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MODEL SIMULASI UNTUK MENENTUKAN KAPASITAS KILANG: STUDI KASUS PT. PERTAMINA (PERSERO)

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SIMULATION MODEL TO DETERMINE REFINERY CAPACITY: CASE STUDY OF PT. PERTAMINA (PERSERO)

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MODEL SIMULASI UNTUK MENENTUKAN KAPASITAS KILANG: STUDI KASUS PT. PERTAMINA (PERSERO)

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ABSTRAK

PT. Pertamina (Persero) telah menyiapkan rencana kerja untuk tahun 2015. Terdapat lima fokus utama yang akan dilakukan dalam rangka membuat perusahaan menjadi lebih baik. Salah satunya adalah dengan meningkatkan kapasitas kilang akibat dari permintaan yang tinggi dan terbatasnya kapasitas kilang. Penelitian ini dirancang untuk menentukan berapa kapasitas kilang baru yang paling baik untuk mengoptimalkan *service level* dengan biaya investasi yang paling minimum. Penelitian ini mengembangkan model simulasi transportasi dan distribusi BBM (bahan bakar minyak) dengan menggunakan kapal dan pipa di daerah Jawa. Sistem ini terdiri dari dua kilang tempat di mana BBM dibuat dan terdiri dari tempat penyimpanan (*storage*) di setiap depot yang dituju. Terdapat tiga skenario yang dilakukan dalam penelitian ini yaitu skenario 0 *existing condition*, skenario 1 *moderate demand increase* dan skenario 2 *high demand increase*. *Service level* dan biaya investasi di evaluasi pada setiap skenario. Hasil dari penelitian menunjukkan bahwa kapasitas kilang yang lebih tinggi bisa menaikkan *service level* yang lebih tinggi dan biaya investasi yang lebih tinggi juga. Penelitian ini membawa rekomendasi penting bagi perusahaan untuk membangun kilang baru dengan keputusan terbaik berdasarkan tiga skenario. Hasil penelitian menunjukkan bahwa skenario yang paling baik untuk dipilih adalah skenario 2 dengan kapasitas 730 KBPD.

Kata Kunci**: Bahan Bakar Minyak, Kapasitas Kilang, Simulasi Diskrit, Simulasi Arena.**

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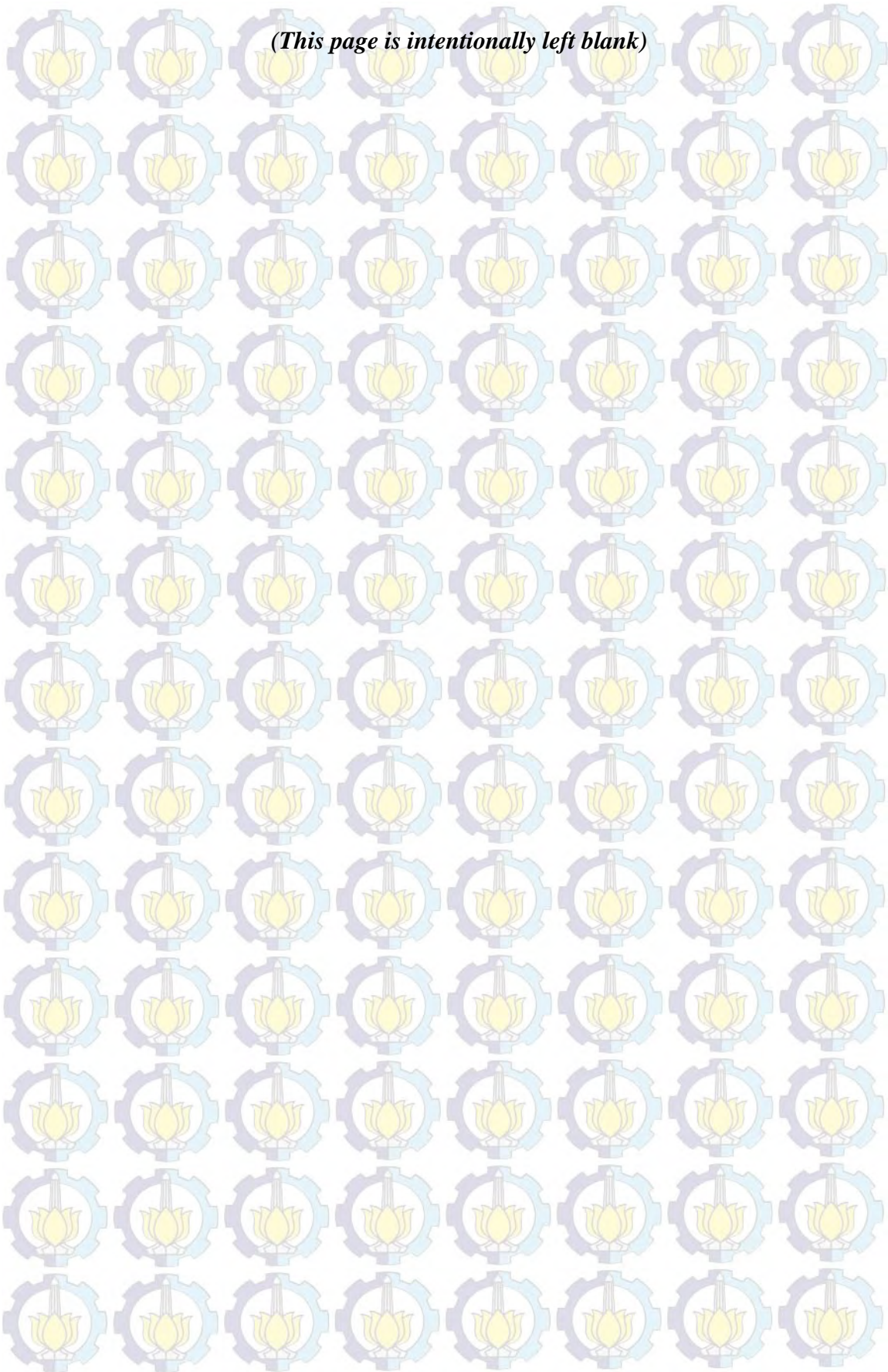
SIMULATION MODEL TO DETERMINE REFINERY CAPACITY: CASE STUDY OF PT. PERTAMINA (PERSERO)

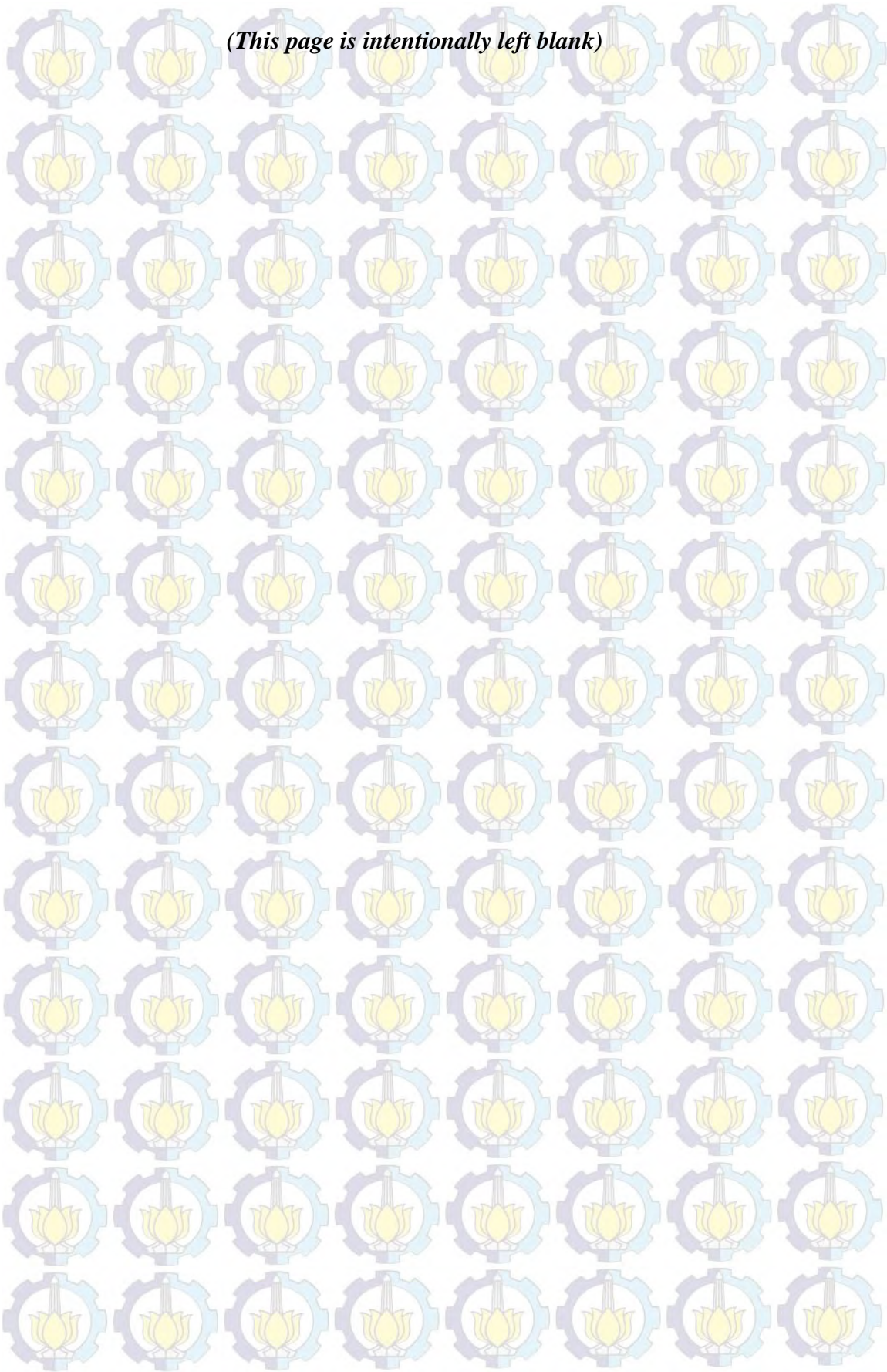**Name**   : Nesya Amalia
NRP   : 2511100175
Supervisor   : Prof. Ir. I Nyoman Pujawan, M. Eng., Ph.D., CSCP.

ABSTRACT

PT. Pertamina (Persero) has prepared a work plan in 2015. There were five main focuses that would be done in order to make the company better. One of them is increasing refinery capacity due to high demand and the limitation of refinery capacity. This paper is designed to determine the best integrated decisions of the new refineries capacity to optimize service level with minimum investment cost. This research develops a simulation model that represent the transportation and distribution of fuel products by the use of ships and pipeline in Java. The system consists of two refineries where the fuel products is made and storage at each depot destinations. Three scenarios related to refinery capacity is conducted. They are scenario 0 as existing condition, scenario 1 as moderate demand increase and scenario 2 as high demand increase. Each scenario is evaluated in terms service level and investment costs. The results suggest that higher refinery capacity can reach higher service level and higher investment costs as well. This paper brings an important recommendation to the company for building new refinery with the best decision based on three scenarios. The result shows that scenario chosen is scenario 2 with capacity 730 generates the best service level and financial performance.

Keywords**:** *Fuel Products, Refinery Capacity, Discrete Simulation, Arena Simulation.*

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ACKNOWLEDGEMENT

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CHAPTER I

INTRODUCTION

In this chapter, the background, problem formulation, research objectives, research benefits, limitations, assumptions, and the report outline are explained in detail to give an overview about the nature of the research.

1.1 Background

In the end of 2014, PT. Pertamina (Persero) has prepared a work plan in 2015. There were five main focuses that would be done by PT. Pertamina (Persero) in order to make the company better. President Director of PT. Pertamina (Persero), Dwi Sutijipto, stated that there were at least two main functions that must be executed. As a corporation, PT. Pertamina (Persero) must grow and develop, improve revenue, and improve profit aligned with other world class oil and energy companies and as the spearhead of national energy provider, PT. Pertamina (Persero) should be brought to the security and sovereignty of energy better (Energia, 2015). In order to realize the main function, Mr. Dwi Sutijipto launched five major strategies. First, PT. Pertamina (Persero) is the mastery of oil fields and gas in the country. PT. Pertamina (Persero) had to fight furiously to take over the blocks that have been out of contract. PT. Pertamina (Persero) should be aggressively developing business in upstream, because approximately 90% of the profit comes from PT. Pertamina (Persero)'s upstream business. Second, PT. Pertamina (Persero) needs to minimize cost with the help of shorten all the business chain process through re-engineering, re-structuring and if necessary do the re-organization in downstream business as well. Third is increasing the capacity of the refineries. With the condition of old refineries, PT. Pertamina (Persero) still has to determine about how refineries can be economical, since the refineries production must be cheaper than imports. Fourth is infrastructure development, especially retail infrastructure. To make sure that all of gas stations are joining strong bond contract with PT. Pertamina (Persero). With subsidy policy removal, allowing foreign competitors invade fuel retail market. Fifth it is rescuing cash flow. It is

simply not only talking about revenue and profit but PT. Pertamina (Persero) also talking about its cash flow (Energia, 2015).

Division of Supply and Distribution (S&D) under Directorate of Marketing and Trading (M&T) PT. Pertamina (Persero) is a division that performs operation reception, stockpiling, and distribution of fuel to meet the public needs across Indonesia. Generally, S&D division is in charge of providing the fuel needs properly at the amount, quality, time, and appropriate place. Besides, they are responsible for the fuel supply in Indonesia. Though Indonesia maintains lower level of crude oil or finished fuel stock compared to neighboring countries (Korea, Japan, Australia, Taiwan, Vietnam, and Thailand), PT. Pertamina (Persero) has been serving the nation about 60.000.000.000 litres fuel distributed annually and about 241.000.000 people to be served all around Indonesia (Infrastructure M&T, 2014). In order to fulfill the demand, PT. Pertamina (Persero) has two sources, those are local fuel from refineries and import fuel. Based on the work plan described above, This research focuses on the third plan which is increasing the capacity of the refineries since there is a fuel products deficit due to increasing demand. According to the data from M&T PT Pertamina (Persero), The following picture shows the graphs of amount of the increasing demand and availability of fuels in refineries.
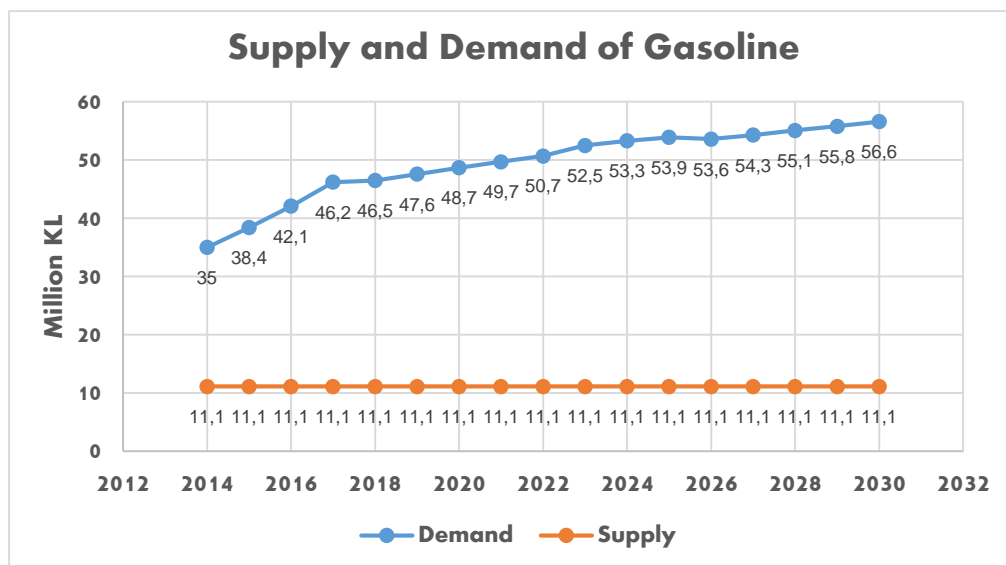
Figure 1.1 Supply Demand Review of Gasoline Product until 2030 (Pertamina, 2014)

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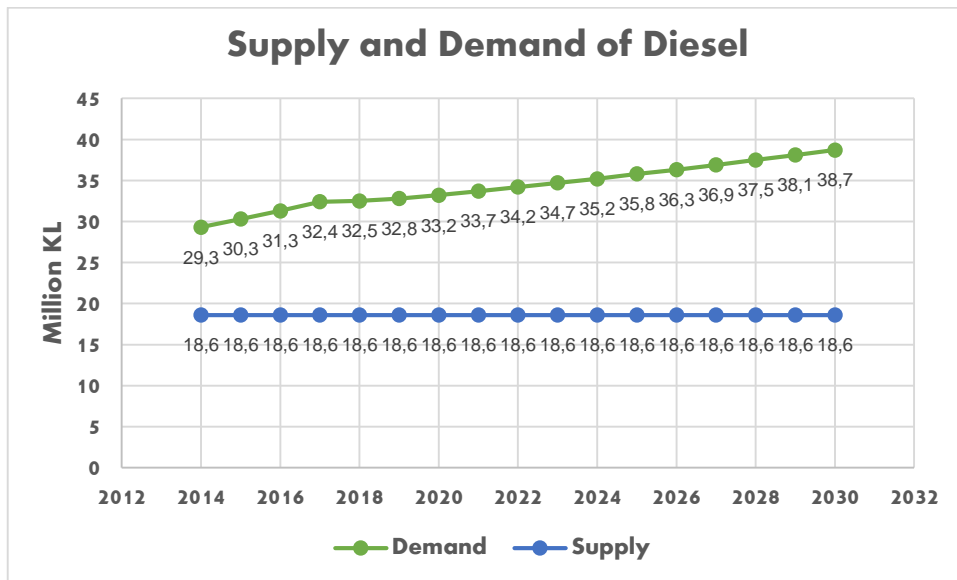
Figure 1.2 Supply Demand Review of Diesel Product until 2030 (Pertamina, 2014)

From figure 1.1 and 1.2, the demand is expected to increase significantly. ±60% of fuel products is distributed to Java that will soon be main location of deficit (Team Analysis Pertamina, 2015). PT Pertamina (Persero) certainly can not fulfill the demand only by local fuel from refineries, but the company must also import the fuel products more than the company itself can produce. Besides, every month, PT Pertamina (Persero) has limited quota for purchasing import product. Based on those conditions, PT. Pertamina (Persero) needs to add volumes by adding new infrastructure (refinery) due to increasing demand and storage limitation. PT. Pertamina (Persero) has the most complicated and the most sophisticated distribution pattern in the world (infoindo.web.id, 2014). The company has 120 depots, 7 refineries, 135 ships, 13.000 islands to be served, and 60% volume transported by ships. To see the pattern in detail, the following picture explains about fuel distribution pattern in PT. Pertamina (Persero).

