FINAL PROJECT – TI 141501

DETERMINING NUMBER OF TANKER FOR AVTUR DISTRIBUTION IN PT PERTAMINA MOR V USING DISCRETE EVENT SIMULATION

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Surabaya 2018

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APPROVAL SHEET

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FINAL PROJECT

Submitted to Qualify the Requirement of Bachelor Degree
Department of Industrial Engineering
Faculty of Industrial Technology
Institut Teknologi Sepuluh Nopember

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SURABAYA, JANUARY 2018

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ABSTRACT

Avtur is one of ten main fuel products which is distributed by PT Pertamina (Persero) MOR V from four supply points to eight end depots. In practice, some of avtur depots have experienced critical condition state. Asides from increasing of demand, an analysis has led to two hypotheses: (1) End depot needs closer source of supply to minimize lead-time of replenishment and (2) Current number of operational tankers is insufficient. Discrete Event Simulation (DES) was chosen as a method to test out the hypotheses. Indicators used as performance measurement are service level and total distribution cost. Results of this research show that constructed simulation model can be used for determining the number of tankers required to reach the desired service level in two conditions: the current one, and when a new supply point or loading port is added. The model can accommodate the experimentation considering several conditions when there is: a change of waiting time duration in initial loading ports and/or in the new loading port, a change of storage tank capacity, and a change of new loading port location.

Keywords: Avtur, Discrete Event Simulation, Distribution, Tanker

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ACKNOWLEDGEMENT

Alhamdulillah, all praises belong to Allah SWT, by whose grace, guidance, and blessings, the author can finish this research entitled **“Determining Number of Tanker for Avtur Distribution in PT Pertamina MOR V Using Discrete Event Simulation”.**

This research is conducted as a requisite to finish Industrial Engineering major and to achieve Bachelor Degree from Institut Teknologi Sepuluh Nopember (ITS), Surabaya. The author would like to express the biggest appreciation and gratitude to those who had supported, motivated, and helped the author during the completion of this research, namely:

1. Stefanus Eko Wiratno, S.T., M.T., as the supervisor, under whose great guidance, direction, and supervision in tutoring for the whole time, this research can be completed on time.
2. Effi Latiffianti, S.T., M.Sc., as the co-supervisor, for her encouragement, immense knowledge, and insightful experiences that help author throughout this research work.
3. Alfian Nasution, who had helped and given direction during the proposal until the data collection of this research in PT Pertamina (Persero)
4. Mas Ami and Mas Paul who guided, enriched the author knowledge, and gave advices during the problem selection.
5. Mas Dimas, Mas Hayyik, Pak Lasno, Mas Siddha, Mas Widya, and Mas Aga who had helped with the data collection, and gave new insights about existing condition of the system under observation through discussions.
6. Prof. Dr. Ir. Budi Santosa M.Sc., Ph.D., and Dody Hartanto, S.T., MT., as reviewers of research proposal, whose advice and feedback had helped the author in correcting the proposal.
7. Yudha Prasetyawan S.T., M.Eng., and and Dody Hartanto, S.T., MT., as reviewers of final report, whose advice and feedback had helped the author in completing this research.

8. Nurhadi Siswanto, S.T., M.S.I.E., Ph.D., as the head of Industrial Engineering Department, and Yudha Andrian Saputra, S.T., MBA, as the secretary of Industrial Engineering Department, whose support and advise have helped the author for the last couple years.
9. Edy Heri Prasetyo and Juwairiah, the most beloved father and mother, as well as all author's family who always support and continuous prays in every situation.
10. Bu Lusi, Bu Ima, Bu Titin, Bu Ellif, other academic staffs and all faculty members of Department of Industrial Engineering of Institut Teknologi Sepuluh Nopember, for all support and help during the vollege years.

Last, the author realizes that this research is far from perfect. Therefore, constructive criticism and positive suggestions will be very useful in improving the quality of subsequent writing. Apart from all that, the author hope that this report can benefit the readers in general, contribute the academic world, and provide improvement for the company.

Surabaya, January 21st 2018

Author

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CHAPTER 1
INTRODUCTION

1.1 Background

PT Pertamina (Persero), known by the short name of Pertamina, is a state-owned company that operates an integrated business core in oil, gas, renewable and new energy committed to providing a real contribution to the welfare of Indonesia (Pertamina, 2017). Distribution region under Pertamina's operations covers all area in the country, from Sabang to Merauke. As illustrated in Figure 1.1, Pertamina divides Indonesia into 8 marketing operation region (MOR): MOR I (Northern Sumatera), MOR II (Southern Sumatera), MOR III (DKI, West Java, Banten), MOR IV (Central Java), MOR V (East Java, Bali and Nusa Tenggara), MOR VI (Kalimantan), MOR VII (Sulawesi), MOR VIII (Maluku and Papua).

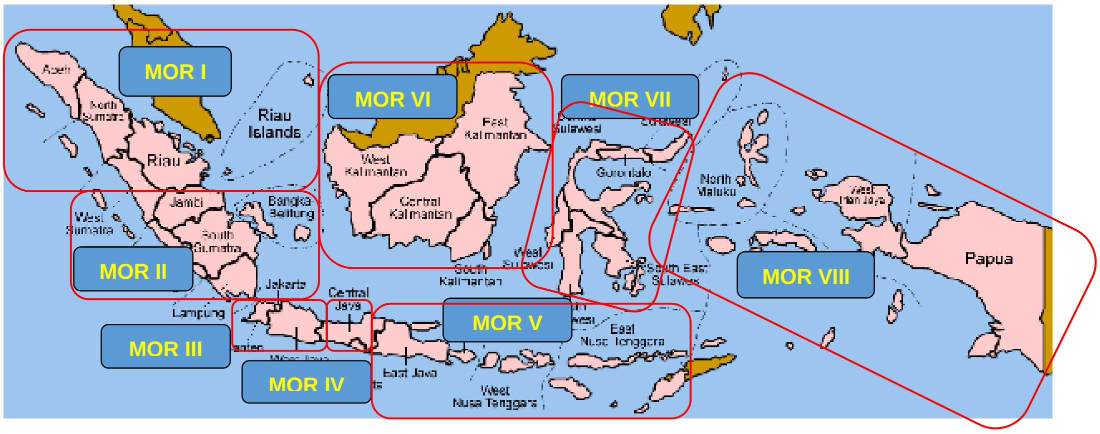

Figure 1. 1 Pertamina Marketing Operational Region (MOR) (Pertamina, 2017)

Indonesia is an archipelago consisting of over 17,000 islands. This condition makes Indonesia one of the most complex fuel-product supply chains in the world due to its geography and population distribution (McKinsey&Company, 2014). It takes various kind of intermodal, such as tanker, rail tank wagon (RTW), pipeline, and bridger or truck, for Pertamina to reach end customers.

Pertamina also has storage tanks scattered across Indonesia as a distribution facility to overcome geographical constraints and demand uncertainty. Types of storage tank are *Terminal Bahan Bakar Minyak* (TBBM) as a transshipment point or main depot, floating storage, and end depot. In avtur distribution system, end depot is called DPPU (*Depot Pengisian Pesawat Udara*).

Nowadays, the role of logistic management has been shifted. Customer value can be created from logistic management through product availability, timeliness and consistency of delivery, ease of placing orders, and other elements of logistic service (Campbell et al., 1997). Pertamina has adopted responsive supply chain with vendor managed inventory model (VMI) in order to fulfill demand in Indonesia. In this model, retailer gives demand information from customer and remaining inventory level instead of deciding what, when, and how much to deliver (Pujawan & Mahendrawathi, 2010). VMI is implemented in distribution of Pertamina's products, including aviation fuel turbine. Pertamina Headquarter (as the supplier) maintains the inventory level of DPPU (buyer) in Indonesia to above prescribed threshold and, at the same time, minimizes the distribution cost. This strategy can be categorized as the inventory routing problem (IRP).

Aviation fuel turbine (well known as avtur) is 1 of 10 main fuel products in Pertamina: Premium, Kerosene, High Speed Diesel, Industrial/Marine Diesel Oil, Industrial/Marine Fuel oil, Avgas, Avtur, Pertamax, Pertamax Plus, Pertamina Dex. The part of Pertamina that takes role as marketer and provider of avtur is called Pertamina Aviation. The Key Performance Indicator (KPI) of Pertamina Aviation is zero occurrence of critical condition on every TBBM and end depot containing avtur. Critical condition is a condition in which the inventory level has reached or fell below threshold prescribed by Pertamina. The threshold for every end depot may be varied depending on supply pattern and depot's condition.

To supply and distribute avtur throughout Indonesia, there were eight tankers performing discharging activities in MOR V during period of June – August 2017. Meanwhile, in planning avtur supply and distribution across Indonesia, Pertamina Aviation also collaborated with other units, i.e. Pertamina Shipping. One of Pertamina Shipping responsibility is providing maritime transportation from refinery unit and/or TBBM to end depot throughout Indonesia, determining tanker scheduling, and monitoring tanker movement.

To ensure that collaboration among functions work well, Pertamina has an integrated program which generates supply pattern and transportation utilization for two months period ahead. From supply pattern, tanker scheduling is then created and will be updated every month. However, on the day-to-day operation, deviation from initial planning can be occurred, leading to critical condition occurrence in some depots and high distribution cost.

Based on the last six months demand, avtur consumption has been increasing. This occurs because some airlines under the management of PT Angkasa Pura I have opened new flight routes as a means to intensify connectivity and to develop tourism in the central and eastern region of Indonesia. The increasing of avtur consumption influences the safety of avtur national stock. In fact, some depots have experience critical condition. Figure 1.2 shows that the most frequent depot which undergoes critical condition during June – August 2017 is Bali, then, followed by Ende.

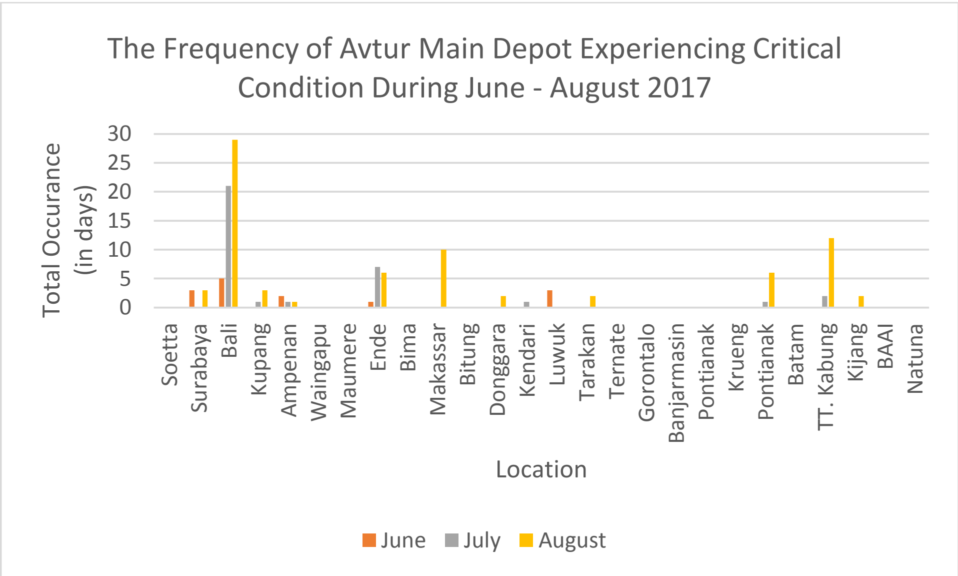

Figure 1. 2 The Frequency of Avtur Main Depot Experiencing Critical Condition during May - August 2017 (Pertamina, 2017)

Increasing of avtur consumption cannot be the sole reason for why depot in Bali and Ende experience critical condition. From the problem, hypotheses to establish from the situation are:

1. Bali needs closer source of supply which can minimize the lead time of replenishment;
2. Current number of operating tankers are insufficient.

