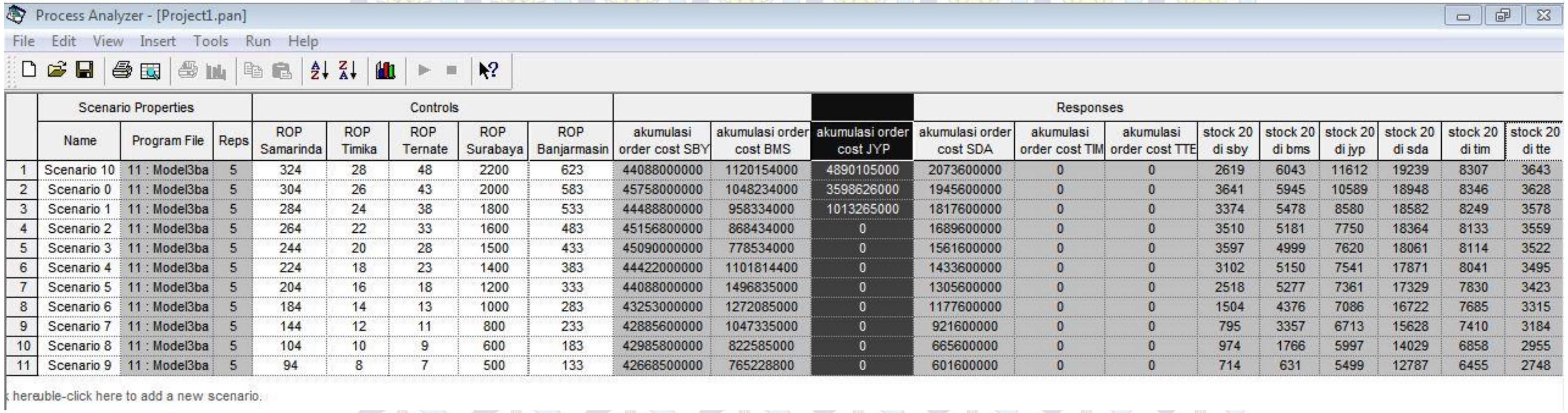


Figure B.1 Ports Simulation Model



Process Analyzer - [Project1.pan]

File Edit View Insert Tools Run Help

| | Scenario Properties | | | Controls | | | | |
|---|---|---|---|---|---|---|---|---|
| | Name | Program File | Reps | ROP Samarinda | ROP Timika | ROP Ternate | ROP Surabaya | ROP Banjarmasin |
| 1 | Scenario 10 | 11 : Model3ba | 5 | 324 | 28 | 48 | 2200 | 623 |
| 2 | Scenario 0 | 11 : Model3ba | 5 | 304 | 26 | 43 | 2000 | 583 |
| 3 | Scenario 1 | 11 : Model3ba | 5 | 284 | 24 | 38 | 1800 | 533 |
| 4 | Scenario 2 | 11 : Model3ba | 5 | 264 | 22 | 33 | 1600 | 483 |
| 5 | Scenario 3 | 11 : Model3ba | 5 | 244 | 20 | 28 | 1500 | 433 |
| 6 | Scenario 4 | 11 : Model3ba | 5 | 224 | 18 | 23 | 1400 | 383 |
| 7 | Scenario 5 | 11 : Model3ba | 5 | 204 | 16 | 18 | 1200 | 333 |
| 8 | Scenario 6 | 11 : Model3ba | 5 | 184 | 14 | 13 | 1000 | 283 |
| 9 | Scenario 7 | 11 : Model3ba | 5 | 144 | 12 | 11 | 800 | 233 |
| 10 | Scenario 8 | 11 : Model3ba | 5 | 104 | 10 | 9 | 600 | 183 |
| 11 | Scenario 9 | 11 : Model3ba | 5 | 94 | 8 | 7 | 500 | 133 |