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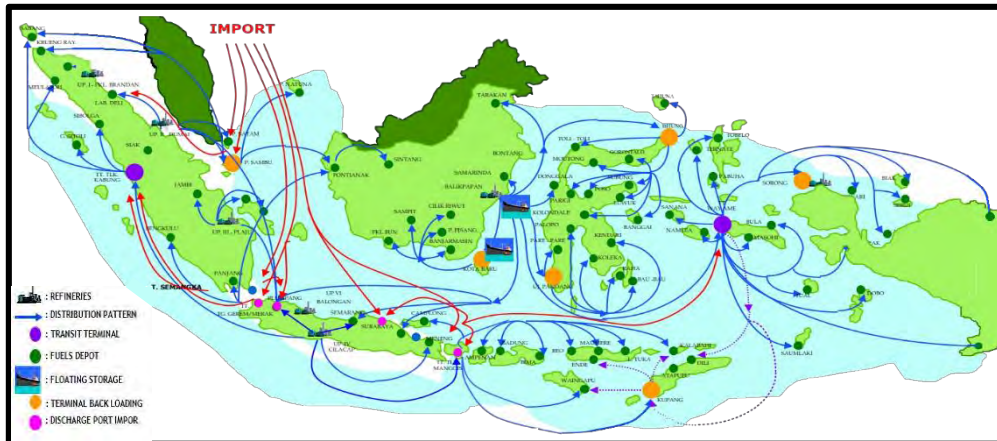
Figure 1.3 National Fuel Supply Pattern (Pertamina, 2014)

From the explanation above, the purpose of this research is to determine the best integrated decisions of the new refineries capacity to optimize service level with the help of simulation. This research builds a simulation based model to get information how the decision will behave without actually executing in the real life to make PT. Pertamina (Persero) has an integration to maximize synergies required to build a competitive downstream business.

1.2   Problem Formulation

In the presence of the high demand and the limitation of refineries capacity which is Java will be main location of deficit, PT. Pertamina (Persero) needs to build new infrastructure (adding volume of refinery) to reduce import products. this research is designed to determine the best integrated decisions of the new refineries capacity to optimize service level.

1.3   Research Objectives

This research aims at two objectives, i.e.:

1. To determine the best capacity of the new refinery
2. To evaluate the impact of the new refineries capacity in service level and investment cost

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1.4 Research Benefits

The benefits that could be achieved through the research are:

- To obtain the best combination of refineries capacity
- To know the impact of the new refineries capacity in service level and investment costs

1.5 Research Scope

The scope of the research includes the limitations and the assumptions of the research which is explained as follows.

1.5.1 Limitations

The limitations of the research are:

- The refineries that will be researched are in Java: Refinery unit IV (Balongan) and Refinery unit VI (Cilacap).
- Specific product observed from PT. Pertamina (Persero) is fuel only (Premium,Pertamax, Pertamax Plus, and Diesel) since it is one of the biggest demand for the company.

1.5.2 Assumptions

The assumptions of the research are:

- Inventory movement, including depot replenishment, loading and unloading, occurs in 24-hour time basis.
- All processes, including shipping assignment, loading, and unloading can be done during weekends.
- After departure from refineries, each ships will directly go to depot.
- Further assumptions used in this research will be discussed in Chapter 4.

1.6 Report Outline

Steps that will be taken to create the report are:

1. Chapter 1 contains the basic knowledge of the research about the background, objectives, benefits, research scope, and report structure.

2. Chapter 2 conducts literature review. This chapter discusses the basic theory about the object, methods, and other additional knowledge that will be used in the research.

3. Chapter 3 presents how the author will do the research. This chapter clarifies the methodology used in the research.

4. Chapter 4 presents the data collection and processing. This chapter elaborates the data and processes it to the final result that later will be analyzed.

5. Chapter 5 gives a deep analysis about the data processed before. The analysis leads the author to the conclusion of the problems.

6. Chapter 6 presents the conclusion of the research along with the suggestions.

CHAPTER II
LITERATURE REVIEW

This chapter describes theories and concepts based on existing literatures that have been developed and are used as basis of this research. Theories and concepts provided in this chapter are logistics management, distribution management, transportation management, inventory, pipeline, simulation and hypothesis testing.

2.1 Logistics Management

Logistics management is a part of supply chain process that plans, implements, and controls the efficient, effective flow and storage of goods, services, and related information from point of origin to the point of consumption in order to meet costumer's requirement (Ballou, 2003). Business logistics is comprised of physical supply (from supplier until manufacturer) and physical distribution (from manufacturer until customers).

To answer the question of the number, size, and location of facilities in a company's distribution system is really complex. As noted by Rushton, Croucher, and Baker (2010), there are many different elements that go to make up the distribution mix, and it is necessary to take into account all of these when considering the question of network structure of facilities location. It is really important for companies to know how their distribution networks might be improved.

PT Pertamina (Persero) has a complicated business logistics because the company should fulfill the national demand all around Indonesia. To describe in details, the following picture show the business logistics of supply and distribution PT Pertamina (Persero).
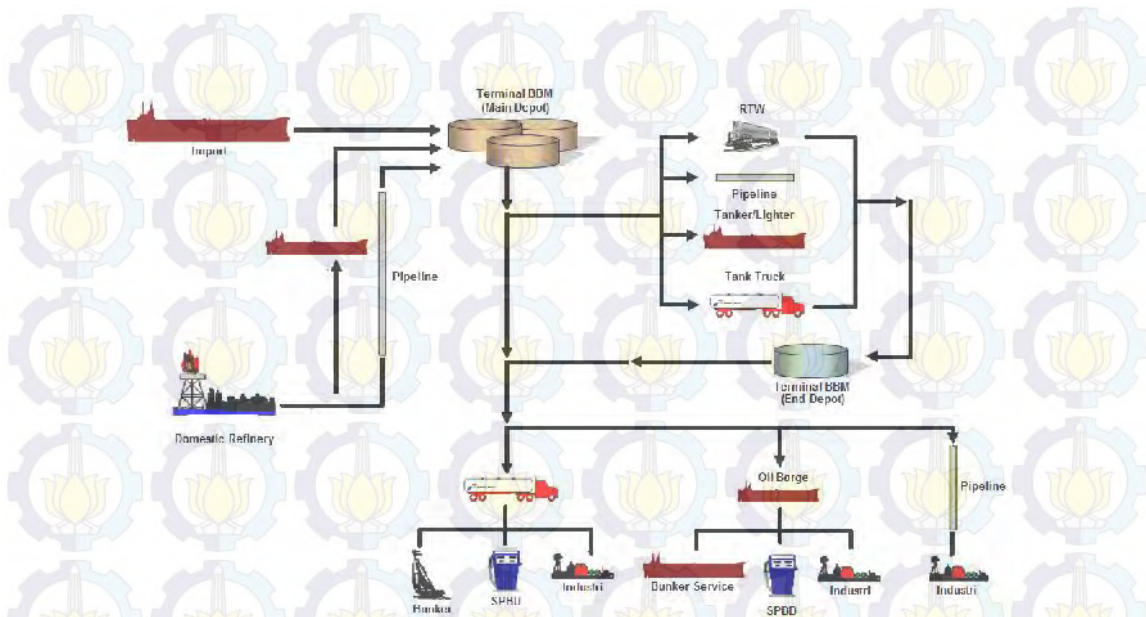
Figure 2.1 Business logistics Supply and Distribution PT Pertamina (Persero)
(Pertamina, 2014)

PT Pertamina (Persero) has two sources; import and domestic refineries. The company distributes the product to the primary depot (main depot) by tanker and pipeline. The primary depot is located in the main area to distribute the product to the end depot located in the smaller area. The company uses four types of transportation to distribute the products to the end depot. They are RTW (train), pipeline, tanker (ship), and tank truck. From the end depot, PT Pertamina (Persero) still has responsibility to distribute the products to bunker, SPBU (gas station), Industry with three transportation; tank truck, oil barge and pipeline.

2.2   Transportation Management

Transportation refers to the movement of products from one location to another as it makes its way from beginning of a supply chain to the ultimate consumer. Transportation plays a key role because products are rarely produced and consumed in the same location and also transportation is a significant component of the cost most supply chain incur. There are two key players in any transportation that take place within a supply chain. The shipper, the party that requires the movement of the product between two points in the supply chain. The carrier, the party that transports the products. In making transportation decisions, factors to be considered varied depending on whether one takes the perspective of a carrier or

shipper. A carrier makes investment decision according to the transportation infrastructure (rails, trucks, ship, etc) and then makes operating decisions to try to maximize the return from these assets. In the other hand, the shipper uses transportation to minimize the total cost (transportation, inventory, information, and facility) while providing an appropriate level of responsiveness to the customer.

2.3   Inventory

Inventory is the stock of any item or resource used in an organization or company. Inventory represent a key economic factor to all organization. The control and the maintenance of inventory is a problem common. Inventory exist because supply and demand are difficult to synchronize perfectly. For many reasons, supply and demand many times differ in the rates at which they respectively provide and require stock. The reason is explained by four functional factor of inventory; time, discontinuity, uncertainty, and economy. Time factor involves the long process of production and distribution required before goods reach the final consumer. The discontinuity factor allows the treatment of various dependent operations such as retailing, distirbuting, warehousing, manufacturing, and purchasing in an independent and economical manner. The uncertainty factor concerns unforseen events that modify the original plans of the organization. The economy factor permits the organization to take advantage of cost reducing alternatives.

Based on its utility, all inventory can be placed in one or more. The categories are working stock, safety stock, anticipation stock, pipeline sock, decoupling stock and psychic stock.

- Working Stock

    Also known as cycle or lot size stock is inventory acquired and held in advance of requirements so that ordering can be done on a lot size rather than on an as needed basis. Lot sizing is done in order to minimize ordering and holding costs, achive quantity discounts, or qualify for favorable freight rates (Tersine, 1994).

- Safety Stock

    Usually called buffer or fluctuation stock is inventory held in reserve to protect against the uncertainties of supply and demand. Safety stock

average out to the amount of stock held during a replenishment cycle as a protection against stockouts (Tersine, 1994).

- Anticipation Stock

Also known as seasonal or stabilization stock is inventory buit up to cope with peak seasonal demand, eratic requirements (promotional programs, strikes, or vacation shutdowns), or deficiencies in production capacity.it is supply or produced in advance of requirements and depleted during peak demand periods to keep production rates level and stabilize the work force (Tersine, 1994).

- Pipeline Stock

Often reffered to as transit stock or work-in-process is inventory put in transit to allow for the time it takes to receive material at the input end, send material through the production process, and deliver goods at the output end. Externally, pipeline stock is inventory on trucks, and railcars or in a literal pipeline. Internally, it is being processed, waiting to be processed, or being moved (Tersine, 1994).

- Decoupling Stock

Is inventory accumulated between dependent activities or stages to reduce the requirement for ocmpletely synchronized operations. It isolates one part of the system from the next to allow each to operate more independently. Thus, it acts as a lubrication for the supply-production-distribution system that protects it againts excessive friction (Tersine, 1994).

- Psychic Stock

Is retail display inventory carried to stimulate demand and act as a silent salesperson. It increases the chance an item is seen and considered for purchase. Full shelves increase sales by exposing customers to as much stock as possible and creating greater product visibility. Understocked shelves as well as stockouts can lead to lost sales and lost customers. While other stock categories support low cost operations, psychic stock is a revenue generating category. It is concerned with revenue generation via

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demand creation versus cost minimization which is supply oriented (Tersine, 1994).

2.4   Pipeline

Pipeline is used primarily for the transport of crude petroleum, refined petroleum products, and natural gas (Chopra, 2006). Setting up the pipeline is the biggest initial fixed cost. Pipeline operations are typically optimized at about 80-90 percent of pipeline capacity. Pipeline are best suited when relatively stable and large flows are required. Pipeline may be an effective way of getting crude oil to a port or refinery. Sending gasoline to a gas station doesn not justify invesment in a pipeline and is done better with a truck. Pipeline pricing usually consists of two components. There are fixed component (related to the shipper's peak usage) and a second charge (related to the actual quantity transported). This pricing structure push the shipper to use the pipeline for the predictable component of demand with other modes often being used to cover fluctuations.

PT Pertamina (Persero) uses pipeline as a transportation of fuel products product. In java, the company uses pipeline from RU Balongan and RU cilacap. This pipeline track can be seen in the map (blue line) of figure 2.2. To see the the pipeline in detail, This is illustrated in Figure 2.3.

Figure 2.2 Pipeline In Java (Pertamina, 2014)

As seen in figure 2.2, PT Pertamina (Persero) has pipeline at cilacap to bandung, cilacap to yogyakarta, and balongan to jakarta.

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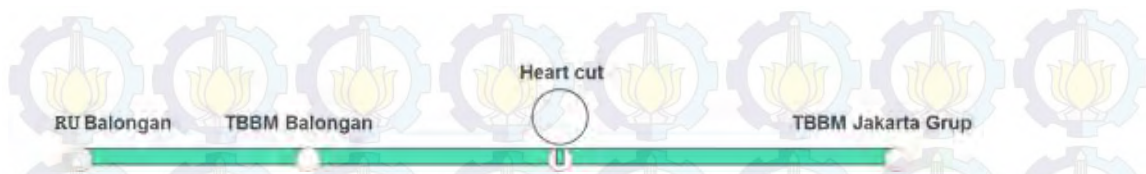
Figure 2.3 Pipeline (Pertamina, 2014)

From figure 2.3, a part of pipeline, heart cut, is a part of pipeline which the fuel terminal gains the pure petroleum products.

2.5   Simulation

Simulation is a method to mimic the behaviour of real system using computer software. Over the last twoor three decades, simulation has been consistenly reported as the most popular operation research tool (Kelton, et al., 2006). Shannon, Long, and Buckles (1980) surveyed members of the Operations Research Division of the American Institute of Industrial Engineers (now the institute of Industrial Engineers) found that among the tools listed, simulation ranked first in utility and interest. Simulation was second in familiarity, behind linear programming, which might suggest that simulation should be given stronger emphasis in academic curricula. The main reason for simulation's popularity is its ability to deal with very complicated models of complicated systems. This makes simulation a powerful tool. Another reason is the cost effectiveness.

There are different kinds of simulations by its characteristics. Static and dynamic based on stationarity of its parameter; continuous and discrete by the occurence of event; and deterministic and stochastic by randomness of parameter. In this research, the problem will be simulated by discrete condition because the variable and attributes needed to be analyzed only when an event occurs. This characterized the problem as discrete event simulation. Simulation needs verification and validation step before deployed to evaluate scenarios like other system modeling. Verification is conducted to ensure that the model is made in accordance with the logic and process flow by how it is expected. Validation is conducted to ensure that model is made in accordance with the real conditions of the observing field (Kelton, et al., 2006).

The working simulation tool for the research is Arena. Arena is a simulation environment consisting of module templates, built around SIMAN

(name of system modeling corporation) language constructs and other facilities, and augmented by a visual front end. Arena provides a module-oriented simulation environment to model practically any scenario involving flow of transactions (discrete or continuous) among a set of processes (Altiok, 2007).

2.6   Hypothesis Testing

Hypothesis testing or significance testing is a method for testing a claim or hypothesis about a parameter in population using data measured in a sample (Gravetter & Wallnau, 1996). In this j method, some hypothesis tested by determining the likelihood that a sample statistic could have been selected, if the hypothesis regarding the population were true. The goal of hypothesis testing is to determine the likelihood that a population parameter, such as the mean is likely to be true. When running a simulation model, it is necessary to determine whether any factor significantly affect the output. If there are only two scenarios, a hypothesis testing can be performed by determining whether two means of variances of different population is different from each other. Hypothesis testing will be conducted in validation test. Since the sample is quite small due to data availability constraints, a t-test is conducted.

Simulation were conducted to determine the statistical power and Type I error rate of the one sample and two-sample t-tests (Winter, 2013). If the t-stat value falls between the interval of –t to +t obtained from t-student distribution table under desired confidence level, the null hypothesis is accepted (Arief, 2014).

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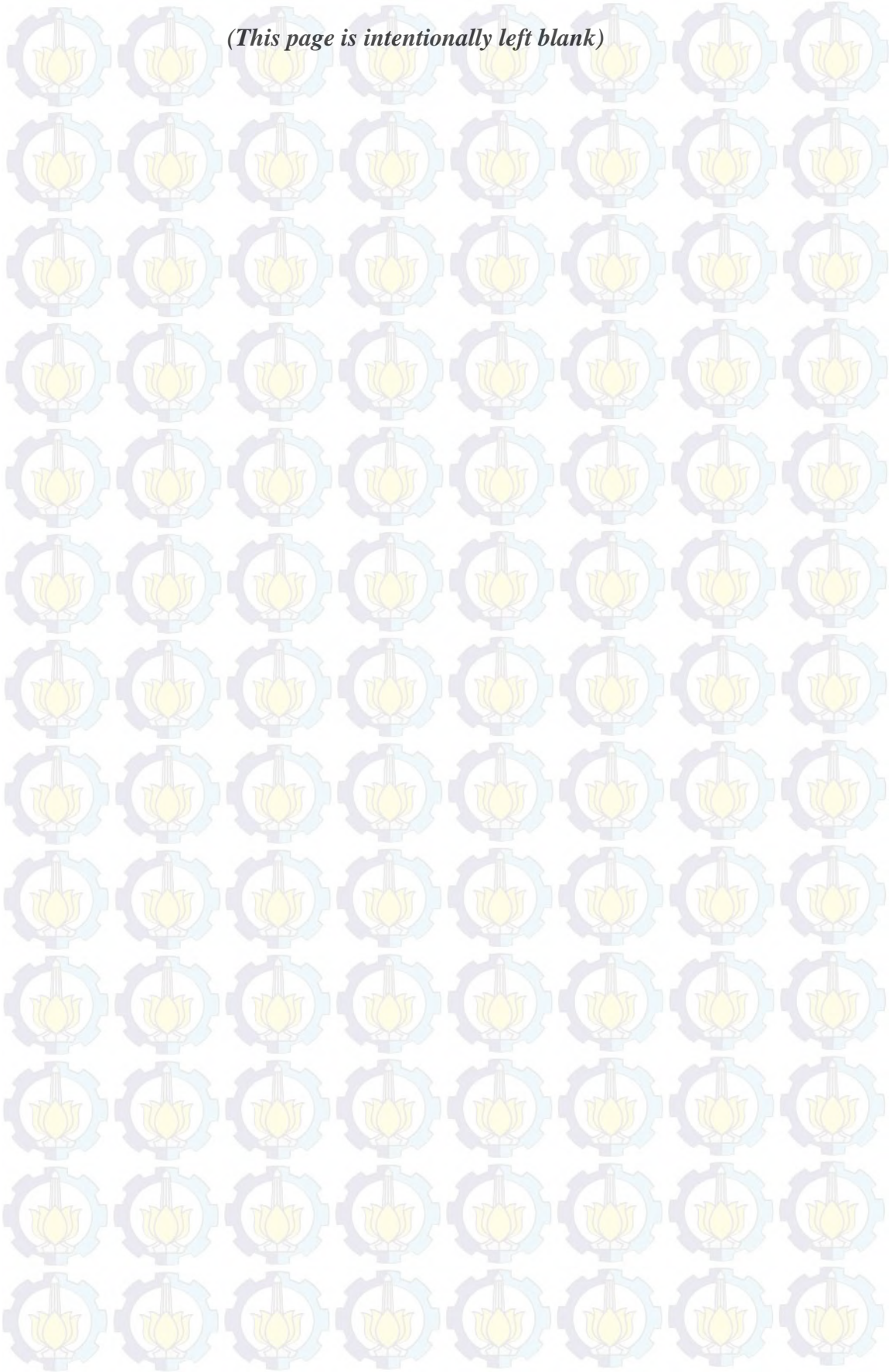
CHAPTER III

RESEARCH METHODOLOGY

In this chapter, the methodology of the research is determined. This chapter provides explanation of how the research is conducted.