However, these hypotheses should be put under further review since implementing plans as a result of the hypotheses can affect other aspects in the system. For instance, to upgrade the capacity of storage tank in an end depot, the readiness of facilities in that end depot should be checked first. Jetty in that end depot, currently, can only be berthed by tankers with DWT of 4100 KL. If storage tank is upgraded without upgrading the capacity of jetty, this decision would be a futile attempt since it takes multiple replenishments to fulfill bigger storage tank and it leads to low utilization of storage tank.

Researches related to routing and scheduling in transportation problem, lately, have been very popular for this past decade. This problem is widely known as Inventory Ship Routing Problem (ISRP). Most of ISRP cases are solved using analytical approaches, for instance an ISRP for multi-product with a heterogeneous fleet model using a hybrid cross entropy-genetic algorithm (CEGA) (Santosa et al., 2016). The objectives of the research were selecting the ship and finding the best route, product allocation, and shipped quantity. The model assumed that the products were always available at the loading port during the planning horizon and consumption rate at each port and the speed of the ship were constant. Another research related to the ship inventory routing and scheduling problem with undedicated compartments was reported by Siswanto et al. (2011). The research problem was the distribution of multi product which cannot be mixed using heterogeneous fleet. The objective of the problem in Siswanto et.al (2010) was to find a minimum cost solution for the ship routing and loading/unloading schedules.

The problem in this report differs from that of Santosa et al. (2016) because it uses four loading ports – two of them are transshipment point in which the inventory level depends on supply from other refinery unit, the product is only one, eight end depots (DPPU) in the system, and the consumption rate is stochastic. in comparison with the problem of Siswanto et al. (2011), the problem in this this report is for a single product, partial loading is not allowed, there are time windows on several discharge ports, not all of ports can receive more than one ship at a time (limited port capacity). Additionally this research scope is limited by the hypothesis that the current number of tankers is insufficient to serve 8 DPPUs during the planning horizon.

With the differences, the methods used in both Santosa et al. (2016) and Siswanto et al. (2011) cannot simply be used in the current problem. With the problem complexity, different approach may be implemented. Complexity in the problem is represented by variability and interdependency. Variability, here, comes from the stochastic of demand and duration of pre-time and post-time, both in loading and discharge port. Meanwhile, collaboration of many functions in Pertamina causing interdependency among elements. For instance, the route and scheduling of tankers are influenced by inventory position of avtur in DPPU, service level of DPPU is affected by service level of other DPPUs, tanker availability in loading port, and tanker specification affects the unloading process since not all of type of tanker are compatible with jetty specification. Thus, discrete-event simulation is one good alternative to be used as a method to solve the problem.

Many previous Final Projects were successfully applying discrete-event simulation for problem solving. Some most recent ones were to determine quantity of tanker for multi-undedicated compartment in fuel oil distribution planning by Anggoro (2015) while Kurniawati (2017) has modeled sea distribution simulation by considering supply and transportation disruption. However, those two models cannot be implemented in this problem due to natural characteristics of simulation that were customized or tailored based on problem to be solved. Thus, a new simulation model is proposed for this problem.

Simulation in this case, can be used to test the hypotheses which have been stated based on the research background. Simulation also best models the interdependency and variability that cannot be obtained by any other way – for instance, it would be hard to predict and modify uncertainties such as bad weather in a mathematical model. By using simulation, bad weathers can be put into simulation by looking at likelihood of occurrence from historical data of company. Adding to the complexity reasons, simulation is appropriate because the cost to experiment of the actual system is greater than the cost of simulation. Suppose, for example, Pertamina wants to know the effect of adding and reducing the number of tanker to distribute avtur in MOR V (East Java, Bali, and Nusa Tenggara). It is highly not recommended for Pertamina to do trial-and-error directly due to expensive operating cost of tanker. Therefore, discrete-event simulation is used to imitate and analyze existing condition of the system, also, to improve system performance by experimenting alternative courses of action through "what-ifs" scenario.

1.2 Problem Identification

Based on the background, the problem in this research is how to determine number of tankers to maintain the inventory level of DPPUs in MOR V, while satisfying demand at minimal cost during a given planning horizon.

1.3 Research Purposes

The purposes of the research are:

1. To develop a conceptual and simulation models of avtur supply and distribution system in Marketing Operation Region (MOR) V
2. To perform an experiment on determining number of operating tanker in MOR V with or without the existence of new TBMM located in Tuban.
3. To find variables which are sensitive to service level

1.4 Research Benefits

The benefits of the research are:

1. The model can be used for future reference for Pertamina.
2. The research is a reference for future research related to development of avtur supply and distribution model.

1.5 Research Scope

1.5.1 Limitations

The limitations in this research are:

1. The object of interest in this research is avtur supply and distribution starting from 1st tier (refinery unit) and/or 2nd tier (TBBM) to end depot (DPPU).
2. Investment cost is not considered in this research

1.5.2 Assumptions

The assumptions used in this research are:

1. There is no shrinkage and deviation in measurement of avtur volume during supply and distribution process using tanker.
2. The avtur production from the refinery unit is infinite.
3. The tankers never break down during the planning horizon.
4. The tanker speed for all type of tankers is 10 knots in average.
5. The bunker consumption during ballast (empty), laden (utilized), and discharging are the same.
6. Allocated volume for every discharge port will be rounded up to the nearest ten.

1.6 Writing Methodology

This research consists of seven chapters, which will be explained as follows.

CHAPTER 1 INTRODUCTION

Chapter 1 in explains about the background, the identified problem, the research scope, purposes, and benefits, as well as the writing methodology on how the report is organized.

CHAPTER 2 LITERATURE REVIEW

This chapter contains theoretical contributions and findings which will be used in this research. This chapter explains about overview of avtur in Pertamina, transportation and distribution management, tanker cost calculation scheme, inventory routing problem, simulation, validation and verification, and the summary of previous researches.

CHAPTER 3 METHODOLOGY

The research methodology explains the steps used in this research, also methods and approximation used in order to do this research systematically.

CHAPTER 4 DATA COLLECTION AND PROCESSING

Chapter 4 explains all the obtained data and how they will be used in this research. Statistical analysis and the use of software for data processing are also explained in this chapter.

CHAPTER 5 SYSTEM MODELLING

Chapter 5 consists of the detailed development of alternative courses of action based on the determined decision variable, followed by formulating the conceptual model, and finally the construction of discrete-event simulation (DES) model using ARENA software.

CHAPTER 6 SIMULATION MODEL ANALYSIS

Chapter 6 is about experimentation, running the simulation model for each alternative courses of action. Simulation result interpretation and sensitivity analysis from the obtained results are also described in this chapter.

CHAPTER 7 CONCLUSION AND SUGGESTION

This final chapter list all conclusions drawn from the research. The suggestion for the current and future research will be also included in this chapter.

CHAPTER 2

LITERATURE REVIEW

2.1 Aviation Fuel Turbine (Avtur) Overview in Pertamina

Aviation fuel turbine or Avtur is the fuel for jet aircraft which consists of hydrocarbon middle distillate having similar distillation and flash point characteristics as kerosene, with maximum aromatic content of 20% volume. It has a freezing point less than -47^{0}C and octane number of 80-145 RON (Dwinugroho et al., 2016). With its special characteristics, avtur has a rather different treatment than other fuel oil during its distribution and handling.

As illustrated in Figure 2.1, avtur might involve different kind of transportation modes during the distribution process. Some of transportation modes are a dedicated system in which it is only reserved for a single product, while sometimes avtur also can be shipped through common-carrier multiproduct transportation modes.

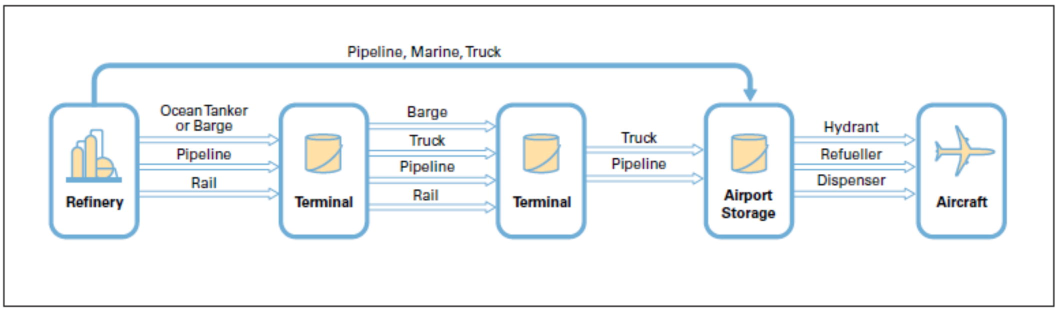

Figure 2. 1 Avtur Distribution System (CHEVRON U.S.A. Inc., 2000)

The supply and distribution pattern of avtur is started from a refinery unit (RU). Then, avtur may be shipped directly to aviation fuel depot / airport storage (DPPU) or commonly distributed through one, or more, TBBM and depot before arriving in DPPU. Figure 2.2 shows that there are 64 DPPU spread across 8 marketing operation region (MOR) in Indonesia.

Figure 2.2 Domestic Aviation Fuel Service Network (Pertamina, 2016)

During avtur supply and distribution system, tanker loads avtur in full capacity to fulfill the effective load factor (EFL) standard and to avoid dead freight or amount that should be paid when space on a vessel does not utilized (Embassy Freight, 2017). Tanker usually unloads all capacity in one TBBM or end depot and goes back to the supply point to serve another depot or TBBM. However, in some cases, tanker will do a multi discharge if the total demand in particular depot is smaller than the maximum capacity of avtur transported by tanker. For instance, a tanker loads avtur from STS (ship-to-ship transfer) Kalbut, then, stops at several DPPUs such as Kupang, Ende, Waingapu, Bima, and Ampenan (MOR V). The deployment of avtur TBBM and DPPU (marked with purple flag including STS Kalbut) in MOR V is illustrated in Figure 2.3. There are four supply points (Cilacap, STS Kalbut, TT. Manggis, and Balikpapan) and eight DPPUs (Ampenan, Bima, Benoa (Bali), Waingapu, Ende, Surabaya, Kupang, and Maumere).

Figure 2. 3 The Deployment of Avtur TBBM and End Depot in MOR V (Pertamina, 2017)

In avtur supply and distribution system, there are certain situations which need particular patterns: regular, alternative, and emergency. (1) Regular situation is in which avtur stock is sufficient: coverage days are exceeded or met up to next supply from supply point. There is also no operational disruption. (2) Alternative situation is in which avtur stock is not sufficient until next supply due to disruptions. However, emerged disruptions still can be handled with altering supply pattern from other nearest supply point by considering speed and economical aspect. (3) Emergency situation is in which avtur stock is not sufficient until next supply and cannot be handled by altering supply pattern. Economical aspect does not put into consideration for this situation.