| | | Responses | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Name | akumulasi order cost SBY | akumulasi order cost BMS | akumulasi order cost JYP | akumulasi order cost SDA | akumulasi order cost TIM | akumulasi order cost TTE | stock 20 di sby | stock 20 di bms | stock 20 di jyp | stock 20 di sda | stock 20 di tim | stock 20 di tte |
| 1 | Scenario 10 | 44088000000 | 1120154000 | 4890105000 | 2073600000 | 0 | 0 | 2619 | 6043 | 11612 | 19239 | 8307 | 3643 |
| 2 | Scenario 0 | 45758000000 | 1048234000 | 3598626000 | 1945600000 | 0 | 0 | 3641 | 5945 | 10589 | 18948 | 8346 | 3628 |
| 3 | Scenario 1 | 44488800000 | 958334000 | 1013265000 | 1817600000 | 0 | 0 | 3374 | 5478 | 8580 | 18582 | 8249 | 3578 |
| 4 | Scenario 2 | 45156800000 | 868434000 | 0 | 1689600000 | 0 | 0 | 3510 | 5181 | 7750 | 18364 | 8133 | 3559 |
| 5 | Scenario 3 | 45090000000 | 778534000 | 0 | 1561600000 | 0 | 0 | 3597 | 4999 | 7620 | 18061 | 8114 | 3522 |
| 6 | Scenario 4 | 44422000000 | 1101814400 | 0 | 1433600000 | 0 | 0 | 3102 | 5150 | 7541 | 17871 | 8041 | 3495 |
| 7 | Scenario 5 | 44088000000 | 1496835000 | 0 | 1305600000 | 0 | 0 | 2518 | 5277 | 7361 | 17329 | 7830 | 3423 |
| 8 | Scenario 6 | 43253000000 | 1272085000 | 0 | 1177600000 | 0 | 0 | 1504 | 4376 | 7086 | 16722 | 7685 | 3315 |
| 9 | Scenario 7 | 42885600000 | 1047335000 | 0 | 921600000 | 0 | 0 | 795 | 3357 | 6713 | 15628 | 7410 | 3184 |
| 10 | Scenario 8 | 42985800000 | 822585000 | 0 | 665600000 | 0 | 0 | 974 | 1766 | 5997 | 14029 | 6858 | 2955 |
| 11 | Scenario 9 | 42668500000 | 765228800 | 0 | 601600000 | 0 | 0 | 714 | 631 | 5499 | 12787 | 6455 | 2748 |

hereuble-click here to add a new scenario.

Figure B.3 Process Analyzer Output

**(This page is intentionally left blank)**

# AUTHOR'S BIOGRAPHY

The author, Didin Dwi Novianto, was born in Mojokerto on 8th November 1993. As the middle child of Bapak Tukino and Mamah Nurgiati, author went to SDN Magersari I Kota Mojokerto (2000-2006) and continued to SMPN 1 Kota Mojokerto (2006-2009). For high school, the author completed the study in SMAN 1 Sooko, Mojokerto (2009-2013). During high school years, the author was actively involved in school organization (OSIS). The author also represented Indonesia as a delegate to participate in Youth Exchange and Study (YES) program sponsored by the US Department of State. The author went to Columbia River High School, Vancouver, Washington State (2011-2012) as a senior year student where he intensely learnt English. After returning home and finishing his high school, the author applied for Bidikmisi scholarship and passed as a student in Industrial Engineering Department, Institut Teknologi Sepuluh Nopember (ITS) Surabaya.

As a college student, the author had actively engaged in several communities and interests. The author volunteered in several organizations, Bina Antarbudaya Surabaya (2013-2017) and ITS International Office (2015-2016). The author was also an active member of Badminton Club (2013-2017) in his department. In his third semester, the author participated in an exchange program to Universiti Tekninal Malaysia Melaka (UTeM). After returning to home country, the author contributed to academic and industrial issues more extensively by becoming an assistant of Logistics and Supply Chain Management (LSCM) Laboratory where he helped the faculty members in laboratory activities for students and industrial practitioners (2016-2017). With his interest in Logistics and Supply Chain Management field, the author was an intern at 2 companies, PT IPMOMI Paiton Probolinggo in Warehouse Division and PT Salam Pacific Indonesia Lines (SPIL) Surabaya in Container Inventory Control (CIC) Division. For further discussion, the author can be reached through email *didin.novianto@gmail.com*.

**(This page is intentionally left blank)**