3.1 Flowchart of Methodology

The methodology is a framework that guides the author how to do the research. The flowchart is shown as follows.
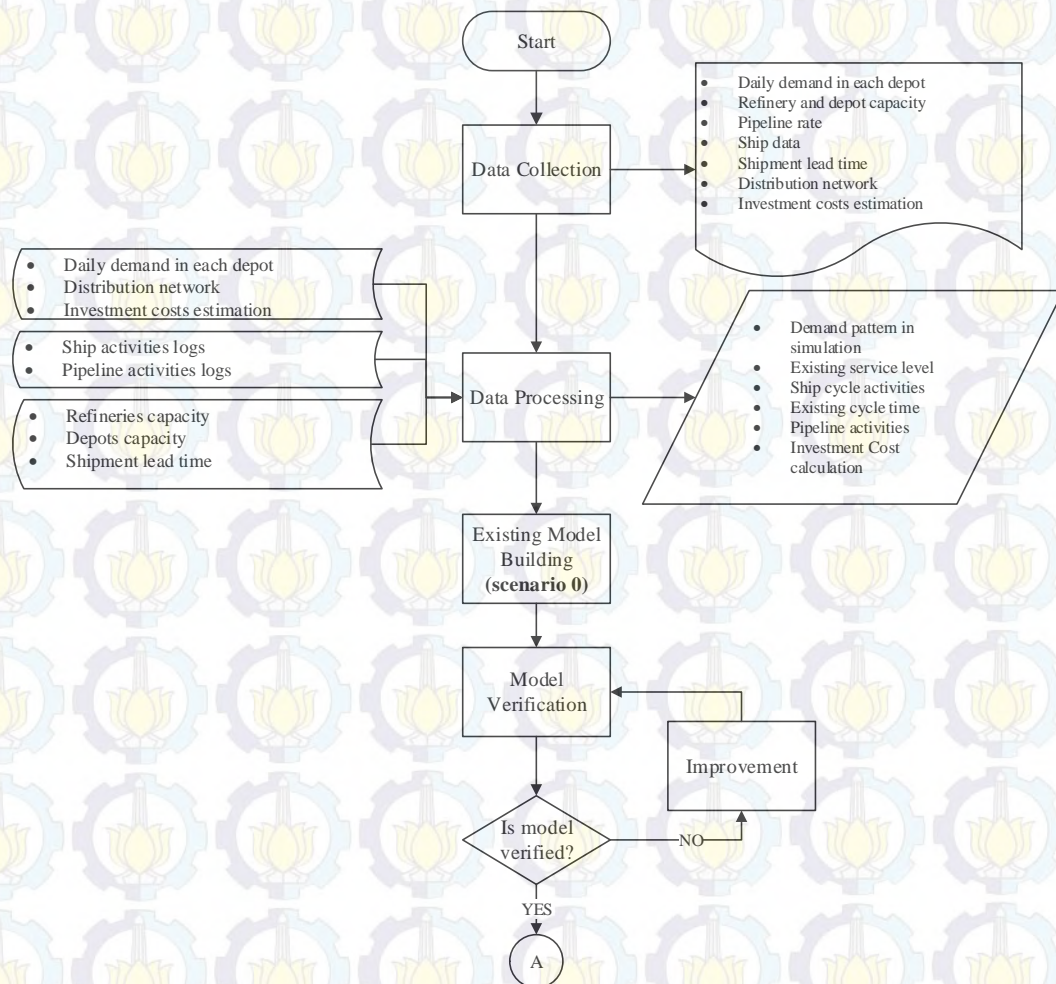
Figure 3.1 Flowchart of Methodology
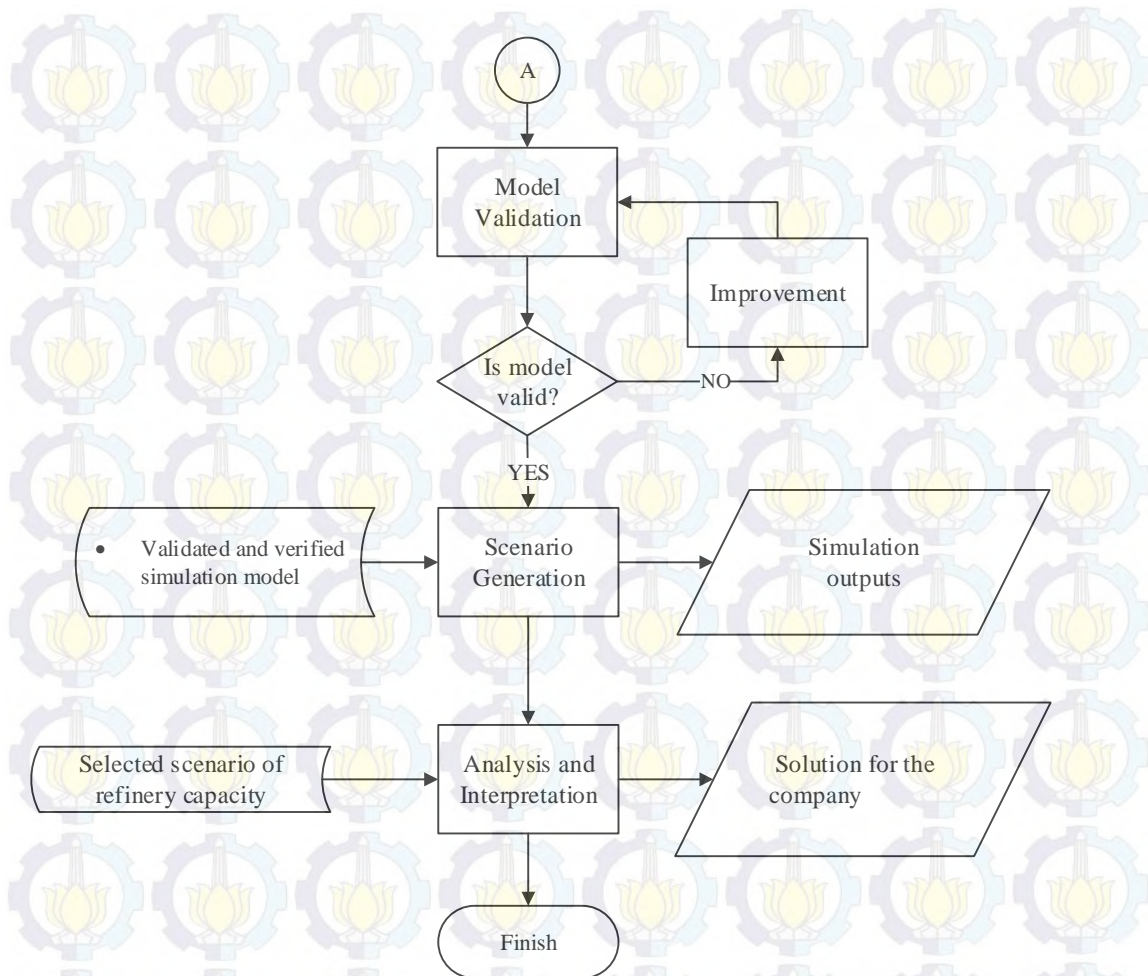
Figure 3.1 Flowchart of Methodology (con't)

3.2 Flowchart Explanation

From the flowchart above, this research could be deployed to five steps which are data collection, data processing, verification and validation, scenario generation, analysis and interpretation. Deeper explanation would be done in the subchapters below.

3.2.1 Data Collection Step

This step is to obtain the real data to get the real fuel products distribution system. All data are obtained from Supply and Distribution (S&D) division under Directorate of Marketing and Trading PT. Pertamina (Persero). Daily demand, refinery and depot capacity, pipeline rate, ship data, shipment lead time, distribution network, and investment cost estimation are collected in this research.

3.2.2 Data Processing Step

The step after collecting data is data processing. In this step, obtained data such as daily demand, ship and pipeline activities logs, distribution network, and investment cost estimation are processes to get parameters for the existing condition in order to build the simulation model. The distribution fit is obtained by a goodness of fit test using ARENA Input Analyzer to determine the best fit distribution to the data. The pattern will be used as an input parameter in simulation. Other parameters like cycle time and service level will be used to the validation step.

The existing condition simulation is conducted by making simulation that represent the real distribution condition at PT Pertamina (Persero). Simulation is made by Arena 14. The following figure shows the flow process of fuel products distribution from refinery to the primary depot.
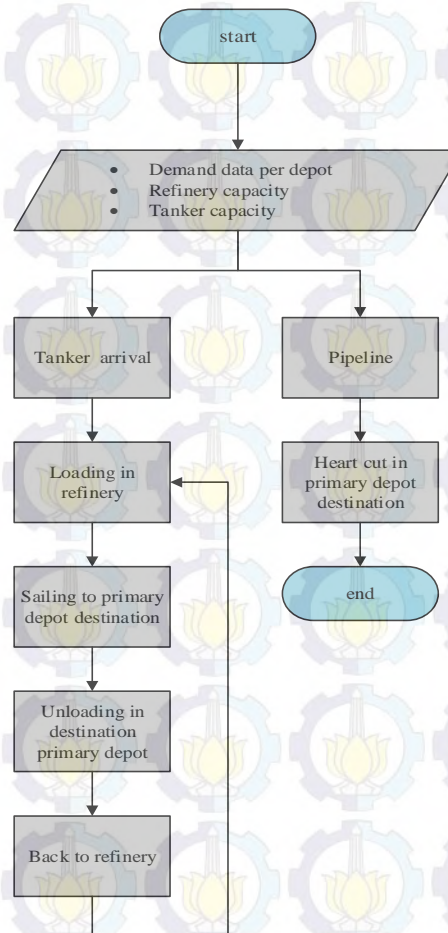
Figure 3.2 The Main Conceptual Model in Existing Condition

Besides the main conceptual model for the existing fuel products distribution condition, there is supporting model for ship activities cycle. The following figure shows the flow process for the ship activities in existing condition.
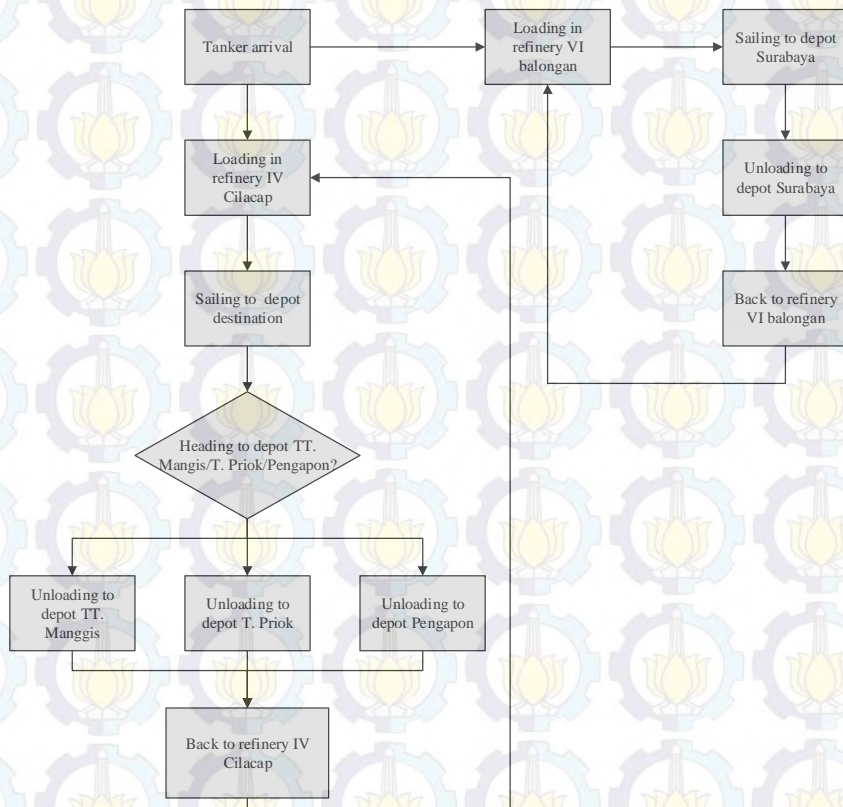
Figure 3.3 The Conceptual Model of Ship Activities in Existing Condition

3.2.3 Verification and Validation Step

All input parameters are obtained and the next step is to build the simulation model itself. By combining input parameters, daily demand in each region pattern, refinery and depot capacity, ship and pipeline activities logs, and fuel products distribution network, an ARENA simulation model is built. By simulating the system with all its uncertainties, the integrated decision on storage and distribution can be checked out to make the system more effective and efficient. However, to make it to do so, a verification and validation model is required.

Verification model is conducted to ensure that the model implementation accurately represents the conceptual description model as it is expected. Model validation on the other hand, is conducted to confirm that the model is working as intended. There are two stage for verification model. The first stage is to make sure

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that there is no error when the model runs simulation and the second stage is to make sure that the logic of simulation is make sense.

The validation model is conducted to know the model is an accurate representation of the real case from the perspective of the intended uses of the model. Technically, this process is done by comparing the simulation output such as the service level and cycle time in each refinery (as a result of distribution system). The comparison will utilize a hypothesis testing to check whether the result of simulation is significantly different with the existing data.

3.2.4 Scenario Generation

After building a validated and verified simulation model, some improvement scenarios are then developed. All of possible refinery capacity will be evaluated. The scenarios can be described as shown in table 2.1.

Table 3.1 Scenarios Planning

Scenario	Description
0	Existing condition
1	Low refinery capacity increase with moderate demand increase
2	High refinery capacity increase with high demand increase

Three scenarios for determine the best refinery capacity are made. There are scenario 0 by existing condition, scenario 1 by low refinery capacity increase with moderate demand increase and scenario 2 by high refinery capacity increase with high demand increase.

3.2.5 Analysis and Interpretation Step

After generating scenario, the last thing to do is analysis of logistics performance based on scenario output by comparing all scenarios and choosing some competing scenarios. These competing scenarios will then be analyzed further to give the best performance for PT Pertamina (Persero).

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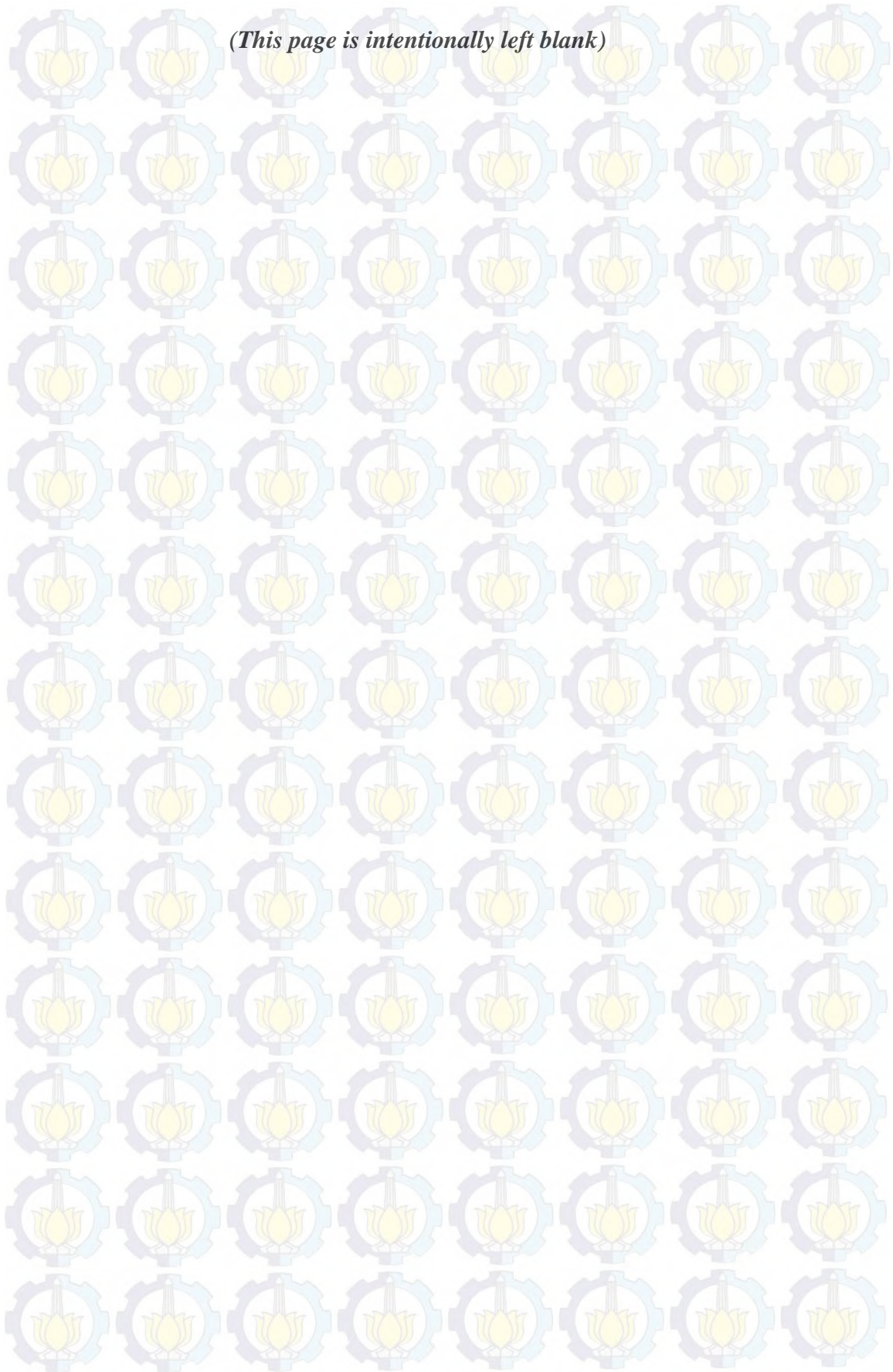
CHAPTER IV
DATA COLLECTION AND PROCESSING

This chapter includes all processes regarding preparing data to build the model. Those processes are data collection, data processing, model building, model validation and verification, scenario generation, and simulation output processing.