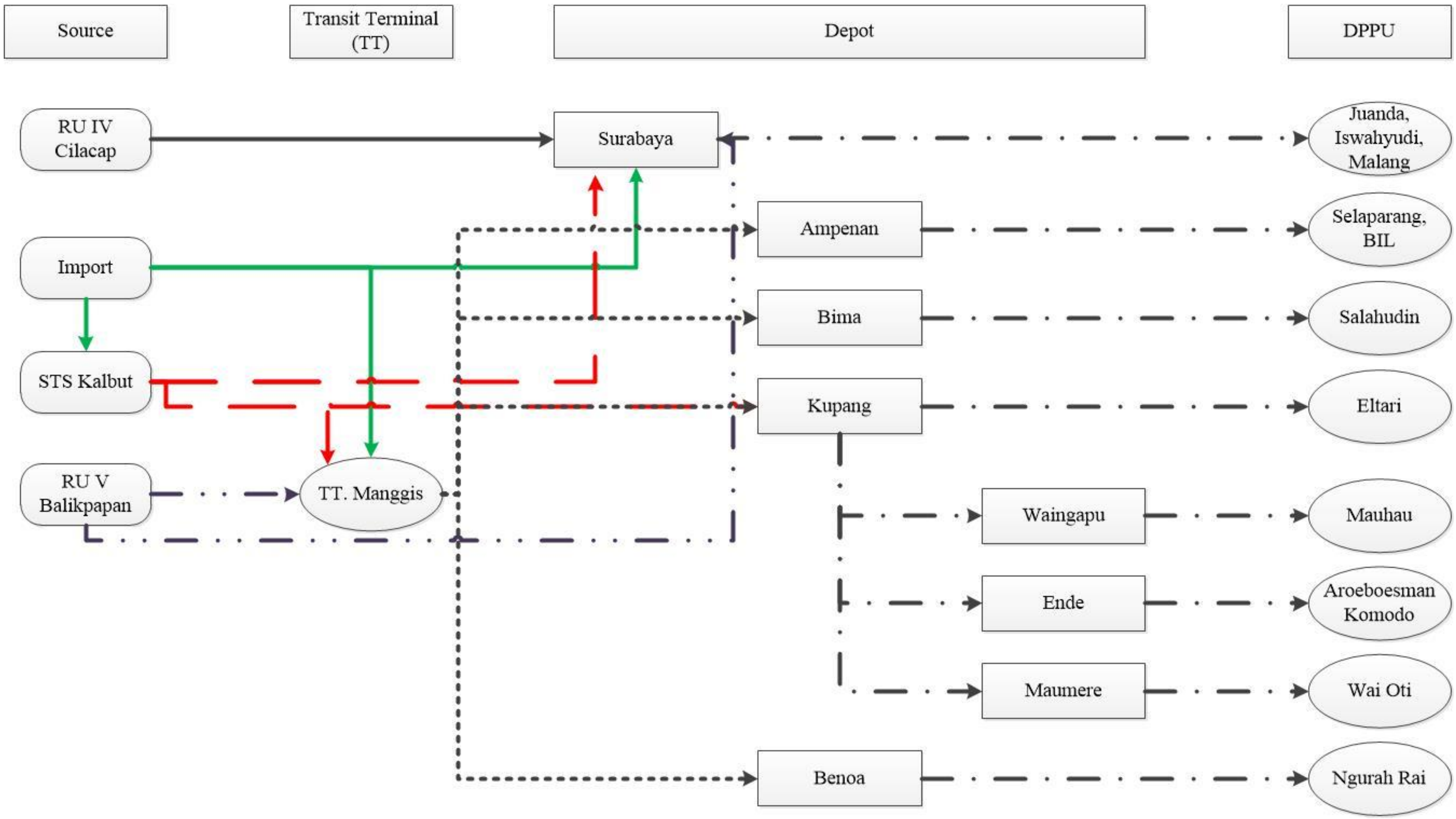

Figure 2. 4 The Supply and Distribution Pattern of Avtur in MOR V during Regular Condition (Pertamina, 2017)

2.2 Transportation and Distribution Management

The ability to ship product to customer on the right time, in the right quantity, and in good condition really determine the product competitiveness in market (Pujawan & Mahendrawathi, 2010). However, for oil fuel as the source of energy, distribution and transportation network hold a vital role in order to maintain the economic welfare of Indonesia. Due to geographic restriction, it usually takes a combination of transportation mode to distribute oil fuel from RU to end customer. Transportation modes which are used by Pertamina are tanker fuel, pipeline, rail truck wagon (RTW), and bridger or oil truck. Every transportation mode has its advantages and limitations showed in Table 2.1.

Table 2. 1 Evaluation of Various Transportation Mode

Transportation Mode	Advantages	Limitations
Tanker	1. Cost efficiency 2. Ship cargo in high volume	1. Affected by the weather conditions 2. Low speed
Pipeline	1. Transport cargo in high accuracy 2. Low speed	1. High investment cost 2. Vulnerable to leakage
Rail Truck Wagon (RTW)	1. No traffic 2. Ship cargo in high volume 3. Moderate speed	Limitation of route selection
Bridger / Oil Truck	1. Door-to-door service 2. Ship cargo in moderate volume 3. Flexible route selection 4. Moderate speed	1. Low reliability due to traffic 2. Costly for long distance destination

Table 2. 2 Relative Rankings of Transportation Mode by Cost and Operating Performance Characteristics (Ballou, 2003)

	Performance Characteristic				
			Delivery-Time Variability		
Mode of transportation	**Cost per ton-mile**	**Average Delivery Time ***	**Absolute**	**Percent****	**Lost and Damage**
	1 = Highest	**1 = Fastest**	**1 = Least**	**1 = Least**	**1 = Least**
Rail	3	3	4	3	5
Truck	2	2	3	2	4

Mode of transportation	Performance Characteristic Cost per ton-mile	Average Delivery Time *	Delivery-Time Variability Absolute	Percent**	Lost and Damage
	1 = Highest	1 = Fastest	1 = Least	1 = Least	1 = Least
Ship	5	5	5	4	2
Pipe	4	4	2	1	1
Airplane	1	1	1	5	3

*Door-to-door Speed

**Ratio of absolute variation in delivery time to average delivery time

Among four transportation modes, the most used and suitable transportation in Indonesia due to geographical, effective, and efficient reasons is tanker. For avtur supply and distribution, the ideal condition is using dedicated compartment in which there is no other product besides avtur in voyage. However, due to geographic and other reasons, this condition is violated in MOR VIII.

2.3 Tanker Cost Calculation Scheme

To support the fuel supply and distribution system, Pertamina uses 59 owned tanker and 160 chartered tankers. There are 8 time-charter tankers used for avtur supply and distribution in MOR V during June – August 2017. The cost incurred when owned tankers are crewing cost, bunker cost, and port clearance. Meanwhile, there are four schemes of chartered tankers which are based on “who is paying what” (Suyono, 2001):

2.3.1 Time Charter

Charterer hire a specific tanker for specified period of time. The hire period may be the duration of one voyage or up to several years. Owner is responsible for capital cost and operating cost (crewing cost, maintenance& repair, administration, insurance). While, the charterer is responsible for voyage cost (bunker cost, port charges).

2.3.2 Bareboat/Demise Charter

Owners lease their entire tanker, yet have control over technical management of ship and commercial operations only. Meanwhile, the charterers have the responsibility of operating the tanker. The charterers pay for operating cost and voyage cost.

2.3.3 Voyage Charter

This charter specifies for the carriage of full cargo for one voyage only – origin port to destination port. Charterer has no responsibility for the operations of the vessel but charterer pays stevedoring (loading/unloading) cost.

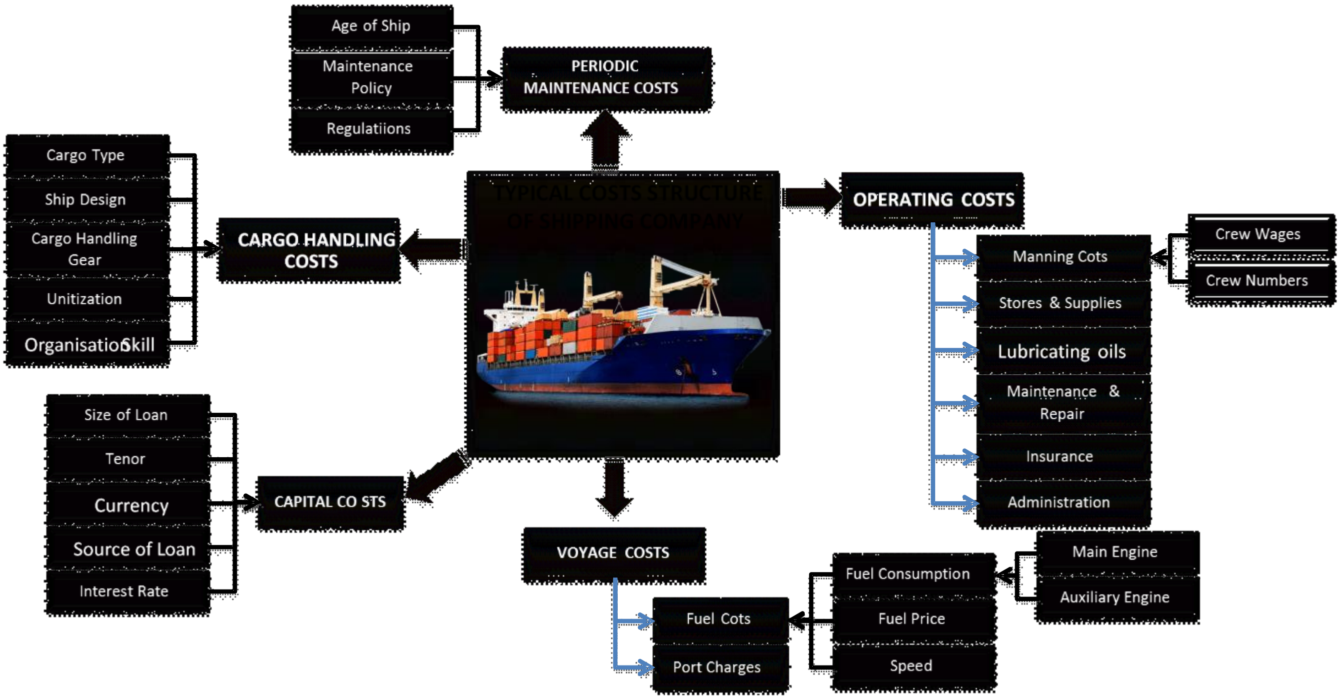

Figure 2. 5 Typical Costs Structure of Shipping Company (Stopford, 2009)

2.4 Inventory Routing Problem

Vendor Managed Inventory (VMI) is a common model implemented by companies around the world to optimize its supply chain. VMI concept is that the supplier monitors the inventory level of each retailer and determines the replenishment policy in order to avoid stock out (Chrysochoou & Ziliaskopoulos, 2015). This problem is a class of inventory routing problem (IRP) which considers an integration of an inventory management problem and a routing problem (Siswanto et al., 2011). The objective is to minimize the distribution cost while satisfying demand during the planning horizon. Three decisions which have to be made in IRP (Campbell et al., 1997) (1) when to serve a customer, (2) how much to deliver to a customer when it is served, and (3) which delivery routes to use. The difference between IRP and traditional vehicle routing problem is IRP is based on inventory instead of order.

Pertamina assigns tanker to distribute avtur and other fuel products to TBBM or depot if the coverage days of its current inventory position has reached or falls below prescribed threshold. Based on Johnson & Malucci (1999), the coverage days can be calculated as follow.

$$CD = \frac{I0}{DOT + AT}$$

Where:

CD : Coverage days / days supply

$I0$: Inventory currently on hand in units

DOT : Daily objective throughput in units/day

AT : Actual throughput / known requirements in units/day

2.5 Simulation

Simulation is a representative of the real-world system. Law & Kelton (1991) stated that if the relationships that compose the model are simple enough, analytic solution can be used to obtain exact information on questions of interest. However, the real-world system is commonly too complex to be evaluated analytically. Thus, the model can be studied through simulation. System is considered as complex if there are interdependency and variability. Sterman (2000) classified complexity into two types:

a. Combinatorial Complexity

   Combinatorial complexity, also known as detail complexity, is related to the number of components in a system or the possible number of combinations of system components. Combinatorial complexity is related to the size of a system.

b. Dynamic Complexity

   Dynamic complexity is related to the interaction of components in a system over time and it is not necessarily related to the size of a system. It can arise in simple systems with low combinatorial complexity.

Based on Law & Kelton (1991), simulation models are classified into three different dimensions:

a. Static vs. Dynamic Simulation Models

   A static simulation model is a representation of a system in which time simply plays no role. On the other hand, a dynamic simulation model represents a system as it evolves over time.

b. Deterministic vs. Stochastic Simulation Models

   A deterministic simulation model does not contain any probabilistic components, while a stochastic simulation model has at least some random input components.

c. Continuous vs. Discrete Simulation Models

   Discrete simulation model concerns the modeling of a system as it evolves over time by a representation in which the state variables change instantaneously at separate points in time. Meanwhile, continuous simulation model concerns the modeling over time of a system by a representation in which the state variables change continuously with respect to time. The decision whether to use a discrete or a continuous simulation model is based on the objectives of study.