4.1 Data Collection

Several data are collected to describe the existing performance of the distribution system and to define several input parameters in order to build the simulation model. Data collection are ship data, shipment lead time and pipeline rate, investment costs, refinery and depot capacity, daily demand and distribution network data.

4.1.1 Ship Activity Logs and Pipeline Logs

It is important to know the set of activities and the duration of each activity performed by ship and pipeline when disributing the product in one cycle. Therefore, the ship activities logs for each voyage are collected. These data are regularly updated by the company. Pipeline logs for depot destination are also collected. By analyzing data from ship activites and pipeline logs, some information describing the existing system can be obtained.

4.1.2 Investment Cost

Other important data to collect is investment cost because it will be used to measure the performance of several scenarios of improvement. The investment cost is given from PT Pertamina (Persero) calculation estimation and it will be an important input to calculate the total cost of each scenario.

4.1.3 Refinery Capacity and Daily Demand

The next important data to collect after collecting data related to ships and pipeline are those about inventories and demand. These data are very important. From these data, the service level, which is the most important parameter in logistics, can be derived. Furthermore, the historical data of release and the amount of fuel products in refineries and depots can be obtained from these data.

4.1.4 Distribution Network Data

The last important data collection is distribution network data to know the real current system in supply and distribution for fuel products. The system description are obtained from documents and interview from division S&D PT. Pertamina (Persero).

In the current system the fuel products is directly shipped from refinery unit towards depot destination. The shipping mechanism starts from the determination of shipments ratio for each depot destination. The command to do the shipping is based on the shipments ratio which is between the total shipments frequency with each depot destination shipment frequency. These ratio will be the basis for determining shipments priority.

Ship comes to do the loading process each day. Each ship can sail when carrying capacity is full. If there is not enough stock in refinery, the ship can not have a sail in order to maximize ships utility. After loading process, ship will sail directly to depot destination. After arriving at depot destination, ship will do the unloading process in there. After unloading process is done, the ship will sail back to the refinery unit with time average 3-4 days. Besides using ships, the company also use pipeline to deliver the fuel products. For pipeline, it will operate 24 hours (without time windows). It will do the loading process with a speed of 1000 Kilo Liter/ Hour (from RU IV) and 800 Kilo Liter/ Hour (from RU VI). Pipeline will stop operating when there is not enough stock in refinery. After that, the depot destination will gain the fuel products from a part of pipeline named heart cut.

4.2 Data Processing

The collected data are then processed to describe the existing performance of the existing system and to define several input parameters in order to build simulation model. Data to process are ships activity logs, pipeline activitiy, refinery capacity, daily demand and investment cost.

4.2.1 Ship Cycle Activities

The ship activities in one cycle can be seen from ship activities logs, started by defining shipping on refinery IV and refinery VI. In this research, activities are

divided into six stages that representing a set of activities in each refinery. The stages are shown in block diagram in Figure 4.1.
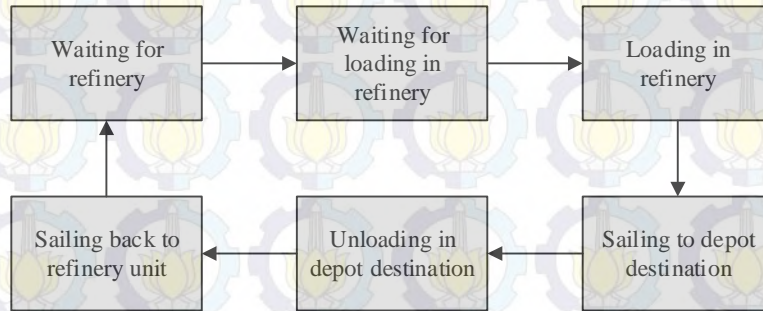
Figure 4.1 Ship Activities Cycles

The description of each stage is given below.

1. Waiting for Refinery

   This stage occurs when a ship has to wait for Refinery Unit (RU) before being able to port because of congestion. Congestion in RU IV and RU VI only happens when these refineries are already occupied by ships for assignment, making the coming ship cannot port immediately. This stage consists of unnecessary activity in form of waiting and therefore can be resolved by scheduling the ship arrivals so that the ships are not coming to the RU at the same time.

2. Waiting for Loading in Refinery

   This stage occurs only when there are not enough inventories in Refinery Unit to load the fuel products. The company will avoid starting the loading process when the inventory is not enough for full loading. So, the loading process can only be started when the inventory capacity reaches full ship capacity. Since the refinery production is stated per day and pipeline assignment occurs hourly, the minimum starting inventory level for loading (ILL) can be derived as

   $$I_l = R - T - T \tag{4.1}$$

   Since

   $$T = \sum_{i=1}^{n} T \tag{4.2}$$

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$$T = C \times L \qquad\qquad\qquad (4.3)$$

RP for refinery production, TS for total capacity from ship that has been assigned, TP is total pipeline that has been assigned hourly, CP is the capacity of the pipeline per hour and LT is the loading process time (hour). Therefore, the waiting for RU will occur only if when a ship reaches this stage, the inventory level is below ILL calculated with equation 4.1. The time duration at this stage will be the time required to build up inventory until it reaches the ILL.

3. Loading in Refinery

This stage is the process of loading the inventory in refinery into any assigned ship. The loading in RU IV and RU VI can be done by pump at the rate of 2210 KL (kilo liter) per hour. The time required for loading in RU IV and RU VI is the ship capacity divided by RU loading rate as mentioned before.

4. Sailing to Depot Destination

This stage representing the activities of ships on sea travelling to the depot destination. The duration of this stage is based on the historical data to get to any destination. Since there are four depot destinations, it is necessary to determine the distribution fit for sailing time to each depot. The number of data input for distribution fit test for sailing time to each depot is different. At this stage, a distribution fit test will be performed using InputAnalyzer in ARENA. The data input for this is shown in table 4.1

Table 4.2 Data Input for Sailing Time to Depot 7

#	Sailing Time (hour)	#	Sailing Time (hour)	#	Sailing Time (hour)	#	Sailing Time (hour)	#	Sailing Time (hour)
1	24.3	11	24.6	21	25.2	31	25.5	41	25.2
2	24.3	12	24.7	22	25.3	32	25.4	42	25.0
3	24.4	13	24.8	23	25.3	33	25.3	43	25.1
4	24.1	14	24.9	24	25.4	34	25.2	44	25.0
5	24.6	15	24.8	25	25.5	35	25.2	45	25.6
6	24.7	16	24.6	26	25.1	36	25.0	46	25.7
7	24.8	17	24.7	27	25.2	37	25.1	47	25.8
8	24.9	18	24.6	28	25.3	38	25.4	48	25.9
9	24.8	19	24.7	29	25.3	39	25.3	49	25.6
10	24.6	20	25.1	30	25.4	40	25.2	50	25.6

From this data, a distribution fit test is carried out. The output of InputAnalyzer for this data is given in Figure 4.2.


```
        Distribution Summary

Distribution:   Triangular
Expression:     TRIA(24, 25.3, 26)
Square Error:   0.015256

Chi Square Test
  Number of intervals  = 5
  Degrees of freedom   = 3
  Test Statistic       = 5.14
  Corresponding p-value = 0.178

Kolmogorov-Smirnov Test
  Test Statistic       = 0.0694
  Corresponding p-value > 0.15
```
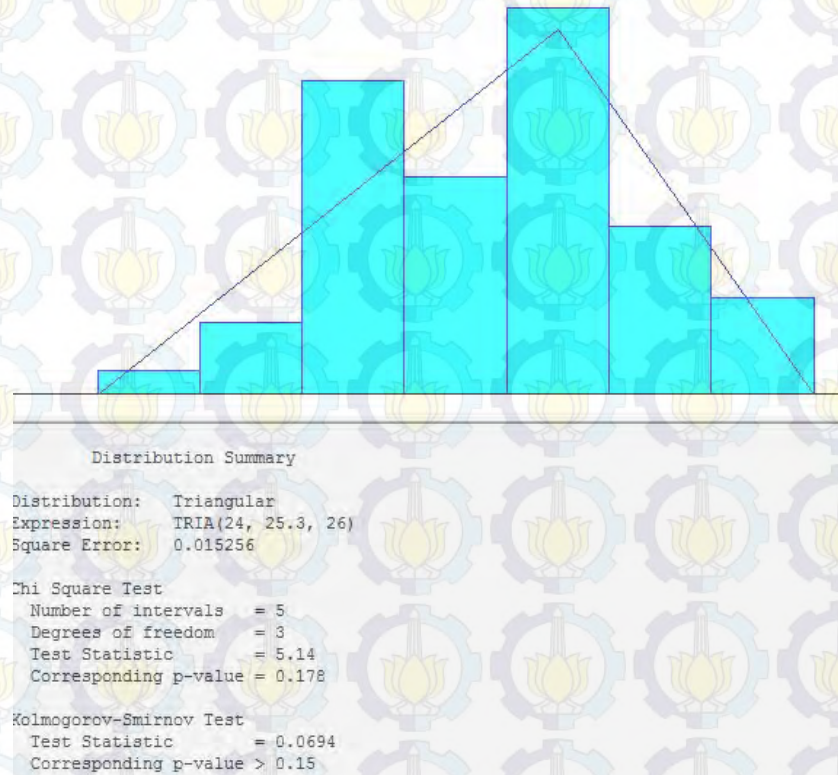
Figure 4.2 Distribution Fit for Sailing Time to Depot 7

From Figure 4.2, the best fit distribution in terms of square error is triangular distribution with minimum 24, moderate 25.3 and maximum 26. The K-S test statistic is small, only at 0.0694. the smaller is the observed value of the K-S statistic, the better is the fit. The corresponding p-value from Kolgomorov-Smirnov (K-S) test is > 0.15 implying that the distribution of the sample is non-significant different from a normal distribution. Even so, the square error is quite low, only at 0.015256. Therefore, this result can be proceeded further to input in the model. The distribution fit test for a ship sailing from RU VI until arriving at Depot 7 is TRIA (24, 25.3, 26). The distribution fit test shows that the sailing time for ship from RU IV to depot 2, depot 3, and depot 4 successively are TRIA (8.9, 8.96, 9.19), TRIA (14, 14.3, 14.6), and TRIA (10.2, 10.4, 10.9).

5. Unloading in Depot Destination

    This stage refers to activities of unloading in depot destination. The unloading can be done by pump at various rate depend on depot destination. Table 4.2 shows the unloading rate in each depot.

Table 4.2 Unloading Rate

Depot Destination	Unloading Rate (KL/Hour)
Depot Surabaya	1008
Depot TT Manggis	860
Depot T Priok	900
Depot Pengapon	860

6. Sailing Back to Refinery Unit

    Similar with Sailing to Depot, this stage is also dealing with activities of sea travelling. The duration of this stage is based on the historical data to get to RU destination. Since there are four depot and two RU, it is necessary to determine the distribution fit for sailing time from each depot. The number of data input for distribution fit test for sailing time to each depot is different. Distribution fit test shows that the sailing time from Depot 7 back to RU VI

has TRIA (24.6, 25, 25.5) and sailing time from Depot 2, Depot 3, Depot 4 back to RU IV follows TRIA(9, 9.29, 9.94), TRIA(15, 15.6, 16), and TRIA(11, 11.6, 12).

4.2.2 Pipeline Activities

The pipeline activity are divided into four stages. The stages are shown in block diagram in figure 4.3.

Waiting for refinery	→	Waiting for injecting in refinery	→	Injecting in Refinery	→	Heart Cut in Depot Destination

Figure 4.3 Pipeline Activities

The description of each stage is given below.

1. Waiting for Refinery

   This stage occurs when the pipes has to wait for Refinery Unit (RU) before being able to flow. This stage consists of unnecessary activity in form of waiting and therefore can be avoided by scheduling the pipeline arrivals so that the pipe are not active at the RU at the same time.

2. Waiting for Injecting in Refinery

   This stage occurs only when there are not enough inventories in Refinery Unit to inject the fuel products. So, the loading process can only be started when the inventory capacity (in hour) reaches the pipeline rate (capacity per hour). The pipeline rate from RU IV is different with the pipeline rate RU VI.

3. Injecting in Refinery

   This stage occurs when the pipes is ready to be flowed into each depot destination. Pipeline 1 and Pipeline 2 are from RU IV and Pipeline 3 and Pipeline 4 are from RU VI. Pipeline from each RU has different rate. The table 4.3 shown the pipeline rate from each refinery.

Table 4.3 Pipeline Rate

Refinery Unit	Pipeline Rate (KL/Hour)
Cilacap (IV)	1000
Balongan (VI)	800

4. Heart Cut in Depot Destination

    This stage occurs when the fuel product flowing from pipeline has arrived at depot destination. The depot gains the fuel products from a part of pipeline (heart cut) and flow it to the inventory.

4.2.3 Investment Cost Calculation

After defining ships activity and pipeline activity, the next step is to define by how the costs are calculated in the system. The most important cost is investment cost to determine which the best refineries capacity due to cost limitation for the company. The refinery investment cost for building with a certain capacity, will be calculated as

$$\text{Investment Cost} = 2487 \times \left(\frac{c}{3}\right)^{0.6}$$

For example, to build refinery with capacity of 400 KBPD, the investment cost is given as follows.

$$\text{Investment Cost} = 2487 \times \left(\frac{4}{3}\right)^{0.6}$$

$$\text{Investment Cost} = 2606 \text{ Million USD}$$

Therefore, to convert kilo litre per day (KLPD) into kilo barrel per day (KBPD) for the investment calculation, the capacity with KLPD is divided by 159 (1 Kilo Barrel = 159 Kilo Litre).

The conversion of investment cost to annual cost is using the assumption of 12% annual interest rate and 20 years of economic life. Let the refinery investment (IC) is about 2.606 Million USD, the investment cost for each refinery ($I_i{}'$), is given as follows.

$$I_i{}' = I_i \times \left(\frac{A}{P}, i, n\right)$$

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$I_i = 2606 \times 0.1339$

$I_i = 348.94$ Million USD

4.2.4 Service Level Calculation

From the historical data, figure 4.4 show the performance of the refineries in 12-months period.
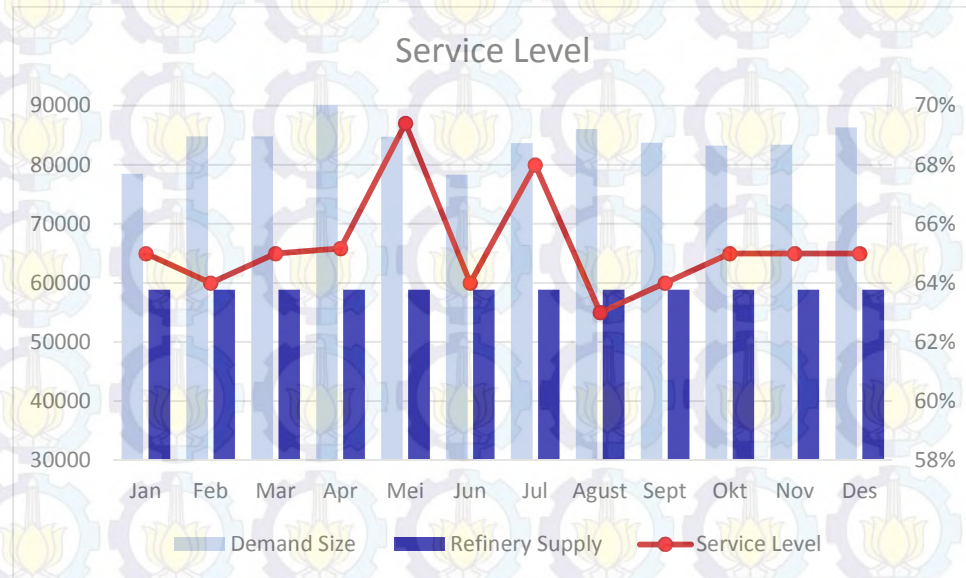
Figure 4.4 Refinery Service Level

Figure 4.4 shows the service level of refineries in twelve months in row. The green bar shows the demand of fuel products in java and the blue bar shows the supply that refineries can afford. By this formula as shown in equation 4.1.1, the performance can be determined.

$$\text{Service Level} = 1 - \frac{(D_i - S)}{D_i} \qquad (4.1.1)$$

It is clear from the figure 4.4 that performance of the refineries is not good enough especially for the fuel products product which is basic needs. The performance from january until december is below 70%. This implies that refineries should have more capacity to produce the fuel products to make the performance acceptable, otherwise it will fall to unsatisfying level.

4.2.5   Daily Demand Pattern

After determining refinery service level and the way to calculated it, the next step is to determine the pattern of daily demand based on historical data. A goodness of fit test will be performed to define what is the best distribution to describe the pattern. Therefore, the daily demand from January to December is tested using ARENA InputAnalyzer after removing some outlier data. The output of InputAnalyzer for daily demand data is given in Figure 4.5.


```
        Distribution Summary

Distribution:   Normal
Expression:     NORM(8.63e+004, 3.39e+003)
Square Error:   0.006691

Chi Square Test
  Number of intervals   = 9
  Degrees of freedom    = 6
  Test Statistic        = 18
  Corresponding p-value = 0.00656

Kolmogorov-Smirnov Test
  Test Statistic        = 0.0683
  Corresponding p-value > 0.15
```
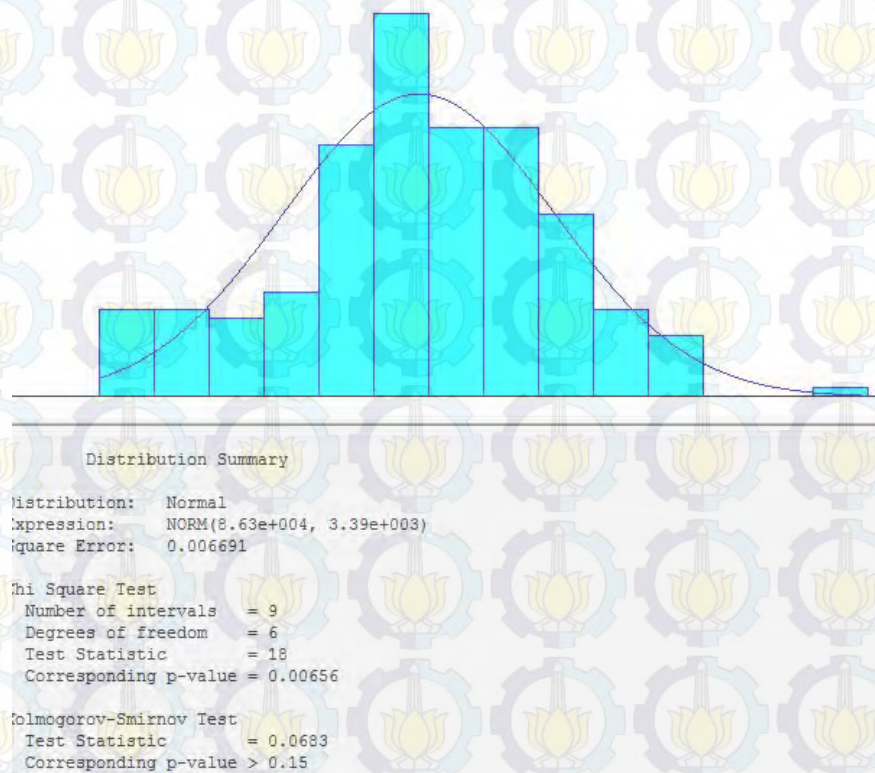
Figure 4.5 Distribution Fit for Daily Demand

The goodness of fit test based on new data shows that demand in refineries follow normal distribution. The K-S test statistic is small, only at 0.06. the smaller is the observed value of the K-S statistic, the better is the fit. The corresponding p-value from Kolgomorov-Smirnov (K-S) test is > 0.15 implying that the distribution of the sample is non-significant different from a normal distribution. Even so, the square error is quite low, only at 0.006691.

4.3   Model Building

After obtaining all input parameters to simulate the system, the next step is to build the simulation model using ARENA. The model is divided into four sub models. First is ship activities, second is pipeline activities, third is the service level, and fourth is inventory level. The interface of simulation model is shown in figure 4.6.
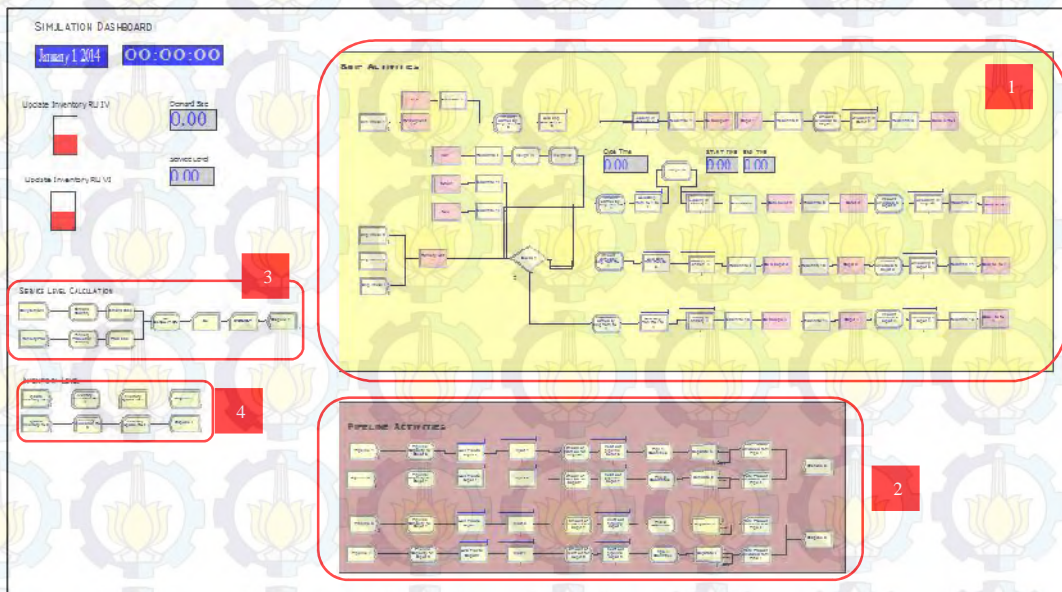
Figure 4.6 Simulation Model Interface

4.3.1   Ship Activities

Ship activities model consists of all activities of ships in a cycle both for those assigned in RU IV and RU VI. Each refinery refers to other depot destination. Therefore, the simulation model for two shipment sources as shown in Figure 4.7.
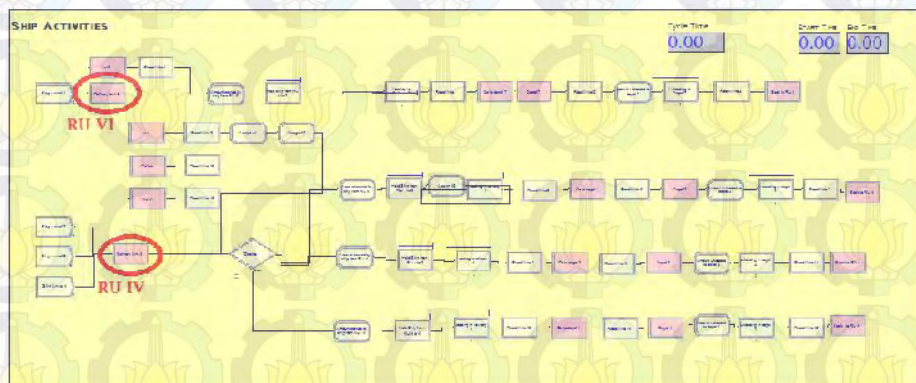
Figure 4.7 Ship Activities Model in ARENA (2 sources of shipments)

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On the existing system, whenever a ship is available in RU, it will be assigned to depot destination directly. There is no rule for determining which depot should be visited first because each ship has their own way to go to the depot. However, the company will avoid starting the loading process when the inventory is not enough for full loading so the ship cannot go directly to the depot destination. Here are some explanation for ship activities in the simulation process which is reflected by figure 4.7:

Step 1. Start the cycle by assigning ships for delivering the fuel products. All orders (fuel products) generated will first be held by hold module until a ship is ready to load. When this condition is met, which is checked by scan for condition, a signal releasing the order from hold module will be sent and processed to loading.

Step 2. Proceed to loading by pump with duration of loading time.

Step 3. Generate sailing time to destination and set sail.

Step 4. Check whether the space in depot is enough for unloading. If yes, proceed to unloading. Otherwise, hold until the space is adequate.

Step 5. Proceed to unloading by pump with duration of unloading time

Step 6. Sail back to refinery. Sailing back to refinery ends ship physical activities during unloading processes

4.3.2 Pipeline Activities

Pipeline activities consists of activities both for those assigned in RU IV and RU VI. Each pipeline from refinery unit refers to four depot destination. Figure 4.9 shows the pipeline activities in simulation model.

Figure 4.9 Pipeline Activities in ARENA

Start by assigning pipe for delivering the fuel products. Because pipeline activities is continuous variable, time between arrival of pipeline is constant for one hour. Pipeline 1 and Pipeline 2 are from RU IV and the pipeline rate is 1000 Kilo Liter per hour. Pipeline 3 and Pipeline 4 are from RU VI and the pipeline rate is 800 Kilo Liter per hour. All orders (fuel products) generated will first be held by hold module until pipeline is ready to inject. When this condition is met, which is checked by scan for condition, a signal releasing the order from hold module will be sent and processed to loading in Refinery Unit. After proceed to loading, the depot destination will gains the orders from a part of pipeline, heart cut. At last, the simulation will record the amount of total product unloaded from pipeline with record module. In order to see the amount (not just the number of arrival), separate modul is used before the record module to read the amount from assign module.

4.3.3 Refineries Service Level

This model is built for the purpose of writing outputs. The simulation model will collect the refinery performance by calculating the refinery production with the daily demand. This will be used in analysis of overall service level.

4.3.4 Inventory Level

This model is built for updating inventory position. The simulation model will collect the update on-hand inventory in refinery. On-hand inventory = Refinery production - ship capacity – pipeline capacity. This update will be used to give a releasing or holding the order signal from hold module in ship and pipeline activities.

4.4 Model Verification and Validation

The next step after building simulation model is goodness assessment, specifically on its two components verification and validation. verify and validate the model to ensure the model follows its logical design and behaves as the real system intended.

4.4.1 Model Verification

Verification is performed in three step. First, the model is tested for errors by ARENA model check to ensure that simulation can run. The result of this test is shown in figure 4.10.

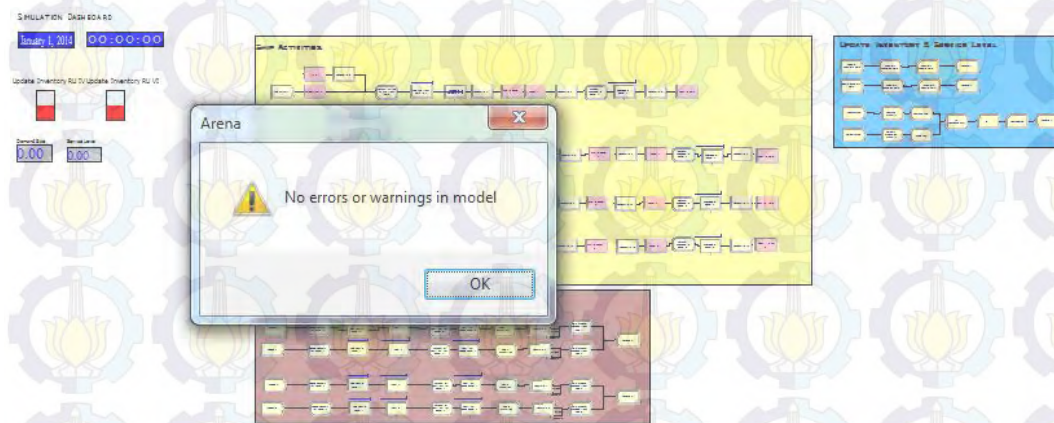**Figure 4.10 Error Check in ARENA**

After testing the model for error check, the second verification step is checked for input parameters and output statistics. This step is to make sure that input parameters and output from logical structure of the model are correctly represented. The ARENA output reports in this research uses SIMAN summary report. The result of this test is shown in figure 4.11.

```
                              Output Summary for 30 Replications
Project: Unnamed Project                              Run execution date : 6/ 3/2015
Analyst: Rockwell Automation                          Model revision date: 6/ 2/2015

                                   OUTPUTS

Identifier                        Average   Half-width Minimum   Maximum # Replications

Refinery Production.NumberIn       365.00    .00000    365.00    365.00     30
Refinery Production.NumberOut      365.00    .00000    365.00    365.00     30
Entity 1.NumberIn                 17520.    .00000    17520.    17520.     30
Entity 1.NumberOut                17520.    .00000    17520.    17520.     30
Ship Arrival 1.NumberIn           3.0000    .00000    3.0000    3.0000     30
Ship Arrival 1.NumberOut          .00000    .00000    .00000    .00000     30
Ship Arrival 2.NumberIn           2.0000    .00000    2.0000    2.0000     30
Ship Arrival 2.NumberOut          .00000    .00000    .00000    .00000     30
Ship Arrival 3.NumberIn           2.0000    .00000    2.0000    2.0000     30
Ship Arrival 3.NumberOut          .00000    .00000    .00000    .00000     30
Ship Arrival 4.NumberIn           2.0000    .00000    2.0000    2.0000     30
Ship Arrival 4.NumberOut          .00000    .00000    .00000    .00000     30
Pipeline RU 4.NumberIn            3.0194E+06 .00000   21516.    1.7520E+07 30
Pipeline RU 4.NumberOut           3.0049E+06 .00000   4000.0    1.7520E+07 30
Pipeline RU 6.NumberIn            7.0168E+06 .00000   7.0168E+06 7.0168E+06 30
Pipeline RU 6.NumberOut           7.0080E+06 .00000   7.0080E+06 7.0080E+06 30
Daily Demand.NumberIn             365.00    .00000    365.00    365.00     30
Daily Demand.NumberOut            365.00    .00000    365.00    365.00     30
Kilang 4.NumberSeized             3008.9    2464.8    4.0000    17525.     30
Kilang 4.ScheduledUtilization     .00317    .00000    .00000    .01039     30
Kilang 6.NumberSeized             .00000    .00000    .00000    .00000     30
Kilang 6.ScheduledUtilization     .00000    .00000    .00000    .00000     30
Dermaga 1.NumberSeized            .00000    .00000    .00000    .00000     30
Dermaga 1.ScheduledUtilization    .00000    .00000    .00000    .00000     30
Dermaga 2.NumberSeized            17521.    .36796    17520.    17523.     30
Dermaga 2.ScheduledUtilization    .00240    .00000    .00000    .00616     30
Dermaga 3.NumberSeized            1.1666    .61298    .00000    9.0000     30
Dermaga 3.ScheduledUtilization    .00146    .00000    .00000    .01130     30
Dermaga 4.NumberSeized            1.6333    .67565    .00000    8.0000     30
Dermaga 4.ScheduledUtilization    .00336    .00139    .00000    .01644     30
Dermaga 6.NumberSeized            1502.4    1232.5    2.0000    8760.0     30
Dermaga 6.ScheduledUtilization    .00000    .00000    .00000    .00000     30
Dermaga 7.NumberSeized            1502.4    1232.5    2.0000    8760.0     30
Dermaga 7.ScheduledUtilization    .00000    .00000    .00000    .00000     30
System.NumberOut                  1.0031E+07 .00000   7.0303E+06 2.4546E+07 30

Simulation run time: 1049.80 minutes.
Simulation run complete.
```

Figure 4.11 Siman Summary Report

Based on figure 4.11, number out for Ship 1, Ship 2, Ship 3 and Ship 4 are zero while the number in from ship 1 is three, ship 2 is two, ship 3 is two and ship 4 is two. These are happened because from the model, the number of ships from RU VI is three and the number of ships from RU IV is two for each depot destination and the ships will be back to RU so there are no output coming out from the model. Furthermore, the number in of refinery production and daily demand are 365 and the number out of them still 365. This proves that the model behaves as intended because the refinery production and daily demand made everyday and the simulation time period is one year or 365 days. These prove that the model has been verified.

After those two steps, the last verification step is performed by examining simulation processes separately to check whether the model behaves according to its design. Therefore, verification with mathematical calculation will be performed.

This section overviews some elements of performance analysis. In consequence, cycle time and service level will be checked.

Cycle time and service level are two important of performance measure input obtained from data and therefore can be tested later for validation by comparing data with simulation output. Even more, these measures will be analyzed further to obtained the best scenario. So, it is important to make sure that the model calculates cycle time and service level correctly.

4.4.1.1 Cycle Time Verification

Cycle time in this research is defined as time interval between ship assignment in refinery unit and ship arrival back after voyage. Verification is conducted by testing the whether what is calculated by ARENA system (calculated by ARENA system by TNOW at the time the cycle ends minus the time the ship has been assigned) is equal to the sum of output in the spreadsheet which is the time of each process. Figure 4.12 and table 4.4 show the ARENA display of cycle time and output in the spreadsheet file.
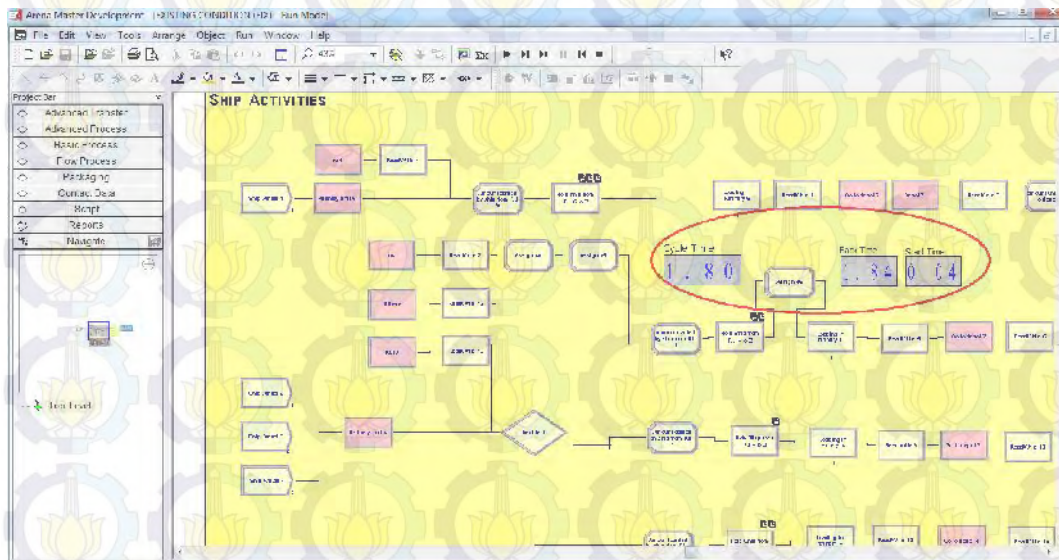

Figure 4.12 Cycle Time Output in ARENA

Table 4.4 Process Time in Spreadsheet File

Loading Time (hours)	Sailing to Depot 2 (hours)	Unloading Time (hours)	Back to RU IV (hours)	Total Time (hours)	Total Cycle Time (Days)
7.00	9.00	18.00	9.20	43.20	1.80

Since the calculation in ARENA is equal to the sum of processes time in the spreadsheet, the cycle time calculation is verified.

4.4.1.2 Service Level Verification

Service Level will be checked by comparing the result of simulation output ARENA with the one calculated manually. The average service level for 365 days of simulation in ARENA is shown in figure 4.13.
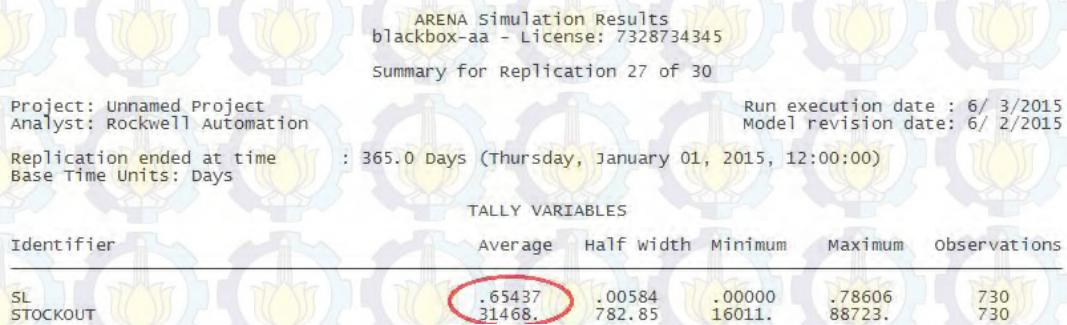
Figure 4.13 Service Level Siman Summary Report for Replication 27 of 30

Based on figure 4.13, the report shows the number of average stockout and the service level. Using Equation 4.1.1 , service level in refineries will be checked.

$$SL = 1 - \frac{(S \qquad)}{D_i}$$

$$SL = 1 - \frac{(3 \qquad)}{3 \quad +5}$$

$$SL = 0.654$$

The result of manual calculation of SL to ARENA output is the same. Hence, the calculation of service level in ARENA has been verified. Moreover, the simulation was run for 30 replication. To see whether the SL is in control limit, the

descriptive statistic is tested using Excel to see the mean, standard error, and standard deviation.