2.6 Verification and Validation

Verification and validation are course of actions which are done to ensure the model is correct. Verification and validation have to be performed again when any changes in model occurred since the model is developed before becoming a valid simulation model. Based on Rockwell Automation (2017), verification and validation are described as follow.

2.6.1 Verification

Verification ensures that the model behaves in a way it is intended. If the model is constructed in segments, then each segment should be verified separately and the final verification must be performed with the completed model.

2.6.2 Validation

Validation ensures that the model behaving the same as the real system. If the system currently exists, some kind of comparison can be made to ensure that the model represents the real world. If the system does not exist, the simulation results can be compared to the similar system. If there is no real system to compare with the simulation, then true validation cannot be performed.

2.7 Summary of Previous Researches

In this research, several journal or findings related to inventory routing problem with or without transshipment are used as references in the process making of this research. The summary of previous researches are shown in Table 2.3.

Table 2. 3 The Summary of Previous Researches

	Fuadie Rahman (2008)	Ratna Trishartanti (2007)	Rizki Setyo Anggoro (2015)	This Research
Title	Pengembangan algortima IRP untuk penjadwalan kapal tanker BBM multi-compartment (Studi kasus PT Pertamina UPMS V)	Pemodelan rute dan penjadwalan kapal tanker multi kapasitas (Studi kasus PT Pertamina UPMS VII)	Penentuan jumlah kapal multi-undedicated-compartment dalam perencanaan distribusi BBM dengan metode simulasi (Studi kasus PT Pertamina MOR V)	Determining Number of Tanker for Avtur Distribution in PT Pertamina MOR V Using Discrete Event Simulation
Problem	Determining scheduling of multi-compartment tanker in order to minimize the total cost while maintaining BBM stock in destination depot	Determining the alternative route including the tanker scheduling with VRP model in order to minimize the total cost while maintaining BBM stock in destination depot	Determining the number of tanker needed for Nusa Tenggara region and determining the number of tanker to anticipate increasing demand for the next 3 years	Determining number of tanker operated in MOR V with or without consideration of existence of new TBBM in Tuban
Method	Heuristic algorithm	VRHTW heuristic	Discrete-event simulation	Discrete-event simulation
Demand	Deterministic	Deterministic	Stochastic	Stochastic
Product	3 (premium, kerosene, solar)	1 (premium)	3 (premium, kerosene, solar)	1 (avtur)
Number of Ship	fixed, heterogeneous	variable, heterogeneous	variable, homogeneous	variable, heterogeneous
Supply Port	1	2	1	4
Demand Port	5	17	8	8

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CHAPTER 3

METHODOLOGY

The research methodology provides sequence of activities that will be performed in this research. The detailed procedure is depicted in Figure 3.1 and Figure 3.2.

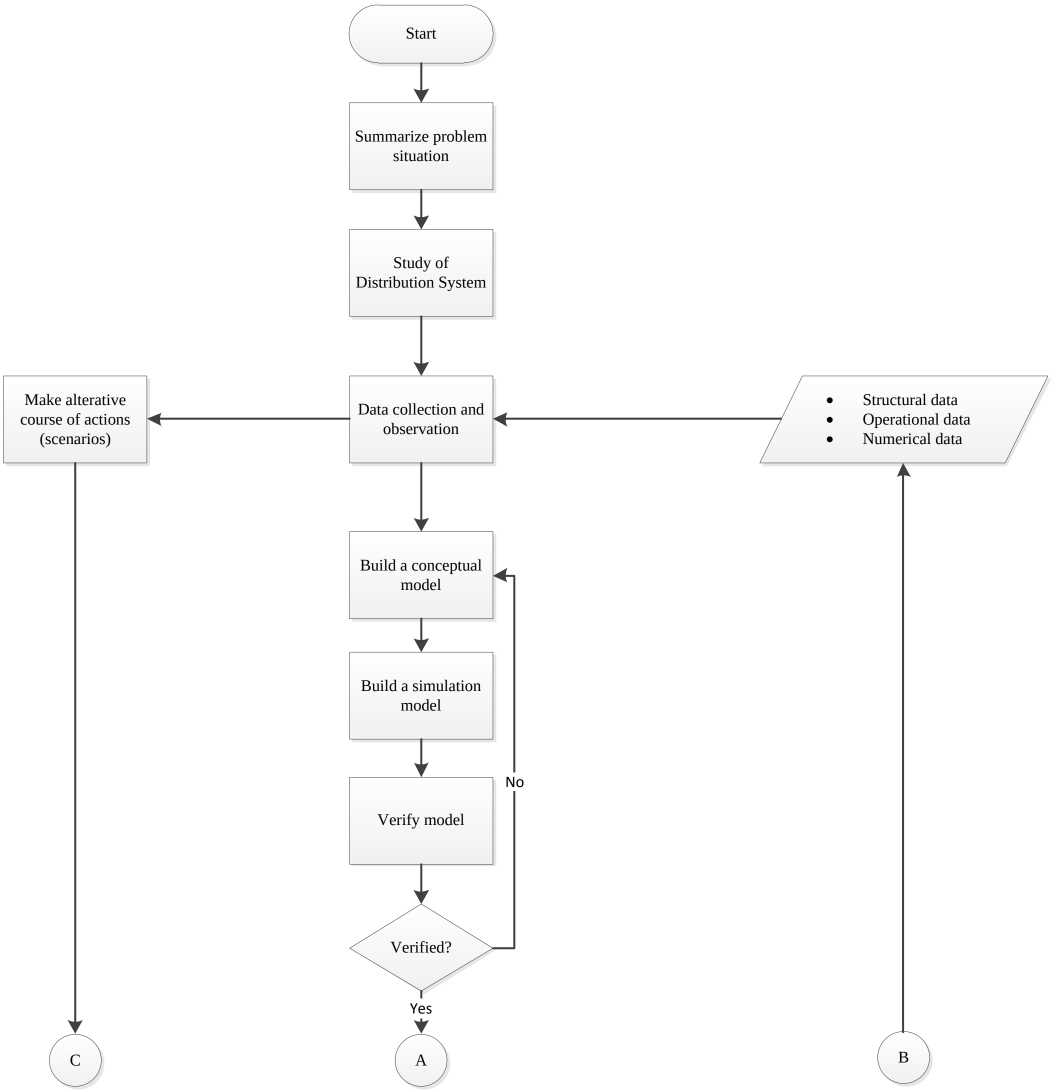


Figure 3. 1 Flowchart of Methodology Research

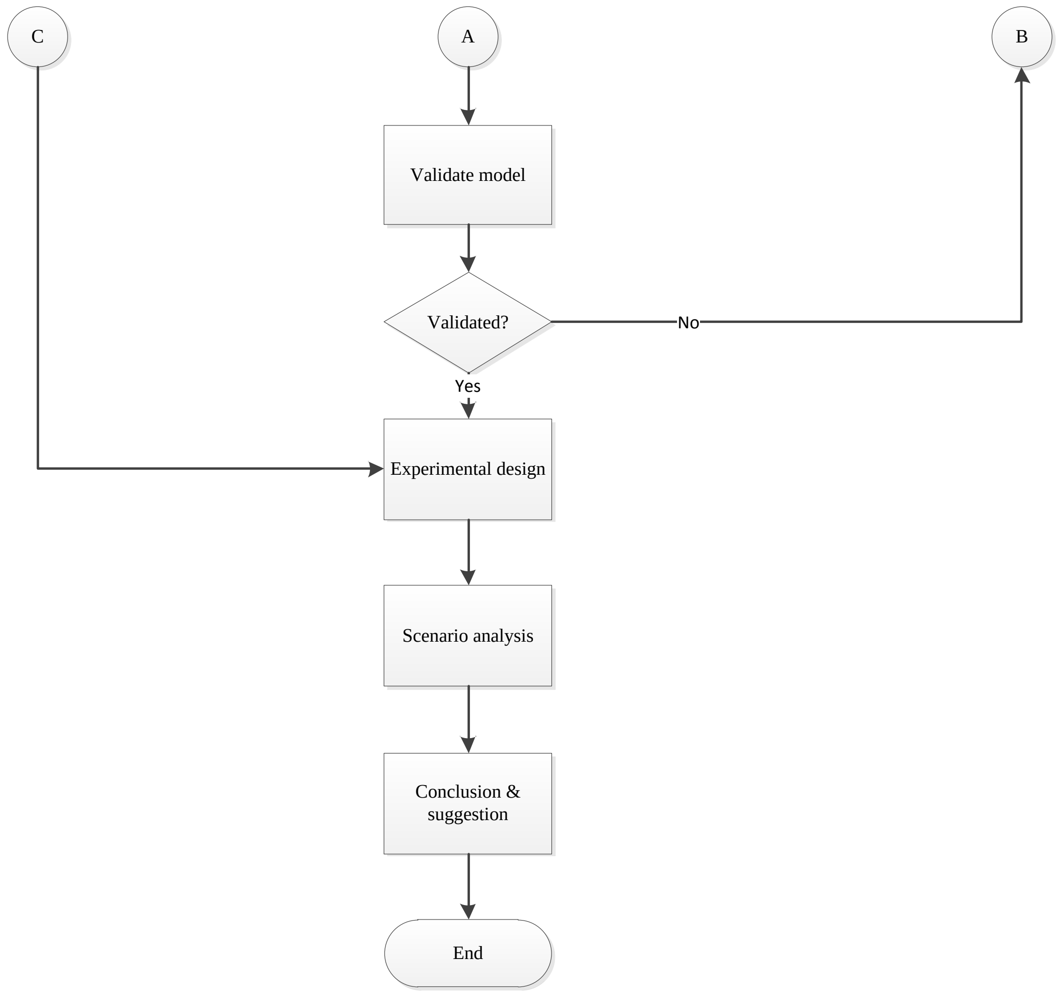


Figure 3. 2 Flowchart of Methodology Research

3.1 Summary of Problem Situation

Pertamina implements VMI model for the supply and distribution system in which Pertamina determines what, when, and how much to deliver to its end customers. It may pass several tiers (refinery unit, TBBM, DPPU) before products reach its intended destination due to geographical and other factors. To simplify monitoring the supply and distribution process, Pertamina divides Indonesia into 8 MOR (Marketing Operation Region).

In 2017, several Indonesia airlines opened new flight routes which increasing the avtur consumption. It makes inventory level of several depots become critical. Thus, it needs alternative courses of action to maintain the inventory level at minimal cost during a given planning horizon. Some hypotheses emerge from this situation: (1) number of current operational tanker is insufficient, and (2) current supply point or loading port (Cilacap) is quite far from discharge port and has high berth occupancy ratio. Thus, closer loading port which still has moderate berth occupancy ratio is expected to quicken replenishment process.

The problem of avtur supply and distribution system is pictured in Figure 3.3. The object of interest in this system is avtur supply and distribution system starting from 1st tiers to DPPUs in MOR V using tanker as the transportation mode.

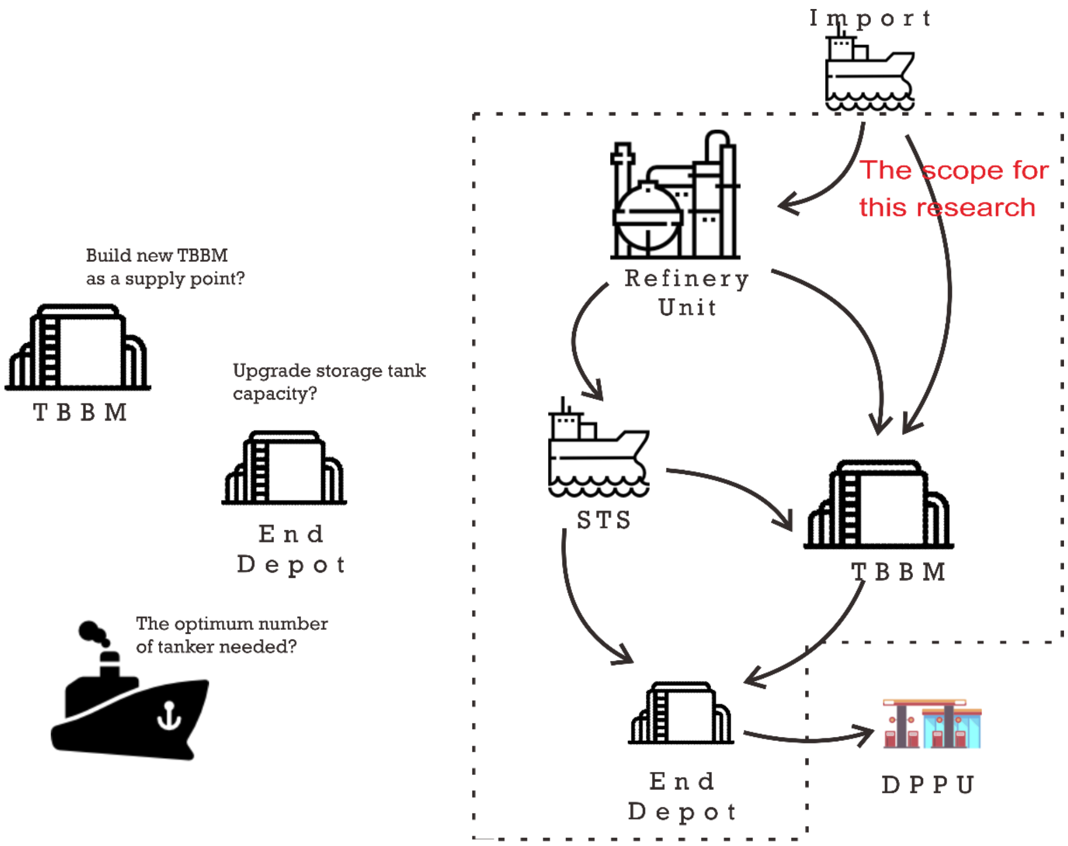


Figure 3. 3 Rich picture of Problem Situation

Based on the summary of problem situation, the six elements of a problem referring to Daellenbach & McNickle (2005) are formulated. The six elements of a problem in this research are:

3.1.1 *The Decision Maker*

The decision maker for avtur supply and distribution system in MOR V are the management of Pertamina: Aviation, shipping, Region V, Supply and Distribution (SnD).

3.1.2 *The decision maker's objectives*

The decision maker's objectives are maintaining the overall service level of avtur above 95%, including service level of Benoa above 90% and minimizing the total cost incurred during avtur supply and distribution system.

3.1.3 *The associated decision criterion*

The associated decision criteria used as rule are minimizing the occurrence of avtur inventory level becomes critical and minimizing fixed and variable cost during supply and distribution system.

3.1.4 *The performance measure*

The associated measure of performance for this research are service level and cost of avtur supply and distribution. For service level, the variable that is being considered is the total days of occurrence of critical condition. This variable is used because zero occurrence of critical condition is the KPI of Pertamina Aviation. However, it is difficult to reach zero occurrence of critical condition since there are many factors which are out of control of Pertamina. Thus, the KPI of Pertamina Aviation can be adjusted into 95% of overall service level and 90% for service level of Benoa.

$$Service\ Level = 1 - \frac{The\ total\ days\ of\ critical\ condition\ occured}{The\ total\ days\ during\ given\ planning\ horizon} \quad (3.1)$$

Distribution cost is calculated based on fixed cost and variable cost. For owned tanker, fixed cost is disregarded, while variable cost consists of bunker consumption, crewing, and port charge. For spot tanker, the cost incurred is similar to time charter. Fixed cost is calculated based on how long a tanker is chartered, not based on the delivery frequency. Variable cost consists of bunker consumption, port charges, and crewing. The inventory holding cost is disregarded because the storage tanks of avtur are owned by Pertamina.

$$Total\ Distribution\ Cost = Fixed\ Cost + Variable\ Cost \tag{3.2}$$

3.1.5 The control inputs or alternative courses of action

The alternative courses of action for this research are determining number of tankers to be utilized, adding another supply point for DPPUs in MOR V, or the best combination which satisfies the decision criterion.

3.1.6 The context

The contexts in which the problem occur is the actual demand for avtur in MOR V.

After the six elements of problem are identified, interrelationship diagram can be constructed. Interrelationship diagram is constructed in order to show the relationship among problems occurring in avtur supply and distribution (Figure 3.4).

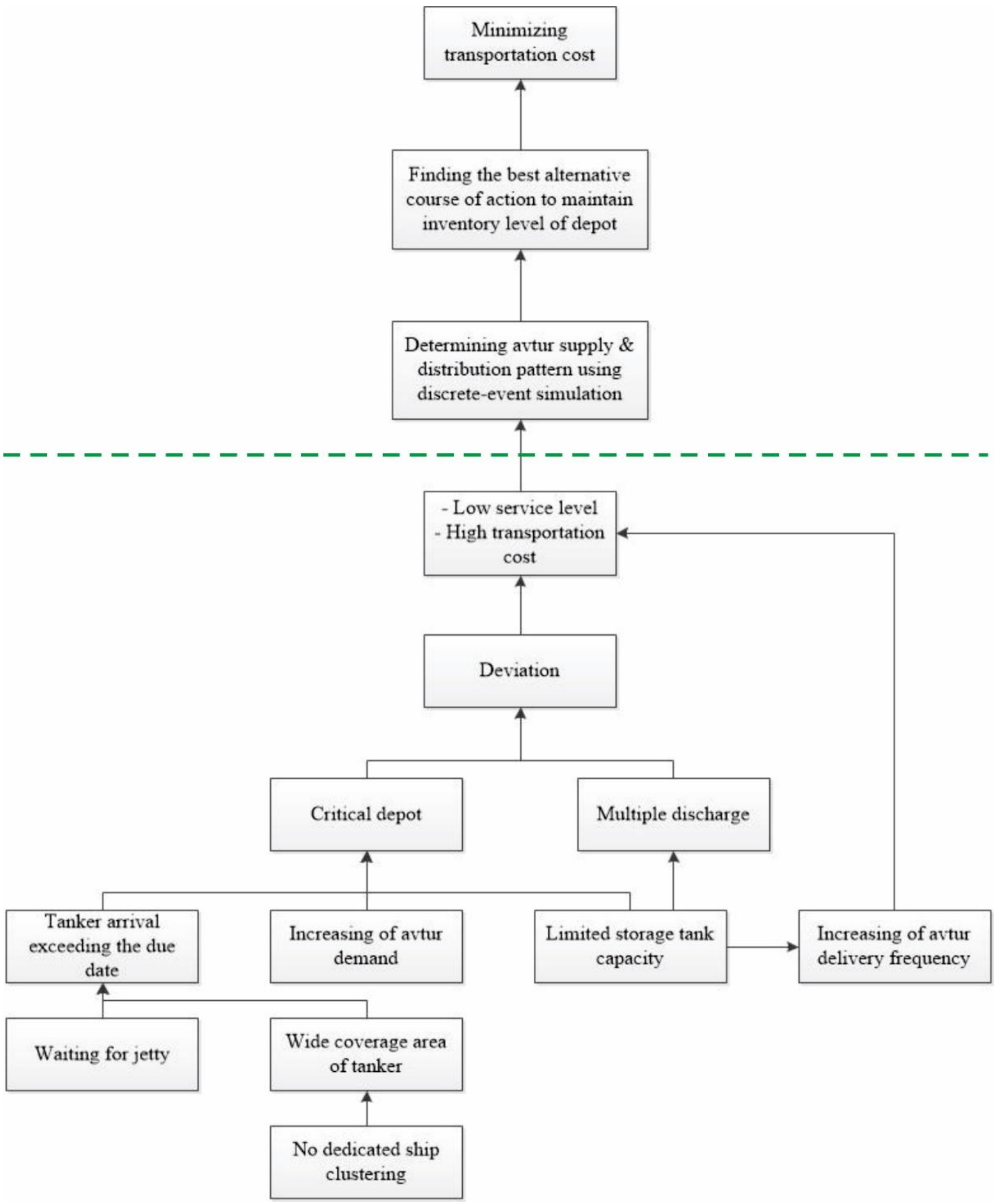


Figure 3. 4 The Interrelationship Diagram

3.2 Identify Problem for Analysis

This subchapter identifies problem elements which are in the system of avtur supply and distribution. Identified elements are system elements, system variables, and system performance metrics.

3.2.1 System Element

System element consists of entity, activity, resource, and control. It define the *who, what, where*, and *how* entities are being processed. The system element of avtur supply and distribution process are as follow.

a. *Entity* is item being processed in system. The entity in this system is tanker which distributes avtur.
b. *Activity* is smallest unit of work which has finite duration. Activity can directly or indirectly process the entity. Activities within this system are illustrated in Figure 3. 4.

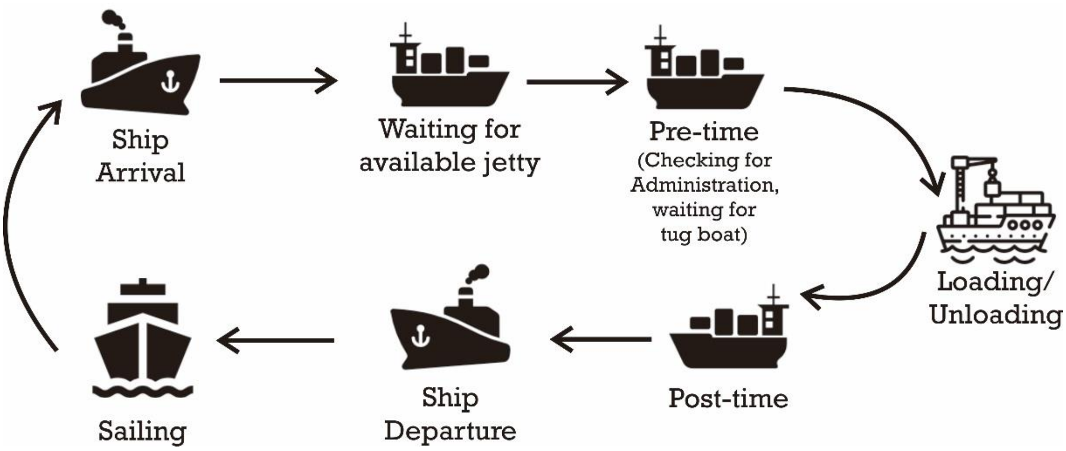


Figure 3. 5 Activities Performed in Avtur Supply and Distribution System

c. *Resource* provides the supporting facilities, equipment, and people to perform activities. Resource has characteristics, such as speed, capacity, dedicated/undedicated, and permanent/temporary. Resources within this system are storage tank, tanker used for avtur supply and distribution, and pump for loading and unloading process.
d. *Control* regulates the mechanisms of activities being performed. Tanker is assigned to TBBM or DPPU when its inventory position has reached reorder point (ROP), then tanker sails back to supply point or to another depot if tanker is doing multiple discharge. The availability slot of jetty also determines whether tanker can be berthed or has to wait until the jetty is available.

3.2.2 System Variable

Variable is a value that can change depending on events occurred in system. It helps to understand how system elements can affect each other. System variable can be classified into decision variable, response variable, and state variable.

a. *Decision Variable* is also called as input factor or independent variable which changing the value of system affects the behavior of system. In this system, the decision variable is number of required tankers
b. *Response Variable,* also known as performance or output variables, measures performance of the system as the response of decision variables. Thus, response variable is dependent variable. The response variables for this system are service level, number of delivery, and total distribution cost.
c. *State Variable* is the status of system at particular time and it is dependent variables. The state variables within this system are status of tanker.

3.2.3 Key Performance Indicator

Key performance indicator (KPI) represents a set of measures focusing on those aspects of organizational performance that are the most critical for the current and future success of the organization (Parmenter, 2007). Decision criteria that will be used in this system are the service level and cost incurred in each scenario. The scenario will be chosen if it can maintain the inventory level of storage tank at minimum cost.