Table 4.5 Service Level Descriptive Statistic

SL SIMULATION	
Mean	0.653677
Standard Error	0.00045
Median	0.65395
Mode	0.65557
Standard Deviation	0.002467
Sample Variance	6.09E-06
Kurtosis	-0.80474
Skewness	-0.28436
Range	0.00883
Minimum	0.64872
Maximum	0.65755
Sum	19.61032
Count	30

From table 4.5 the mean is 0.653677, the standard error is 0.00045, standard deviation is 0.002467. Although the standard error is quite low, to make sure that the data is verified, a control chart using $0.654 \pm 2\sigma$ is given in figure 4.14.
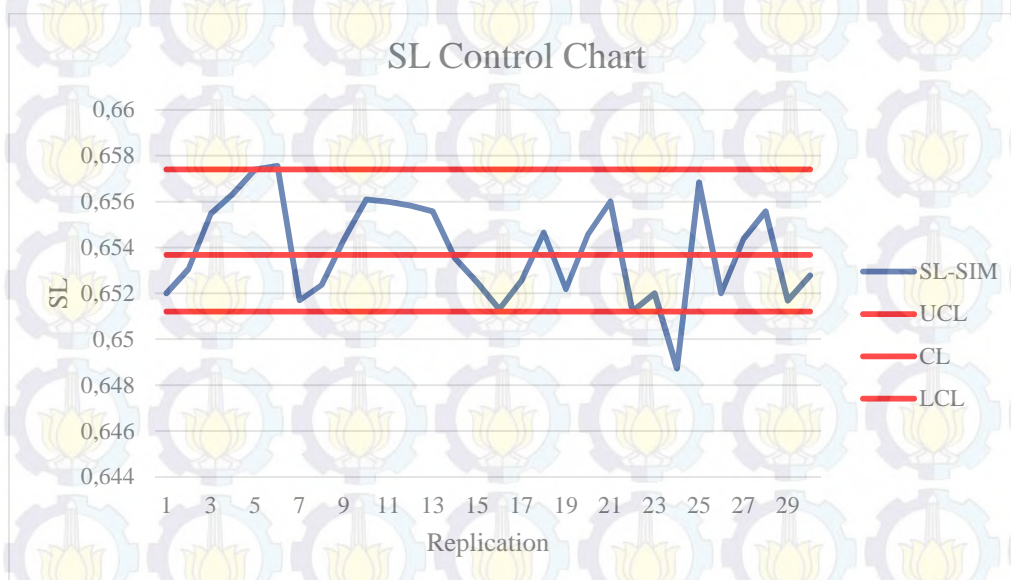

Figure 4.14 Service Level Control Chart

Based on figure 4.13, from 30 replication, there is just one data that out of control. With alpha 0.05, the data is still accepted. After all, the service level in ARENA has been verified. After verification, the model is then tested for validation to ensure the model can represent the real system.

4.4.2 Model Validation

Validation for this model will be carried out by comparing cycle time (CT) in each refineries (RU IV and RU VI) and service level (SL) obtained from company data and simulation output under existing situation (Scenario 0). To do the validation, the Scenario 0 is set to run for 30 replications and the replication length of one year (365 days). CT is collected per voyage and SL is collected per one year period. These data are then tested for significant difference. Since there is very limited number of existing data, t-test is chosen with additional assumption of unequal variances. Using 95% of confidence level, a report of t-Test using Data Analysis of Microsoft Excel is generated and shown in Table 4.6 and Table 4.7

Table 4.6 CT Statistical Significance T-Test Assuming Unequal Variance

	CT SIM	CT REAL
Mean	1.80938	1.815
Variance	0.0002	0.00023
Observations	28	28
Hypothesized Mean Difference	0	
df	54	
t Stat	-1.4275	
P(T<=t) one-tail	0.0796	
t Critical one-tail	1.67356	
P(T<=t) two-tail	0.15919	
t Critical two-tail	2.00488	

Table 4.7 SL Statistical Significance T-Test Assuming Unequal Variance

	SL SIM	SL REAL
Mean	0.65368	0.654404
Variance	6.1E-06	5.10E-32
Observations	30	30
Hypothesized Mean Difference	0	
df	29	
t Stat	-1.61336	
P(T<=t) one-tail	0.06	
t Critical one-tail	1.69913	
P(T<=t) two-tail	0.1175	
t Critical two-tail	2.04523	

This particular test is two tailed test to know whether the means are different. First, it is important to look at the t-Stat values and compare it with t-Critical two-tail values. All t-Stat values are within the range of negative value of t-Critical two-tail to its positive value, implying that under 95% confidence level, there is no statistically significant difference between simulation output and existing data. So, the null hypothesis cannot be rejected. Second, from the table, all of the P(T=t) two-tail is larger than 0.05, clearly indicating that the null hypothesis cannot be rejected. These results validate the simulation model, meaning that it can represent the real system and therefore can be analyzed further.

4.5 Scenario Generation

This research tries to find the best new refinery capacity to maximize service level while considering the investment cost as small as possible. The idea to serve high service level is by increasing the refinery capacity at the farthest, but larger capacity would increase the investment cost. However, simulation with scenario generations would be necessary. Some of the alternatives of the all refinery capacity possibility in this simulation is shown in figure 4.15:
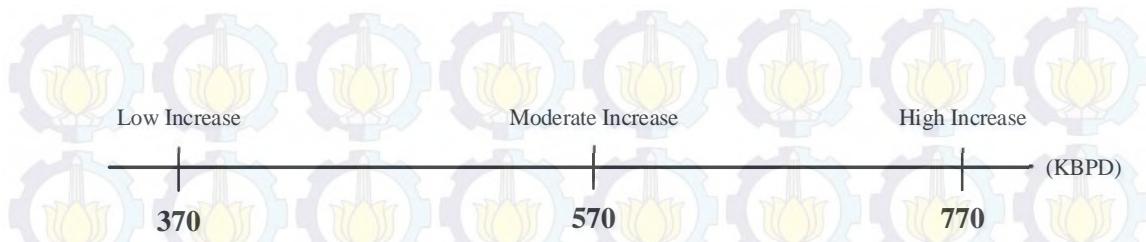
Low Increase   Moderate Increase   High Increase

370   570   770   (KBPD)

Figure 4.15 Scenario Generation

Figure 4.15 shows the all refinery capacity possibility for each refinery. The increase of refinery capacity is divided into 3 part, they are low increase, moderate increase, and high increase. The range for low increase is below 570 KBPD. For moderate increase, the range of the capacity is between 570 KBPD and 770 KBPD. The high increase starts when the capacity is above 770 KBPD. Scenario will be carried out by changing the parameters of refinery capacity started from low increase for scenario 1 and high and moderate increase for scenario 2. Service level and investment cost will be the response of the scenario.

4.6   Simulation Output

After generating all scenarios, the next step is to run the simulation. Since there are more than one parameters to run in scenarios, ARENA ProcessAnalyzer is used to help setting parameters in each scenario and replication. Figure 4.16 and Figure 4.17 shows the ProcessAnalyzer model which is built to run the simulation.
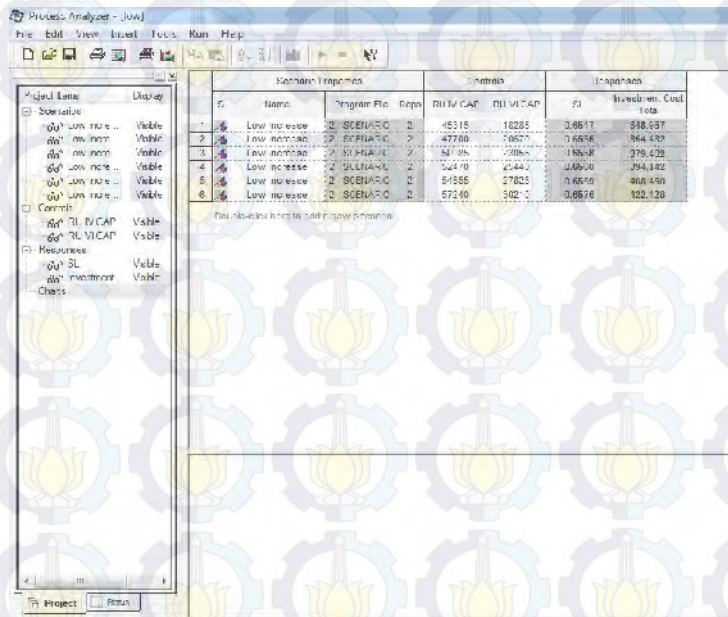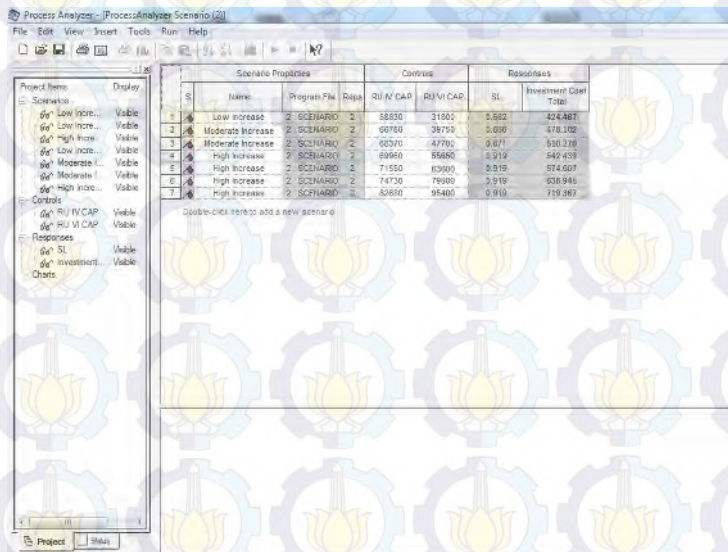
Figure 4.16 ProcessAnalyzer Module Scenario 1

Figure 4.17 ProcessAnalyzer Module Scenario 2

The ARENA ProcessAnalyzer is a tool that support Parametric Analysis of the models, by allowing modeler to create, run, and compare simulated scenarios and observing the effect of specified controls on prescribed responses. The control variables are refinery capacity from RU IV and RU VI and the response variables are service level and investment cost. All ProcessAnalyzer replication run in batch

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mode (without animation). As each scenario run is completed, the corresponding response values appear.

From the simulation outputs, the summary of each scenario in terms of service level and investment cost is shown in table 4.8 and table 4.9. The value displayed is the average of two replications values for each scenario.

**Table 4.8 Average Service Level and Investment Costs for Scenario 1**

#	Scenario Properties			Responses	
	RU IV Capacity	RU VI Capacity	Total Capacity	Service Level	Annual Investment Costs
Low Increase	285	115	400	0.6547	348.957
Low Increase	300	130	430	0.6556	364.432
Low Increase	315	145	460	0.6558	379.481
Low Increase	330	160	490	0.6560	394.142
Low Increase	345	175	520	0.6569	408.449
Low Increase	360	190	550	0.6576	422.428

Table 4.9 Average Service Level and Investment Costs for Scenario 2

#	Scenario Properties			Responses	
	Capacity RU IV	Capacity RU VI	Total Capacity	Service Level	Annual Investment Costs
Low Increase	370	200	570	0.682	424.487
Moderate Increase	420	250	670	0.800	478.101
Moderate Increase	430	300	730	0.871	510.270
High Increase	440	350	790	0.919	542.439
High Increase	450	400	850	0.919	574.608
High Increase	470	500	970	0.919	638.945
High Increase	520	600	1120	0.919	719.367

Table 4.8 and table 4.9 shows the summary of simulation output from ProcessAnalyzer. The capacity located in the table is the capacity after being converted from KLPD (Kilo Liter per Day)into KBPD (Kilo Barrel per Day).
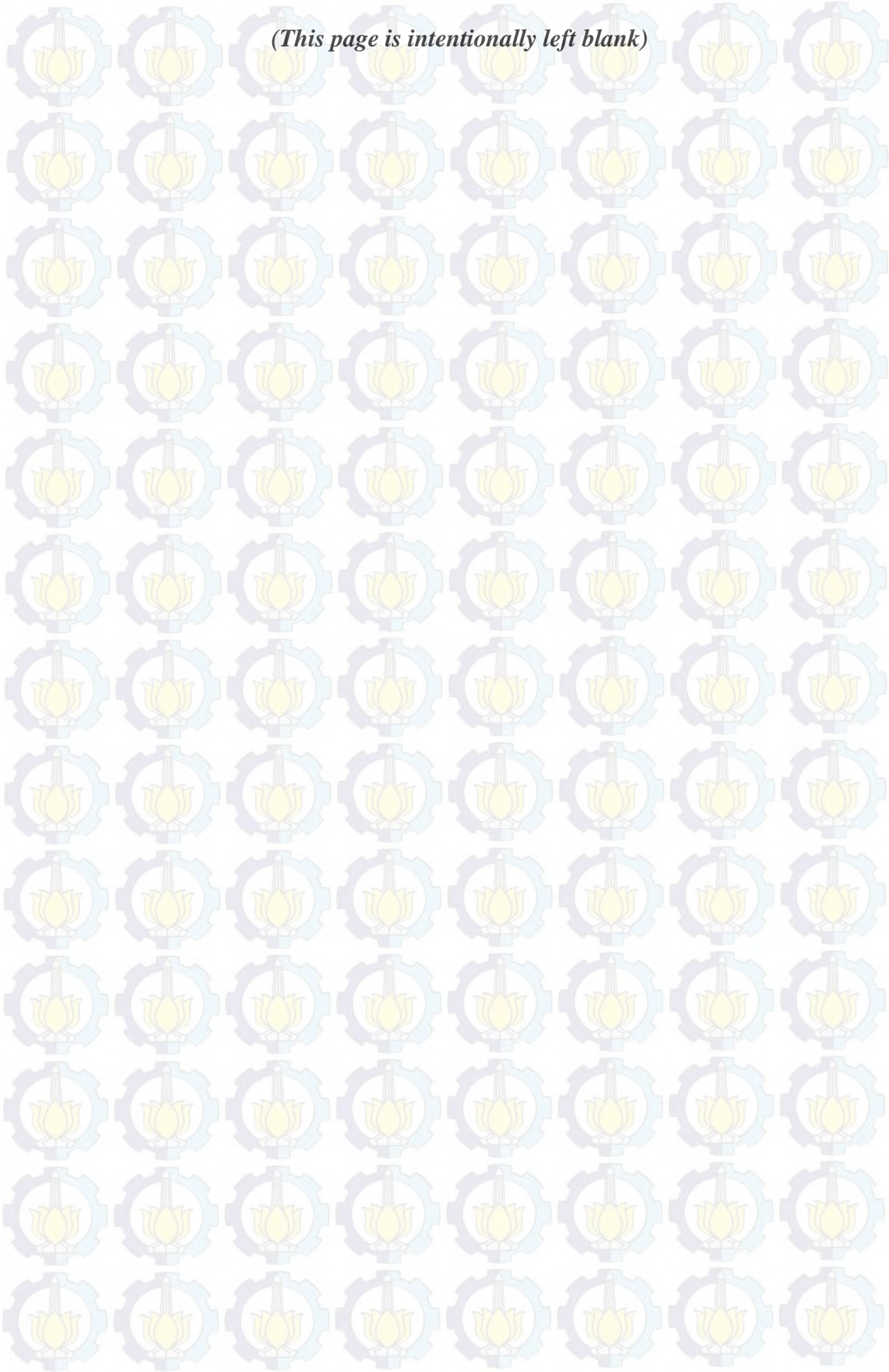
CHAPTER V
ANALYSIS AND INTERPRETATION

This chapter includes analysis and interpretation of the results of simulation output for all scenarios generated.

5.1 Analysis of Using Low Refinery Capacity Increase with Moderate Demand Increase in Service Level and Investment Cost

In this research, to make some improvement scenarios, all of possible refinery capacity will be evaluated. This scenario performed experiment which was begun with an increasing refinery capacity of 15 KBPD (low increase) with demand average from 2015 until 2025.