3.3 Data Collection and Observation

This step identifies required data for this research. The system data can be categorized as structural data, operational data, and numerical data. Table 3.1 shows the data requirement.

Table 3. 1 Data Collection of Avtur Supply and Distribution

Structural Data		
Tanker Ship	***Loading Port***	***Unloading Port***
Type of tanker	Location of loading port	Location of unloading port
	Number of jetty for avtur	Number of jetty for avtur
Operational Data		
Tanker Ship	***Loading Port***	***Unloading Port***

Tanker routing and scheduling	Time windows	Time windows
Numerical Data		
Tanker Ship	***Loading Port***	***Unloading Port***
Velocity	Port Capacity	Port Capacity
Pump rate	Pump rate	Demand Rate
Sailing time	Pre-time and waiting time	Pre-time and waiting time

3.4 Make Scenarios

Scenarios are made based on current problem situation in avtur supply and distribution process and data that have been successfully collected. Later, the scenarios will be tested in simulation model. The results of scenarios will be compared to find the best solution. The best scenario is the one which can fulfil the decision criteria in KPI.

3.5 Build a Conceptual Model

Robinson (2006) defines conceptual modelling as the abstraction of a model from a real system, which includes simplification of reality. It develops understanding of the relevant system by determining the objectives, inputs, outputs, content, assumptions, and simplification of the model. A conceptual modelling can be represented using many tools, such as process flow diagram, logic flow diagram, activity cycle diagram (ACD), and influence diagram.

3.6 Build a Simulation Model

Simulation model is an imitation or a representation of the real system as it progresses throughout time. The simulation approach of this system is discrete-event simulation in which the state of system changes at the point of time. This research uses the help of Arena Simulation: Discrete Event Simulation software to construct model by referring to the conceptual model. Through Arena, "what-if" scenarios can be run to provide visibility, identify best practices, and to evaluate future process designs. Later, the number of replications needed are determined and simulation replications are performed in order to get a good representative of sample size.

3.7 Verification and Validation

This step helps to reduce error as much as possible during transforming process of real-world system into simulation model. Verification process ensures the simulation model follows the conceptual model, while validation process ensures the conceptual model represents the real-world system. These process are performed whenever the model is developed or some changes are applied within it.

3.8 Experimental Design

In this phase, experiments are performed to scenarios which have been determined before. This process is done by changing the decision variable of avtur supply and distribution in model to obtain the output through response variable.

3.9 Output Analysis

After output is obtained, ANOVA testing is performed to study the effect of a lot of factors on a response variable. Then, sensitivity analysis is performed by changing the parameter within system and observing the changes. Sensitivity analysis is used in order to see how much the results will change under certain conditions.

3.10 Conclusion & Suggestion

The last step of the research is formulating conclusion and suggestion. The conclusion is formulated by comparing between result of simulation model and the problem identification stated at the beginning phase of research. After that, suggestion is formulated intended not only for the current research, but also for the future research related to avtur supply and distribution process.

CHAPTER 4

DATA COLLECTION AND PROCESSING

4.1 Description of Existing Condition

There are 2 refinery units (RUs), 2 transshipment points, and 8 end depots to facilitate avtur distribution in MOR V (Table 4.1) using tanker in different capacity and characteristics. During distribution process, tanker has to load avtur in full capacity.

Table 4. 1 Facilities of Avtur Distribution System in MOR V

Node	Location	Status
1	**Ampenan**	End Depot (DPPU)
2	**Benoa**	End Depot (DPPU)
3	**Bima**	End Depot (DPPU)
4	**Ende**	End Depot (DPPU)
5	**Kupang**	End Depot (DPPU)
6	**Maumere**	End Depot (DPPU)
7	**STS Kalbut**	Transshipment Point (TBBM)
8	**Surabaya**	End Depot (DPPU)
9	**Tanjung Manggis**	Transshipment Point (TBBM)
10	**Waingapu**	End Depot (DPPU)
11	**Balikpapan**	Supply Point
12	**Cilacap**	Supply Point

Transshipment point (TBBM) or intermediate storage is place where loading and unloading activities can be performed alternately. Two possible reasons for Pertamina to do transshipment is to change the means of transportation during distribution and to shorten lead time between supply points to DPPUs. STS Kalbut and T. Manggis receive avtur from Cilacap by tanker with large capacity. Then, smaller tankers will take avtur from TBBM to distribute it to end depots. This is occurred due to limited capacity of jetty in end depots which cannot accommodate large tankers. For mechanism of loading and unloading process in transshipment point (TBBM), large tanker which acts as supplier is preceded over smaller tanker which is going to distribute avtur to DPPUs.

The coverage area of avtur distribution system is divided into three clusters based on its supply points. Table 4.2 mentioned the regular coverage area of avtur distribution system in MOR V based on its supply points.

Table 4. 2 Coverage Area of Avtur in MOR V

Supply Point	Coverage Area
Cilacap	Surabaya, STS Kalbut, T. Manggis, Ampenan, Benoa, Bima, Ende, kupang, Maumere, Waingapu
Balikpapan	Benoa (Bali), Ampenan
STS Kalbut	Ampenan, Benoa, Bima, Ende, kupang, Maumere, Waingapu
T. Manggis	Ampenan, Benoa, Bima, Ende, kupang, Maumere, Waingapu

Under each cluster, the distribution route is undedicated based on criticality of end-depot. Determination of criticality can be calculated using coverage days of demand (CDD) formula (will be explained in the next chapter). For one voyage, there is possibility of multiple discharge for tanker due to criticality condition in several end-depots which occurred at the same time. Limited capacity of storage tank in several DPPUs can be another reason why multiple discharge is occurred.

In avtur distribution system, there is no disruption such as downtime production and breakdown of tanker Thus, SOH in refinery unit will be updated to maximum capacity once it has reached minimum level of avtur. However, there are still congestion due to jetty availability and readiness of tank before avtur is discharged from tanker. This system also does not consider maintenance activity since it is assumed that tanker is in good condition during simulation horizon.

4.2 Data Collection

This subchapter will show required data for constructing avtur supply and distribution system in Pertamina. The data consists of structural data, operational data, and numerical data.

4.2.1 Structural Data

Structural data describe the layout and identify items that are processed. In the mooring facilities specifications, the data consists of mooring facilities name, activity performed in the mooring facilities such as loading, unloading, or both, and the last data are products transferred through any specific mooring facilities since not all of jetty is intended for avtur line.

4.2.2 Operational Data

Operational data explain how the system operates, such as route and scheduling of tanker and operation time for every loading and discharge port in this avtur distribution system.

There is operational time for each port in this avtur system distribution. From twelve ports, six of them operate in 24 hours and others operate in certain duration. Those which operate in 24 hours are main ports, while the rest are small ports. Small ports with time windows mean a tanker should wait until the earliest time window if it arrives outside of time windows. Meanwhile, for the main ports, a tanker can be berthed anytime at jetty as long as jetty is available.

For scheduling, tanker will be assigned to critical depot as soon as tanker is available in loading port. This occurred as means to maintain inventory level in discharge port and avoid the critical condition. If there is no critical depot by the time tanker evaluates ROP in every discharge port, tanker will wait to re-evaluate for the next day.

For routing, inventory level and distance are two main considerations. The selection of destination is based on ROP (reorder point) in discharge port. Then, discharge ports which are under ROP will be ranked based on coverage days of demand (CDD). Discharge port with the smallest CDD will be visited first. Then, the second discharge port will be visited afterward, and so on. Usually the routing of tanker is dedicated unless there is emergency condition which makes tanker routing is changed.

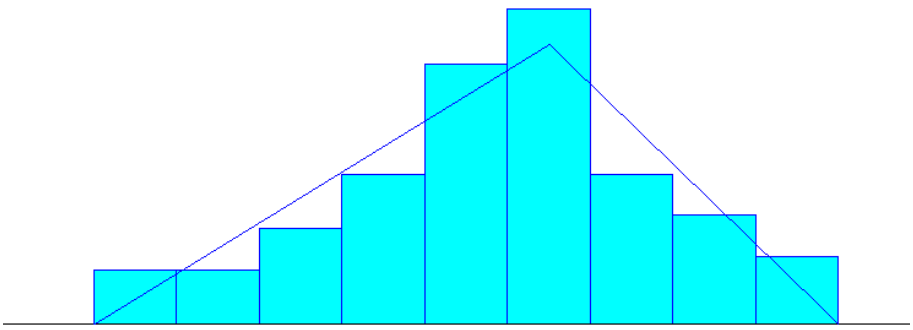
4.2.3 Numerical Data

Numerical data provide quantitative information within the system Unloading duration can be obtained by dividing capacity of avtur in tanker to pump rate. Meanwhile, DWT value is used as constraint to find out whether jetty in loading or unloading port can be visited by tanker with certain type. The speed used in avtur distribution system is 10 knots. Lead time (in days) can be calculated by dividing distance between ports to tanker speed. Lead time table can be found in Appendix A. For pre-time and waiting time in destination and loading port, the data are obtained from *Integrated Port Time* (IPT) for each port.

Distribution cost is needed to calculate total distribution cost at the end of year. This total distribution cost will become performance measure along with service level. Since all of used tankers in this simulation model are time-charter tankers, components of total distribution cost are variable cost and fixed cost. Variable cost used in this research are port charge and bunker cost consumption, while fixed cost is charter rate.

4.2 Data Processing

Numerical data which have been obtained, then, are processed to be input in ARENA simulation model. Processing data is performed by doing fitting distribution to the numerical data. Fitting process is done using input analyzer from ARENA software. Figure 4.2 shows example one of results for fitting distribution for demand rate in Benoa (Bali).



```
        Distribution Summary

Distribution:   Triangular
Expression:     TRIA(1.99e+003, 2.5e+003, 2.82e+003)
Square Error:   0.006319

Chi Square Test
  Number of intervals   = 6
  Degrees of freedom    = 4
  Test Statistic        = 2.57
  Corresponding p-value = 0.638

Kolmogorov-Smirnov Test
  Test Statistic        = 0.0659
  Corresponding p-value > 0.15
```

Figure 4. 1 Fitting Distribution of Demand Rate in Benoa (Bali)

Based on Figure 4.2, it is known that distribution for demand rate in Benoa is triangular distribution. The recapitulation result of fitting distribution is shown in Table. 4.3.