After the trial with ProcessAnalyzer, service level and investment cost as response are obtained. Figure 5.1 and figure 5.2 show the service level and the investment cost graphic .
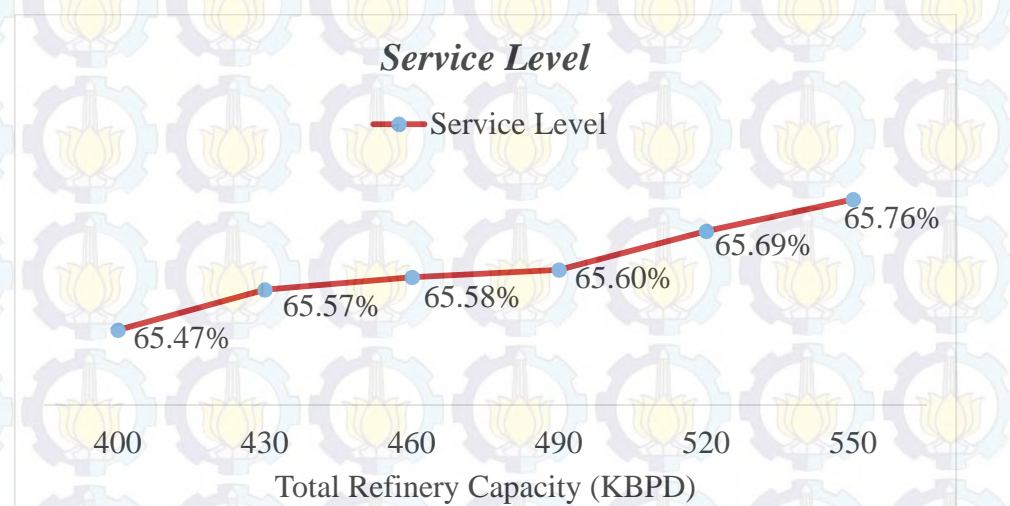

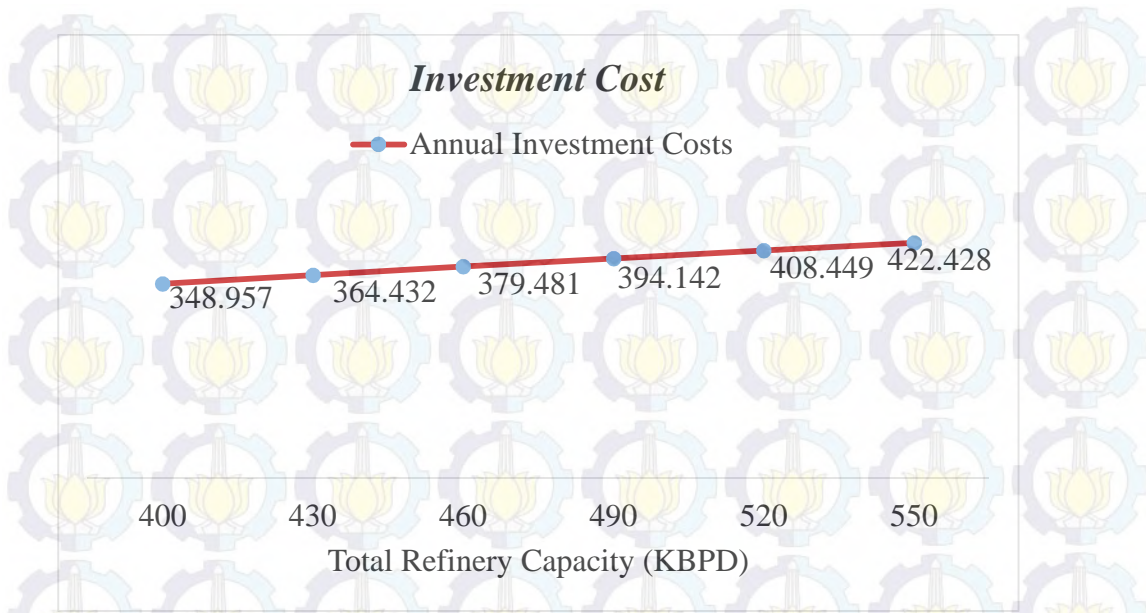**Figure 5.1 Service Level Graphic for Scenario 1**

Figure 5.2 The Annual Investment Cost Graphic for Scenario 1

From the graphic, as the refinery capacity increased, the service level and the investment cost is increasing. But, the low increase did not affect the company service level. The service level is about 65% while the target from the company is 86%.

5.2 Analysis of Using High Refinery Capacity Increase with High Demand Increase in Service Level

After running the scenario 1, all of possible refinery capacity will be evaluated again in the scenario 2 started with an increasing of 100 KBPD from existing condition. Therefore, the scenario began with 370 KBPD for low increase, 570 KBPD for moderate increase and 770 KBPD for high increase. After running the scenario 2 with ProcessAnalyzer, the change of service level can be seen in figure 5.3
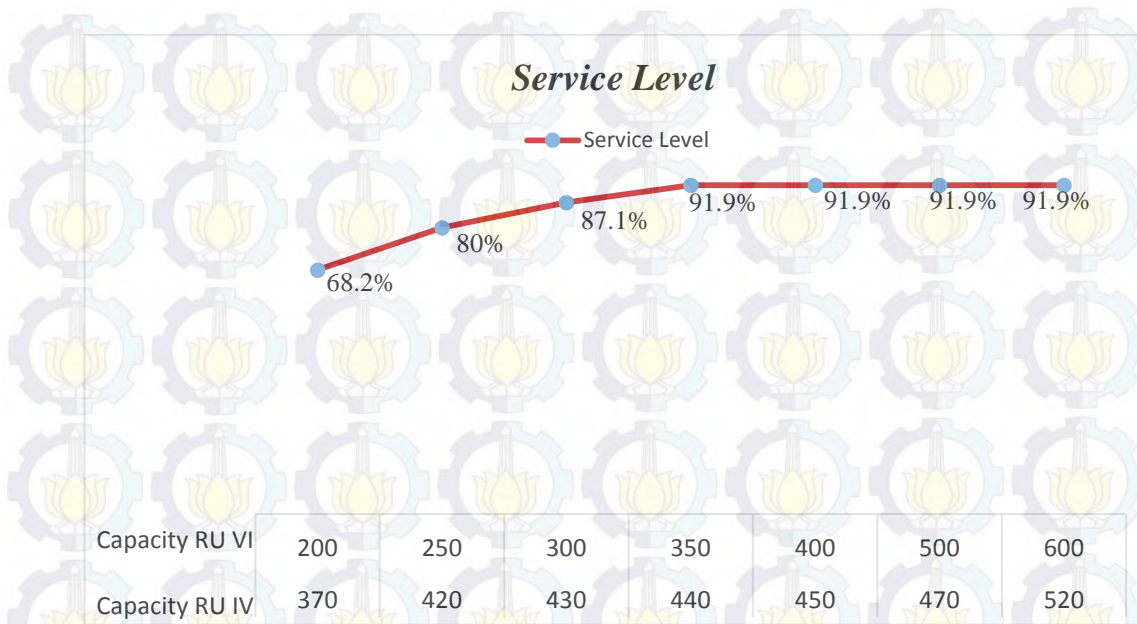
Service Level

	68.2%	80%	87.1%	91.9%	91.9%	91.9%	91.9%
Capacity RU VI	200	250	300	350	400	500	600
Capacity RU IV	370	420	430	440	450	470	520

Figure 5.3 Service Level Graphic for Scenario 2

It is clear that higher refinery capacity can reach higher service level. However, starting from high increase scenario, the service level is not increasing (at 91.9%). This occurs when the capacity is increased from 790 KBPD, ship and pipeline as transportation can not afford bringing the fuel product entirely everyday. If the company has a service level target that bigger than 0.919, then the advanced scenario should be made. The advanced scenario must consider several things like the number of ships, the ships capacity, the depot capacity (as a storage) and etc. This research is conducted to achieve the company objectives. The company has 86% target for service level to fulfill the demand until 2025 with investment cost limit that has been prescribed. So, the advanced scenario is not necessary to be done.

5.3 Analysis of Using High Refinery Capacity Increase with High Demand Increase in Investment Cost

After running the scenario 2 with ProcessAnalyzer, the change of investment cost is given in figure 5.4
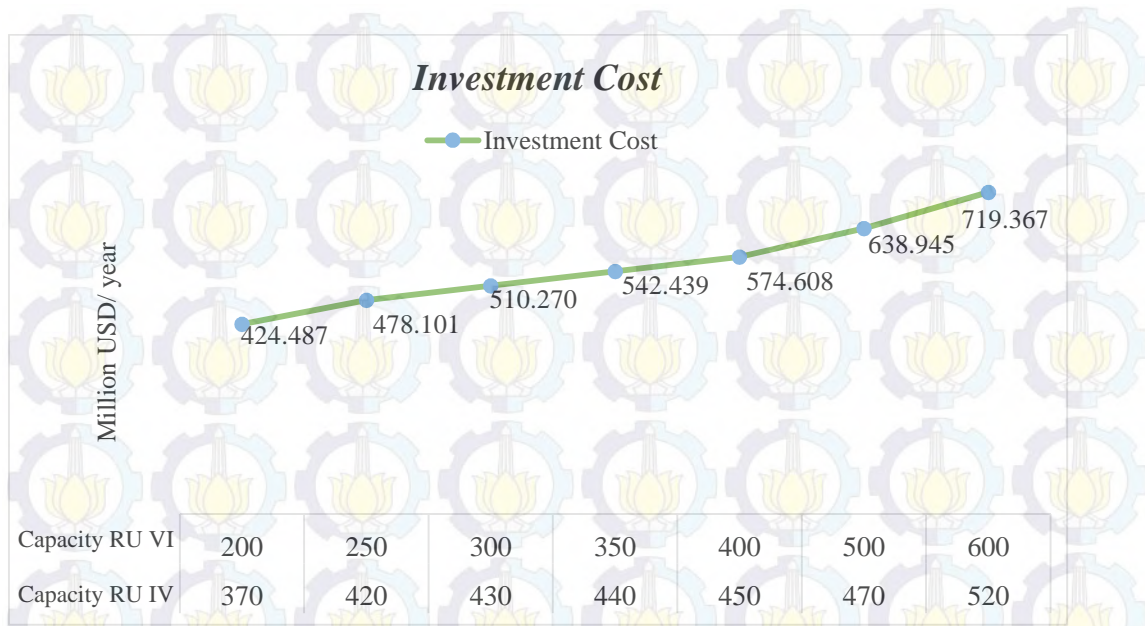
Figure 5.4 The Annual Investment Cost Graphic for Scenario 2

From the graphic, it can be seen that higher refinery capacity can reach higher investment cost. But, line looks steeper started when the refinery capacity is 850 KBPD (450 KBPD from RU IV and 400 KBPD from RU VI), which is high increase capacity. Adding high increase refinery capacity is an expensive investment. Nevertheless, the company has limitation for the total investment costs allocation as much as 6000 Million USD.

5.4 Efficient Frontier Analysis

It is clear that in logistics, there is a trade off between cost and service level. In this research, there is also strong trade off between investment costs and service level. The reason is the higher storage capacity (Refinery Unit), the higher service level should be. Thus, the investment cost associated with storage capacity is also higher.

In figure 5.5, a plot of investment cost (horizontal) against the service level (vertical) for each scenario is presented. The blue-red dots show that there is a correlation between cost and service level. Higher investment cost achieved higher service level. In this figure, the red dotted curve, frontier curve, is an approximate frontier line that connects the most competitive options. The frontier curve can be used to guide the investment costs and service level targets for the company. The

service level of each scenario varies one another by the position of dots representing each scenario. The closer the dots to the frontier curve, the better the solution is. But, it is important to note that there should be a lower limit of acceptable service level and in this research the service level threshold is 86%. The existing condition (scenario 0) produces solution where dots are quite far from frontier curve. This suggest that existing condition can be improved by implementing other scenario whose dots are closer to the frontier curve. From the graph in figure 5.5, it is obvious that the range of service level in scenario 2 from one run to the other could be significantly different (though at some points are the same). Comparing all scenarios that closer to the frontier curve, it is obvious that only the scenario 2 that exhibits the achievements service level compared to the existing condition while all scenario 1 almost the same service level. Looking at both cost and service level, all four scenarios in scenario 2 are good compared to the existing condition. Therefore, from all four scenarios, the scenario chosen is the second scenario with 730 KBPD total capacity (430 KBPD from RU IV and 300 KBPD from RU VI). It is the best because it produce lower cost and achieve company's service level.

The service level is 87.1% and it has been better than the target from the company. As the new capacity is, the company must pay as much as 510.270 Million USD per year or the company must pay 3811 Million USD of total investment costs. By building capacity in accordance with the target service level, the company can raise the service level of 22% (from 65% to 87.1%) and save the costs up to 670 Million USD or 15% of the total investment cost allocation. This can be used for other needs of the company
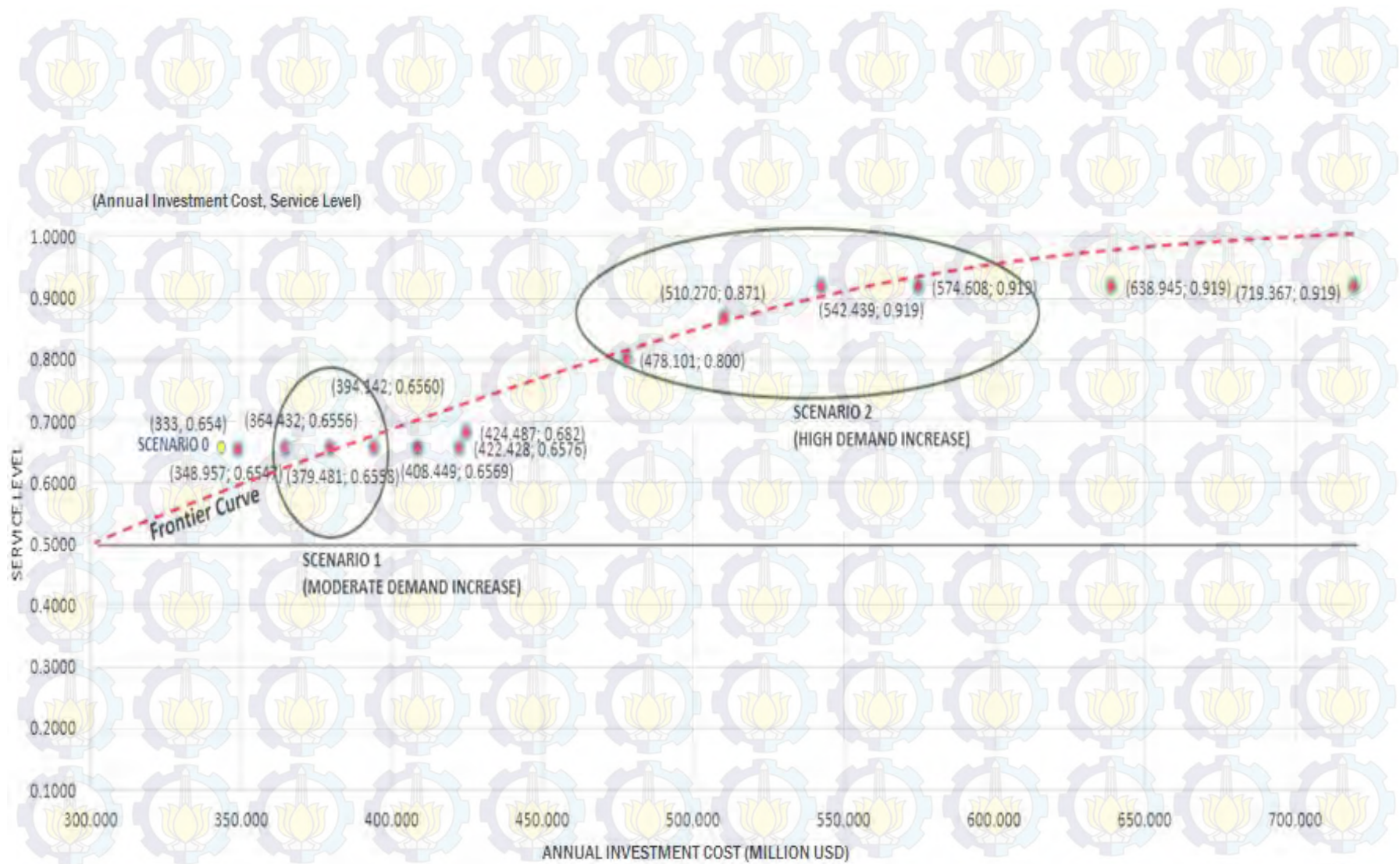
Figure 5.5 Position of Scenario Performance Relative to the Frontier Curve

CHAPTER VI
CONCLUSION AND RECOMMENDATION

This chapter includes the conclusion obtained from analysis and interpretation and also provides recommendations for further researches.

6.1   Conclusion

After doing this research, several conclusions to present are:

1. The simulation model developed in this research has been able to evaluate the new refinery capacity. The existing condition (scenario 0) can be improved by making several scenarios with trial and error. Therefore, to achieve a lower investment cost and acceptable service level, the combination of refinery capacity in Refinery Unit (RU) IV and Refinery Unit (RU) VI are 430 KBPD (Kilo Barrel per Day) and 300 KBPD (Kilo Barrel per Day) with 24-hour operating time for pipeline, and operating 9 ships (6 ships from RU IV and 3 ships from RU VI) as the best chosen scenario to improve the existing situation. The service level is 87.1% and the total investment costs is 3811 Million USD. By building capacity in accordance with the target service level, the company can raise the service level of 22% (from 65% to 87.1%) and save the costs up to 670 Million USD or 15% of the total investment cost allocation.

2. Moderate demand increase does not give significant affect on service level. In order to achieve acceptable service level, refinery capacity should be added to at least 670 KBPD (Kilo Barrel per Day). However, when refinery capacity is further increased, there is a part where service level is steady at 91.9%. This is happen due to the ships and the pipeline can not afford bringing the fuel product entirely though the refinery can produce it in large quantities.

6.2   Recommendation

Several recommendations given based on the result of this research:

1. The company can provide funds as much as 3811 Million USD total investment costs for building new refinery with 430 KBPD capacity for RU IV and 300 KBPD for RU VI.

2. For future researches, it is advisable from this research to evaluate several advance scenarios by considering the pipeline rate, depot capacity, ships in terms capacity, loading and unloading rate, and berth constrains to find the best service level.

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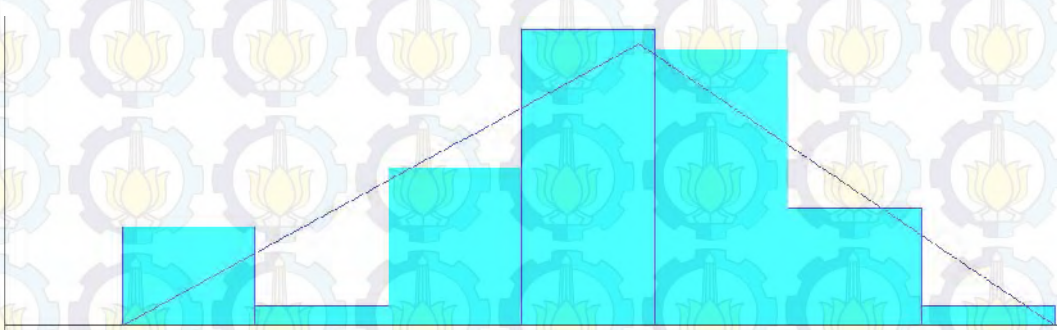
ENCLOSURE

Enclosure 1 – DISTRIBUTION FIT TEST

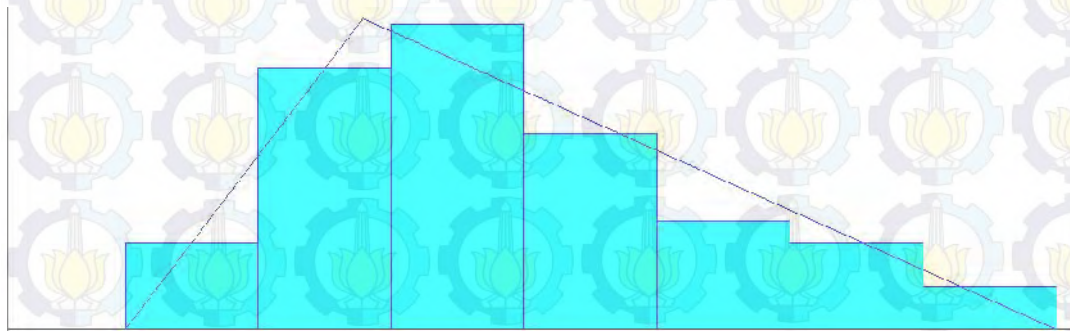### Distribution Fit for Sailing Time to Depot 2
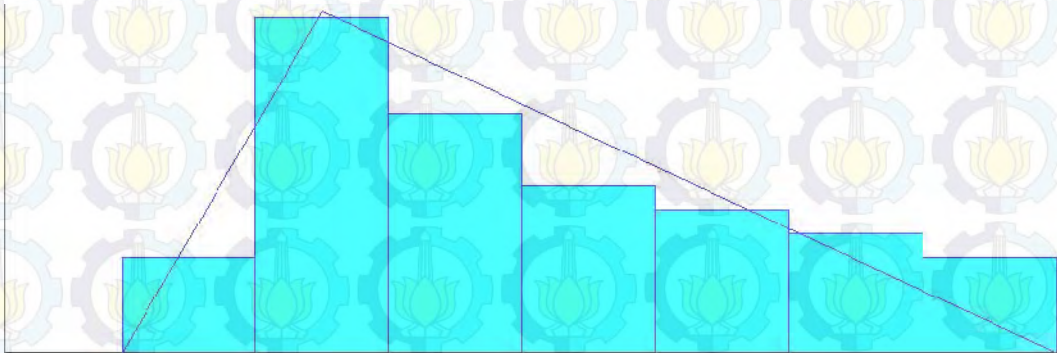

```
        Distribution Summary

Distribution:   Triangular
Expression:     TRIA(8.9, 8.96, 9.19)
Square Error:   0.007229

Chi Square Test
  Number of intervals  = 5
  Degrees of freedom   = 3
  Test Statistic       = 3.56
  Corresponding p-value = 0.328

Kolmogorov-Smirrov Test
  Test Statistic       = 0.105
  Corresponding p-value > 0.15
```

Distribution Fit for Sailing Time to Depot 3
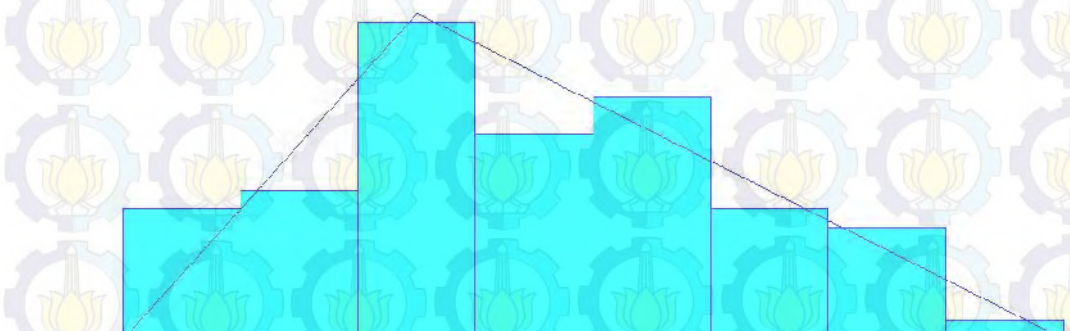


```
        Distribution Summary

Distribution:   Triangular
Expression:     TRIA(14, 14.3, 14.6)
Square Error:   0.018237

Chi Square Test
  Number of intervals  = 5
  Degrees of freedom   = 3
  Test Statistic       = 1.97
  Corresponding p-value = 0.587

Kolmogorov-Smirrov Test
  Test Statistic       = 0.126
  Corresponding p-value > 0.15
```

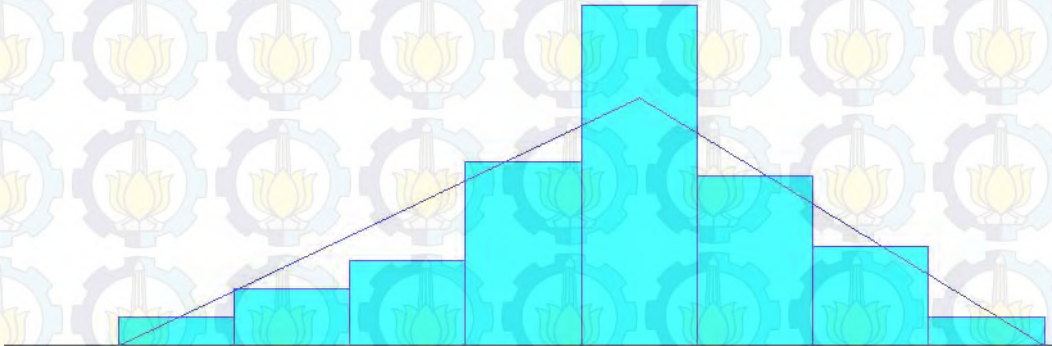**Distribution Fit for Sailing Time to Depot 4**


```
        Distribution Summary

Distribution:    Triangular
Expression:      TRIA(10.2, 10.4, 10.9)
Square Error:    0.002912

Chi Square Test
  Number of intervals  = 5
  Degrees of freedom   = 3
  Test Statistic       = 0.916
  Corresponding p-value > 0.75

Kolmogorov-Smirnov Test
  Test Statistic       = 0.7598
  Corresponding p-value > 0.15
```

Distribution Fit for Sailing Back from Depot 2 to RU IV


```
        Distribution Summary

Distribution:    Triangular
Expression:      TRIA(9, 9.29, 9.94)
Square Error:    0.007413

Chi Square Test
  Number of intervals  = 5
  Degrees of freedom   = 3
  Test Statistic       = 1.31
  Corresponding p-value = 0.729

Kolmogorov-Smirnov Test
  Test Statistic       = 0.060
  Corresponding p-value > 0.15
```

Distribution Fit for Sailing Back from Depot 3 to RU IV


```
        Distribution Summary

Distribution:   Triangular
Expression:     TRIA(15, 15.6, 16)
Square Error:   0.015566

Chi Square Test
  Number of intervals   = 6
  Degrees of freedom    = 4
  Test Statistic        = 5.55
  Corresponding p-value = 0.24

Kolmogorov-Smirnov Test
  Test Statistic        = 0.102
  Corresponding p-value > 0.15
```
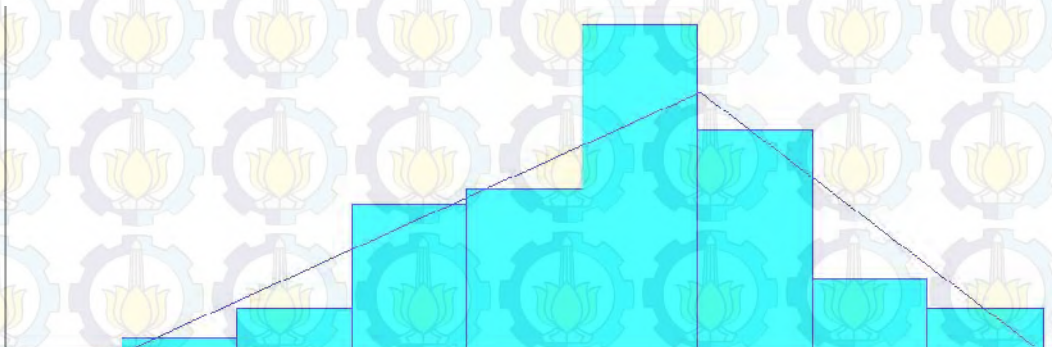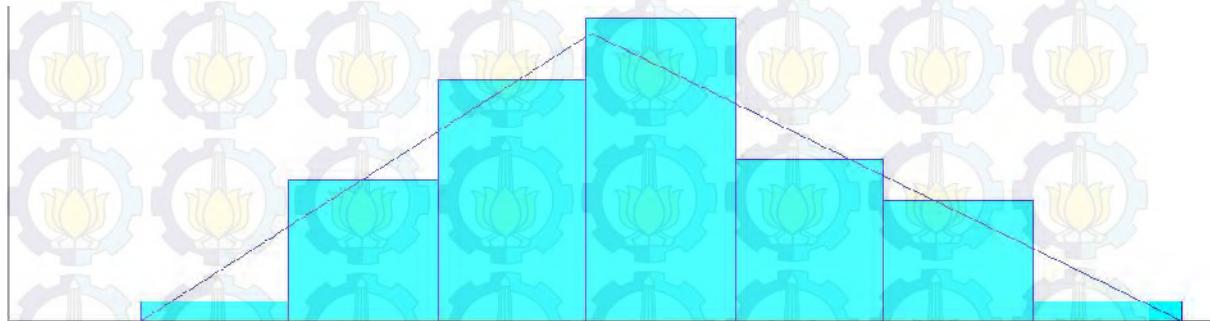
Distribution Fit for Sailing Back from Depot 4 to RU IV


```
        Distribution Summary

Distribution:   Triangular
Expression:     TRIA(11, 11.6, 12)
Square Error:   0.012915

Chi Square Test
  Number of intervals   = 5
  Degrees of freedom    = 3
  Test Statistic        = 5.71
  Corresponding p-value = 0.135

Kolmogorov-Smirnov Test
  Test Statistic        = 0.0849
  Corresponding p-value > 0.15
```

Distribution Fit for Sailing Back from Depot 7 to RU VI


```
        Distribution Summary

Distribution:   Triangular
Expression:     TRIA(24.6, 25, 25.6)
Square Error:   0.003876

Chi Square Test
  Number of intervals   = 5
  Degrees of freedom    = 3
  Test Statistic        = 0.864
  Corresponding p-value > 0.75

Kolmogorov-Smirnov Test
  Test Statistic        = 0.0551
  Corresponding p-value > 0.15
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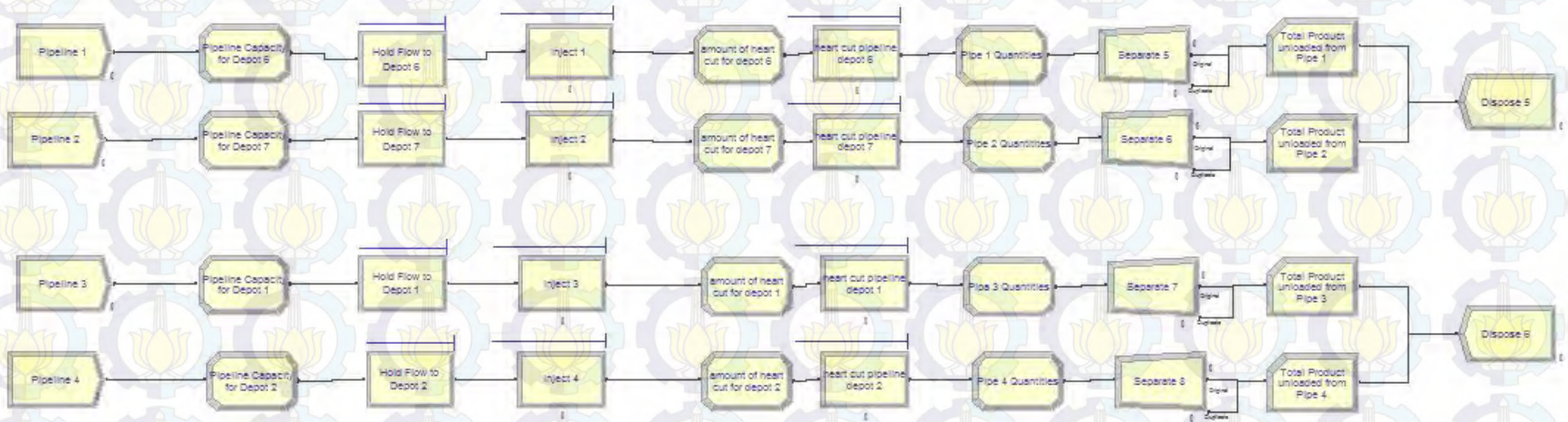
Enclosure 2 – SIMULATION MODEL
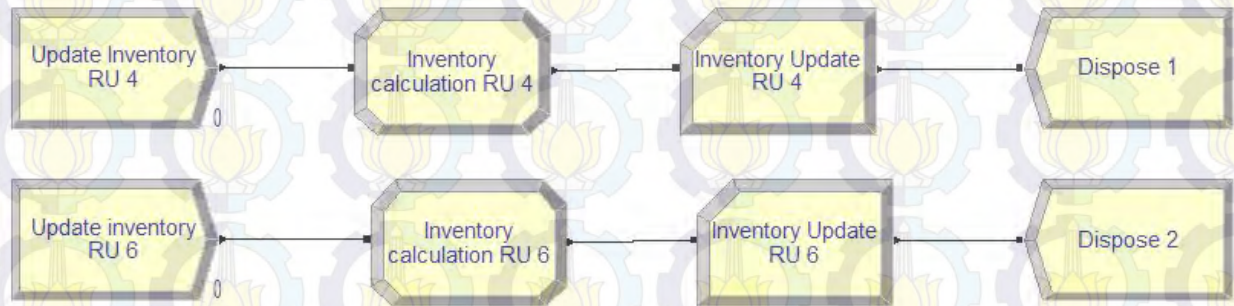
Ship Activities Model in ARENA

SHIP ACTIVITIES
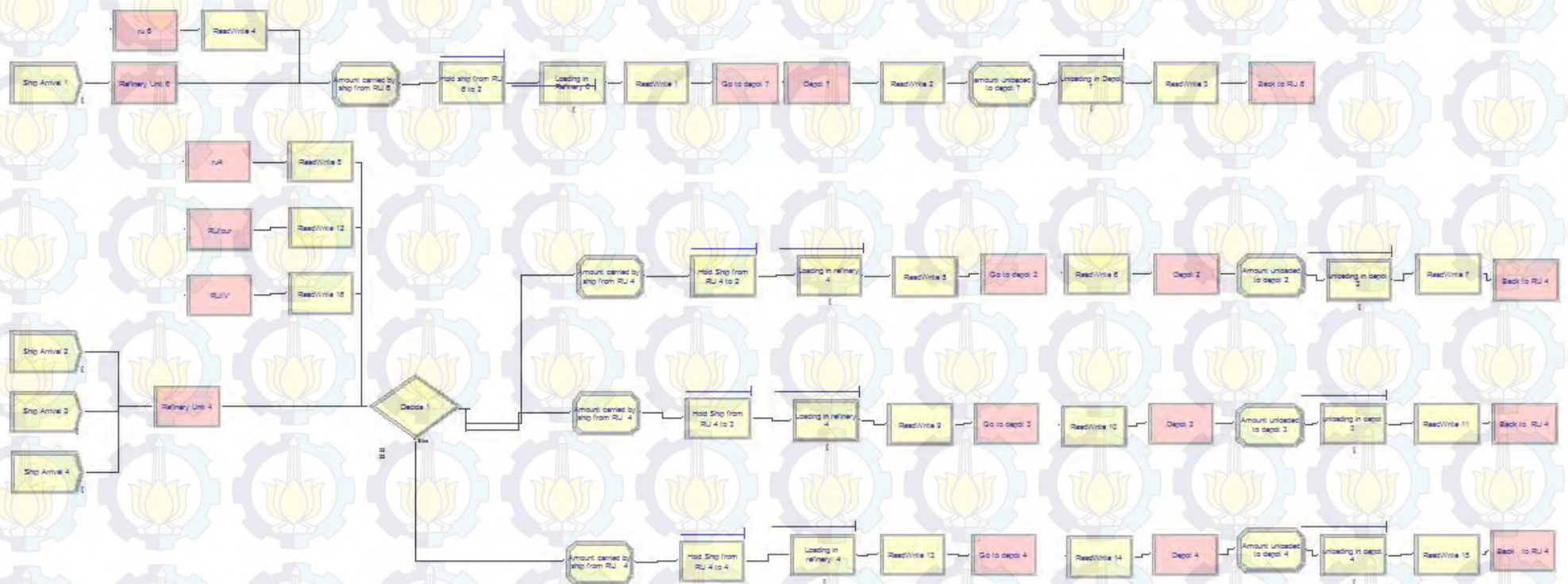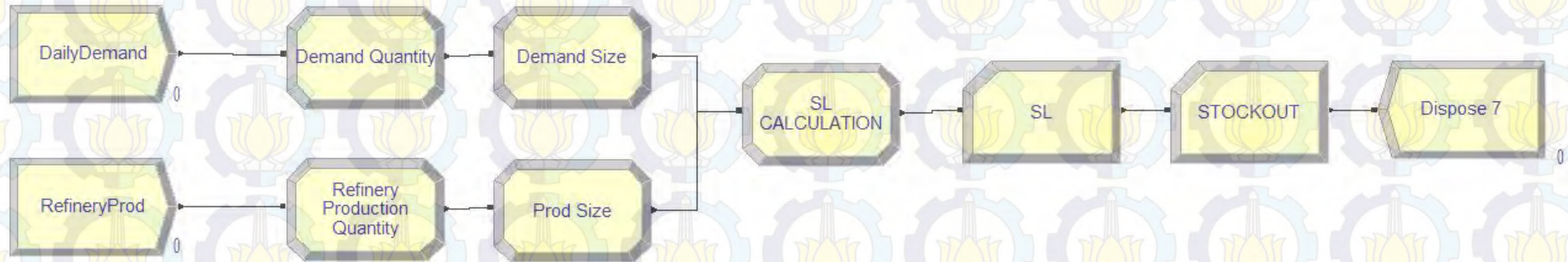
Pipeline Activities Model in ARENA

PIPELINE ACTIVITIES

Inventory Update Model in ARENA

Service Level Model in ARENA

Investment Calculation Model in ARENA

AUTHOR'S BIOGRAPHY

This is Nesya Amalia. Since her birth in Palembang on September 27th, 1993, she is being the first child of Wawan's Family. She went to TK Tamansiswa Palembang (1997-1998) for kindergarten and continued to SDN Kenari 08 PG, Jakarta (1997-2003) for elementary school. She continued to SMP LABSCHOOL JAKARTA for junior high school (2004-2007) and SMAN 68 JAKARTA for senior high school (2007-2011). During her school life, she has made it a point to strive for her goals, which were nothing less than her grandest dreams. One of her dreams is to become an engineer just like her parents. Another is to travel around the world. She applied for a college with SNMPTN and passed as a student in Department of Industrial Engineering of Institut Teknologi Sepuluh Nopember (ITS) Surabaya.

As a college student, Nesya had actively in several communities and interests. She worked as a staff in AKATARA HMTI, BEM ITS, and participated in many activities in ITS. Because she is really interested in Supply Chain Management field of studies, during her semester break, She works for PT. Pertamina (Persero) Department of Supply and Distribution for her internship course work (2014). In her spare time, Nesya enjoys spending time with her family and her piano.