Table 4. 3 Recapitulation of Data Processing

Parameter	Distribution	Unit
Demand rate in Ampenan	NORM(110, 20)	Kiloliter/day
Demand rate in Benoa	NORM(110, 20)	Kiloliter/day
Demand rate in Bima	TRIA(1.99e+003, 2.5e+003, 2.82e+003)	Kiloliter/day
Demand rate in Ende	NORM(6.01, 3.57)	Kiloliter/day
Demand rate in Kupang	NORM(23.4, 4.45)	Kiloliter/day
Demand rate in Maumere	TRIA(65, 76.3, 127)	Kiloliter/day
Demand rate in Surabaya	NORM(6.78, 2.67)	Kiloliter/day
Demand rate in Waingapu	NORM(1.28e+003, 215)	Kiloliter/day
Pretime in Ampenan	NORM(3.82, 2.46)	Days
Posttime in Ampenan	EXPO(0.118)	Days
Waiting for Jetty in Ampenan	0.01 + EXPO(0.166)	Days
Pretime in Benoa	-0.001 + EXPO(0.427)	Days
Posttime in Benoa	EXPO(0.0991)	Days
Waiting for Jetty in Benoa	0.04 + EXPO(0.202)	Days
Pretime in Bima	-0.001 + EXPO(0.663)	Days
Posttime in Bima	EXPO(0.074)	Days
Waiting for Jetty in Bima	EXPO(0.312)	Days
Pretime in Ende	-0.001 + EXPO(0.217)	Days
Posttime in Ende	EXPO(0.0602)	Days
Waiting for Jetty in Ende	0.05 + EXPO(0.0796)	Days
Pretime in Kupang	-0.001 + EXPO(0.181)	Days
Posttime in Kupang	EXPO(0.468)	Days
Waiting for Jetty in Kupang	0.02 + EXPO(0.164)	Days
Pretime in Maumere	-0.001 + EXPO(0.235)	Days
Posttime in Maumere	EXPO(0.261)	Days
Waiting for Jetty in Maumere	EXPO(0.26)	Days
Pretime in STS kalbut (LP)	-0.001 + EXPO(0.181)	Days
Posttime in STS Kalbut (LP)	EXPO(0.0874)	Days
Waiting for Jetty in STS Kalbut (LP)	0.05 + EXPO(0.12)	Days
Pretime in STS kalbut (DP)	-0.001 + EXPO(0.25)	Days

Parameter	Distribution	Unit
Posttime in STS Kalbut (DP)	EXPO(0.193)	Days
Waiting for Jetty in STS Kalbut (DP)	EXPO(0.188)	Days
Pretime in Surabaya	-0.001 + EXPO(0.12)	Days
Posttime in Surabaya	0.08 + EXPO(0.0893)	Days
Waiting for Jetty in Surabaya	0.17 + EXPO(0.0647)	Days
Pretime in T. Manggis (LP)	-0.001 + EXPO(1.59)	Days
Posttime in T. Manggis (LP)	0.04 + EXPO(0.0365)	Days
Waiting for Jetty in T. Manggis (LP)	0.07 + EXPO(0.152)	Days
Pretime in T. Manggis (DP)	EXPO(1.77)	Days
Posttime in T. Manggis (DP)	0.08 + EXPO(0.01)	Days
Waiting for Jetty in T. Manggis (DP)	0.17 + EXPO(0.055)	Days
Pretime in Waingapu	EXPO(2.04)	Days
Posttime in Waingapu	EXPO(0.038)	Days
Waiting for Jetty in Waingapu	0.07 + EXPO(0.0894)	Days
Pretime in Balikpapan	-0.001 + EXPO(0.0258)	Days
Posttime in Balikpapan	EXPO(1.74)	Days
Waiting for Jetty in Balikpapan	0.14 + EXPO(0.379)	Days
Pretime in Cilacap	-0.001 + EXPO(0.442)	Days
Posttime in Cilacap	EXPO(1.07)	Days
Waiting for Jetty in Cilacap	-3 + EXPO(3.43)	Days

Several assumptions are added in order to complete the mechanism of avtur distribution system:

1. In simulation model, demand will be generated once every morning, since in existing condition and under normal condition, bridgers lift avtur from end depot in time between 7 AM – 10 PM.
2. Tanker which arrives near the end of time windows will be accepted, as long as jetty is available

3. Inventory cost is disregarded because storage of avtur both in loading port and DPPUs are owned by Pertamina
4. Calculation of service level is done in the morning when demand is generated.

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CHAPTER 5
SYSTEM MODELLING

5.1 Conceptual Model

This subchapter will show the conceptual model of avtur distribution system which consists of conceptual model of general system, conceptual model for updating stock-on-hand (SOH) in discharge port, conceptual model of loading mechanism, conceptual model for selecting discharge port, and conceptual model of unloading mechanism.

5.1.1 Conceptual Model of General System

Figure 5.1 represents the general conceptual model of avtur distribution system. The conceptual model is started by arrival of tanker at loading port (LP). Then, there is a process in which the reorder point (ROP) of every discharge port (DP) are evaluated. If stock-on-hand (SOH) of discharge port is under its ROP, then it will be selected as destination of tanker. If there are more than one discharge port which under ROP, the delivery order is based on coverage days of demand (CDD). This process also consists of volume allocation if the destination is more than one discharge port After the destination order is set, loading process is begin and it will be followed by departing of tanker to destination.

When tanker arrives at discharge port, avtur is unloaded based on volume allocation which has been determined before. Then, tanker will depart to another discharge port, if there is any, or to supply point. The selection of supply point will be based on historical data of tanker route.

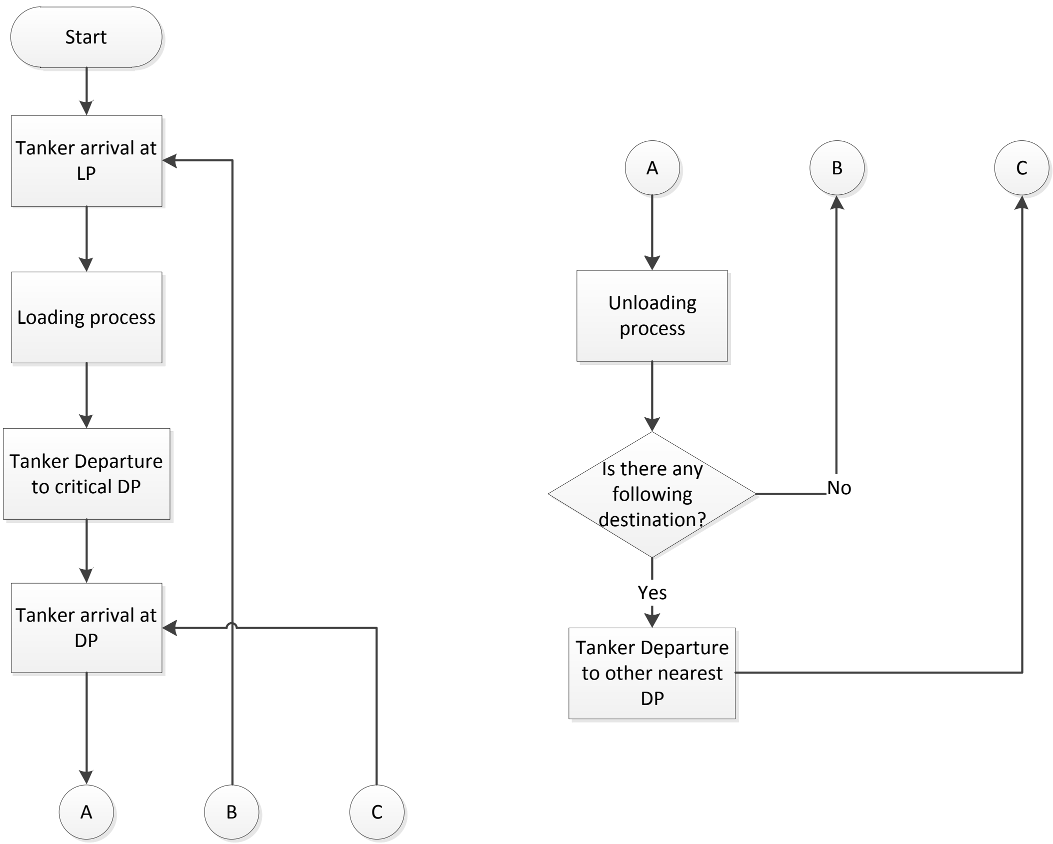

Figure 5. 1 Conceptual Model of General System

5.1.2 Conceptual Model for Updating Stock-on-Hand (SOH) in Discharge Port

Figure 5.2 reflects the conceptual model for updating SOH in discharge port. It is started by generating demand every day. Then, there will be evaluation of SOH in discharge port, whether the SOH is within minimum stock or not, before updating SOH. If demand arrives when SOH is under or passing minimum stock, there will be update for critical value variable in which that day will be marked as day in critical condition. This variable will be used to calculate the service level which explained in formula (3.1).

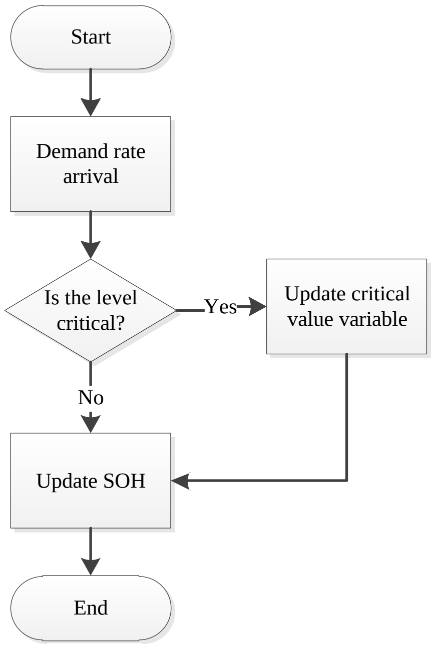

Figure 5. 2 Conceptual Model for Updating SOH

5.1.3 Conceptual Model of Loading Mechanism

This subchapter explains about the conceptual model of avtur loading mechanism which is depicted in Figure 5.3.

1. Set Initial Condition

   Conceptual model of loading mechanism is started by setting initial condition which consists of determining number of tanker, capacity of tanker, tanker initial position, DWT of tanker, capacity of jetty in every ports, initial SOH of avtur in every loading and discharge port. Initial tanker position is assumed heading to loading ports.

2. Tanker Arrives at Loading Port (LP)

   Tanker will arrive at loading ports which are located in Cilacap, Balikpapan, Tanjung Manggis, and Kalbut.

3. Check Time Windows

   When tanker arrives at loading port, make sure tanker arrives within time windows, or else, tanker has to wait until the time reaches time windows. Port in Balikpapan and Cilacap operate 24 hours a day, while Port in Tanjung Manggis and STS Kalbut operate within time windows.

4. Check The Availability of Jetty

Before entering loading port, the availability of jetty is checked whether it is occupied or not. If it is occupied, tanker has to wait until status of jetty is idle. Then, tanker can enter the port.

5. Pre-time process

   There will be pre-time process for tanker before loading avtur. This process is series of events which occurred while tanker enters port and before loading process, such as waiting for cargo calculation, waiting for lab analysis, waiting for line of avtur, waiting for bad weather, and waiting for order from port officer.

6. Check Critically of Every Discharge Port (DP)

   This process is performed to determine the order of avtur distribution to more than one discharge ports. This process will be explained, furthermore, in the next subchapter.

7. Loading Process

   This process is performed to transfer avtur from storage tank of loading port to tanker based on capacity of tanker. Duration of loading process is determined in formula as follows.

   $$Loading\ time = \frac{tanker\ capacity}{pump\ rate\ of\ loading\ port} \tag{5.1}$$

8. Post-time Process

   Post-time process is series of events which occurred after hose disconnect from tanker and before tanker departs from loading port. For instance, cargo calculation, waiting for port pilot or officer, and waiting for tide.

9. Tanker Depart to Destination

   After that, tanker departs to discharge port which has been determined before. With tanker speed of 10 knots, sailing time can be known from formula as follows.

   $$Sailing\ time = \frac{distance\ between\ ports}{tanker\ speed} \tag{5.2}$$

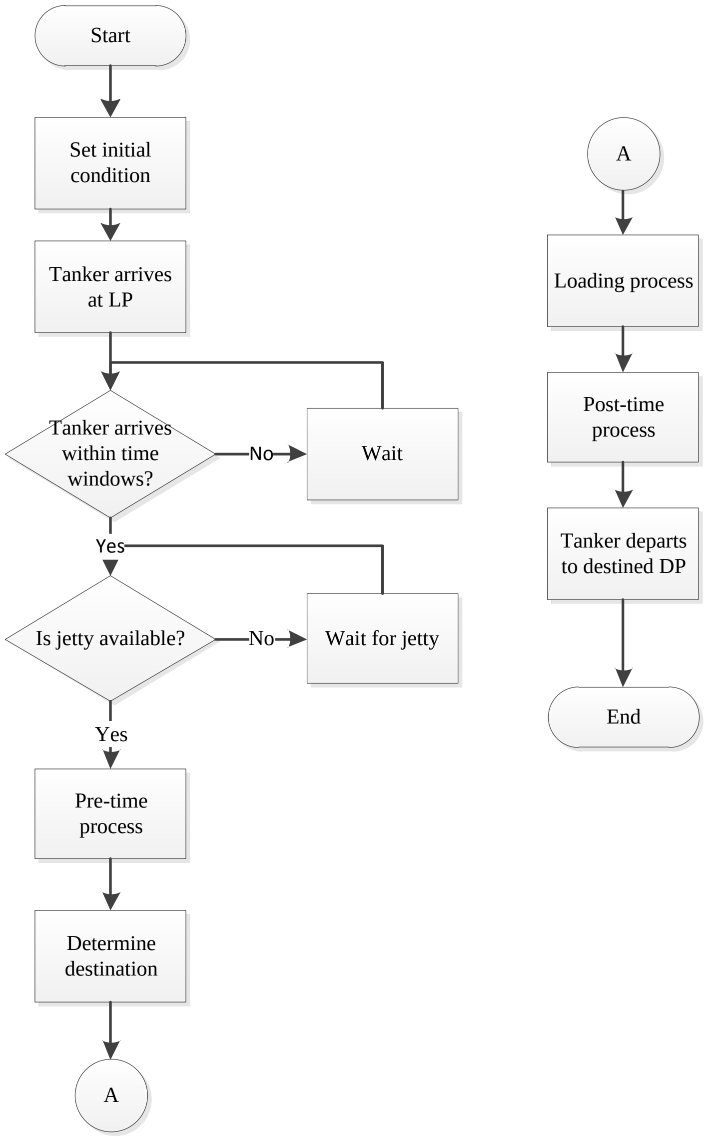

Figure 5. 3 Conceptual Model for Loading Mechanism

5.1.4 Conceptual model for Selecting Discharge Port

For selecting discharge port to be visited, there are two variables used as considerations: reorder point (ROP) and coverage days of demand (CDD). ROP is used to determine which discharge ports that is needed to be supplied. Then, distribution order is determined by the value of CDD. The discharge port with smallest value of CDD will be number one priority of distribution. The formula for ROP and CDD calculations are as follow.

$$ROP = minimum\ stock + (average\ demand \times sailing\ time) \qquad (5.3)$$

$$CDD = \frac{SOH\ in\ DP + Intransit\ inventory}{Average\ demand \times sailing\ time} \qquad (5.4)$$

Figure 5.4 and Figure 5.5 depict conceptual model for selecting discharge port.

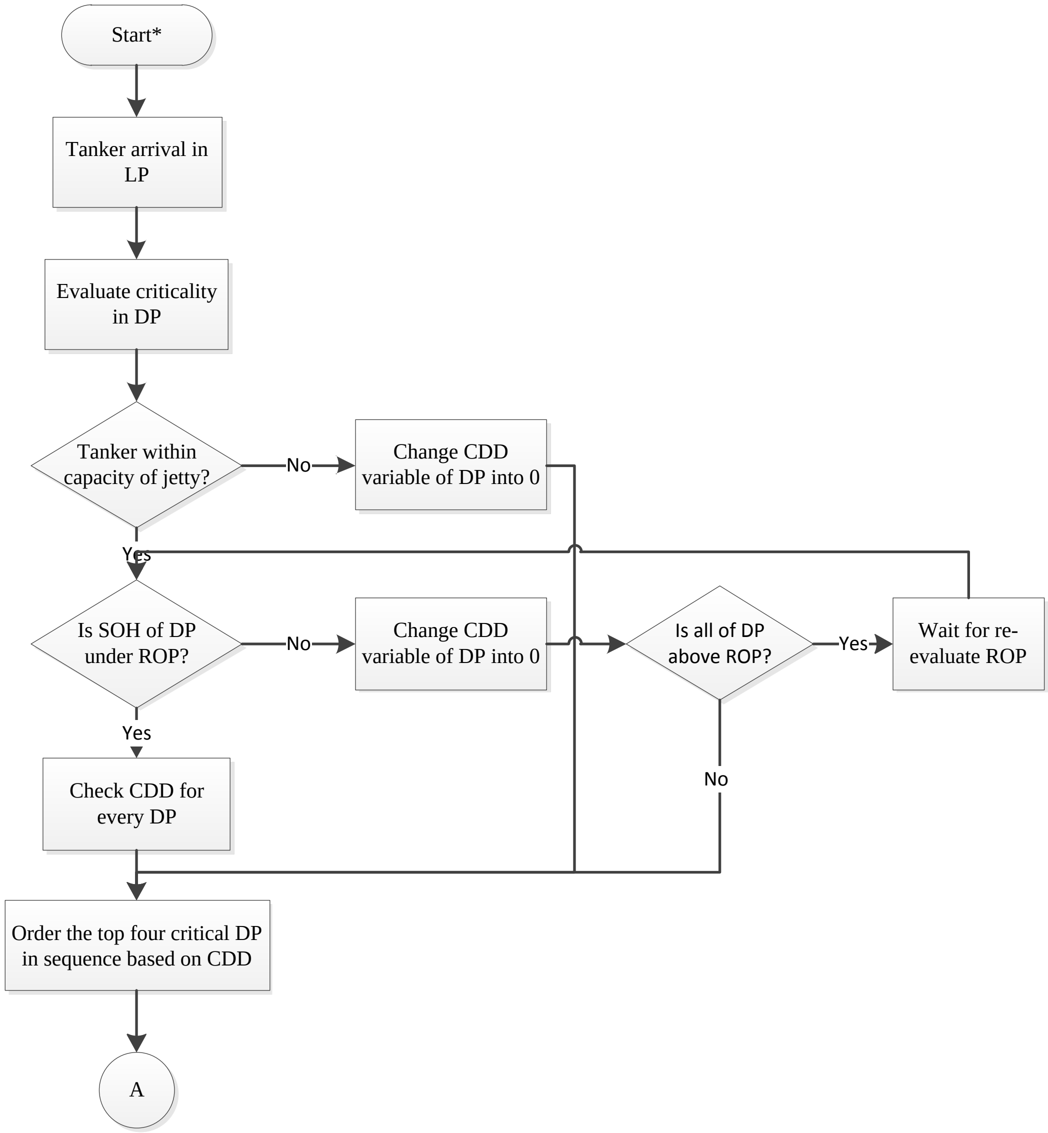

Figure 5. 4 Conceptual Model for Selecting Discharge Port

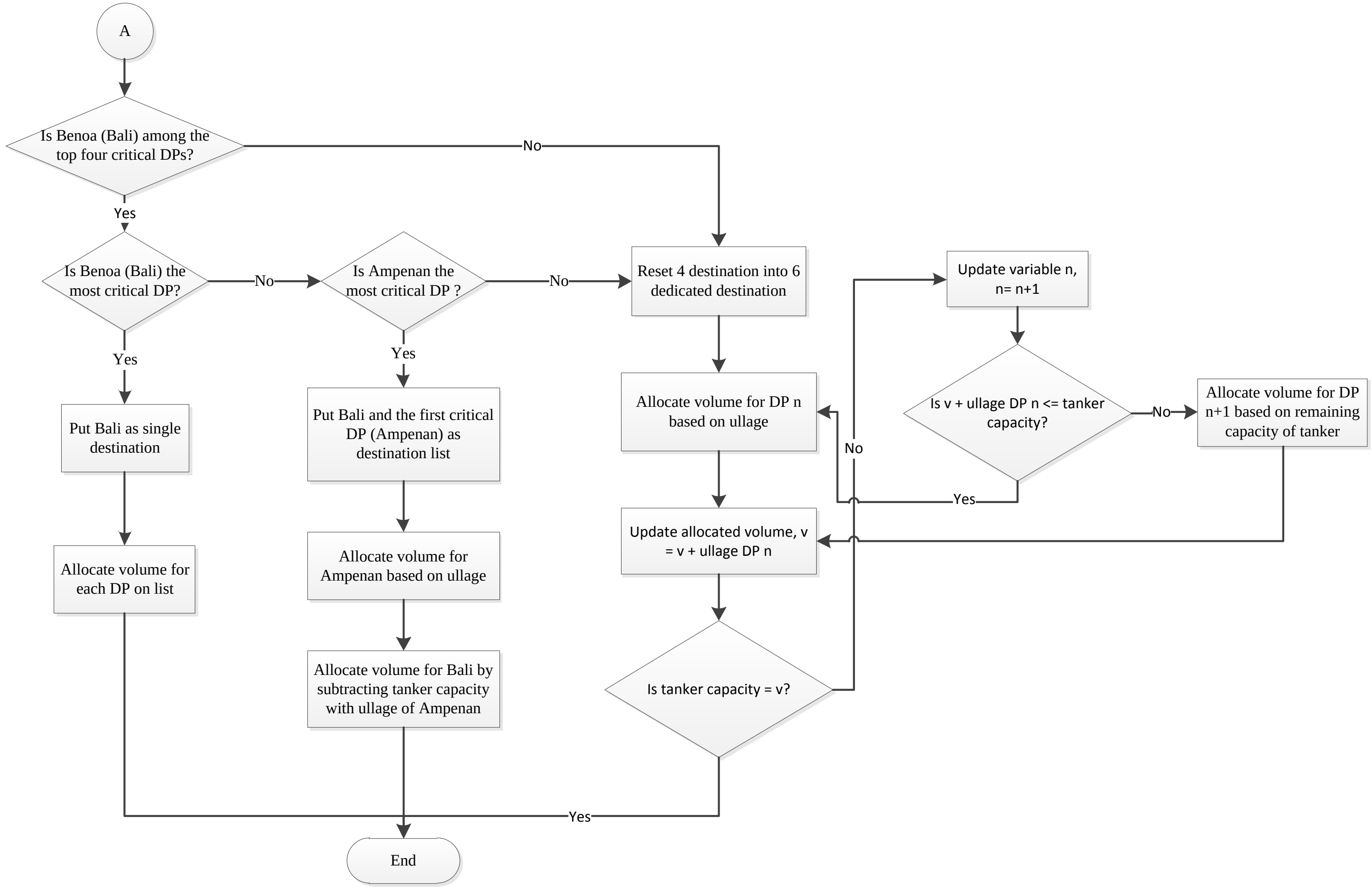

Figure 5. 5 Conceptual Model for Selecting Discharge Port (cont'd)

1. When tanker arrives in loading port, it evaluates whether or not the capacity of jetty in discharge port can be visited by tanker. If DWT of tanker exceeds the capacity of jetty, then change the variable value of CDD into 999 to omit discharge port, which has smaller jetty capacity than DWT of tanker, from destination candidate.
2. Then, SOH in discharge port is checked whether or not it is under the ROP. If SOH of discharge port is under ROP, CDD calculation can be performed to discharge port. If SOH is above ROP, change the variable value of CDD into 999. If all of discharge port is above ROP, then, tanker will wait in port to re-evaluate CDD on the next day.
3. After that, discharge ports are ranked based on CDD to determine which discharge port should be visited first. The maximum destination that can be visited by a tanker is four discharge port for one trip. This is done in order to prevent inefficiency in avtur distribution.
4. Among 10 discharge ports in MOR V, Bali is top priority during avtur distribution due to high number of international flights. Once critical condition of avtur occurred in Bali, it will caught international awareness and it will attract competitors to replace position of Pertamina as avtur distributor in Bali. Thus, there are rules of avtur volume allocation as response to that condition:
    a. Volume allocation, for tanker with multiple-discharge points, is based on remaining ullage in each end depots. If ullage of end depot is smaller than tanker capacity, discharged volume will be based on ullage. Otherwise, discharged volume will be based on remaining volume within tanker.
    b. Since Bali is top priority, tanker destination will go solely to Bali if Bali has the smallest CDD value among other three discharge ports.
    c. Ampenan is always with Bali. If Bali has the second smallest value of CDD, tanker will distribute avtur to Ampenan and then to Bali.
    d. If Bali has the third smallest value of CDD, Bali will be omitted from destination route and wait for another tanker.

e. Bima, Ende, Kupang, Maumere, and Waingapu are always visited simultaneously through multiple-discharge using a tanker with capacity of 4100KL. If one of these ports is in critical condition, tanker will also visit other ports even though they have not reached their ROP. If there is remaining volume within tanker, Bali will be the last destination for tanker to discharge the remaining volume.

5.1.5 Conceptual Model of Unloading Mechanism

Figure 5.6 illustrates the conceptual model of unloading avtur in discharge port.

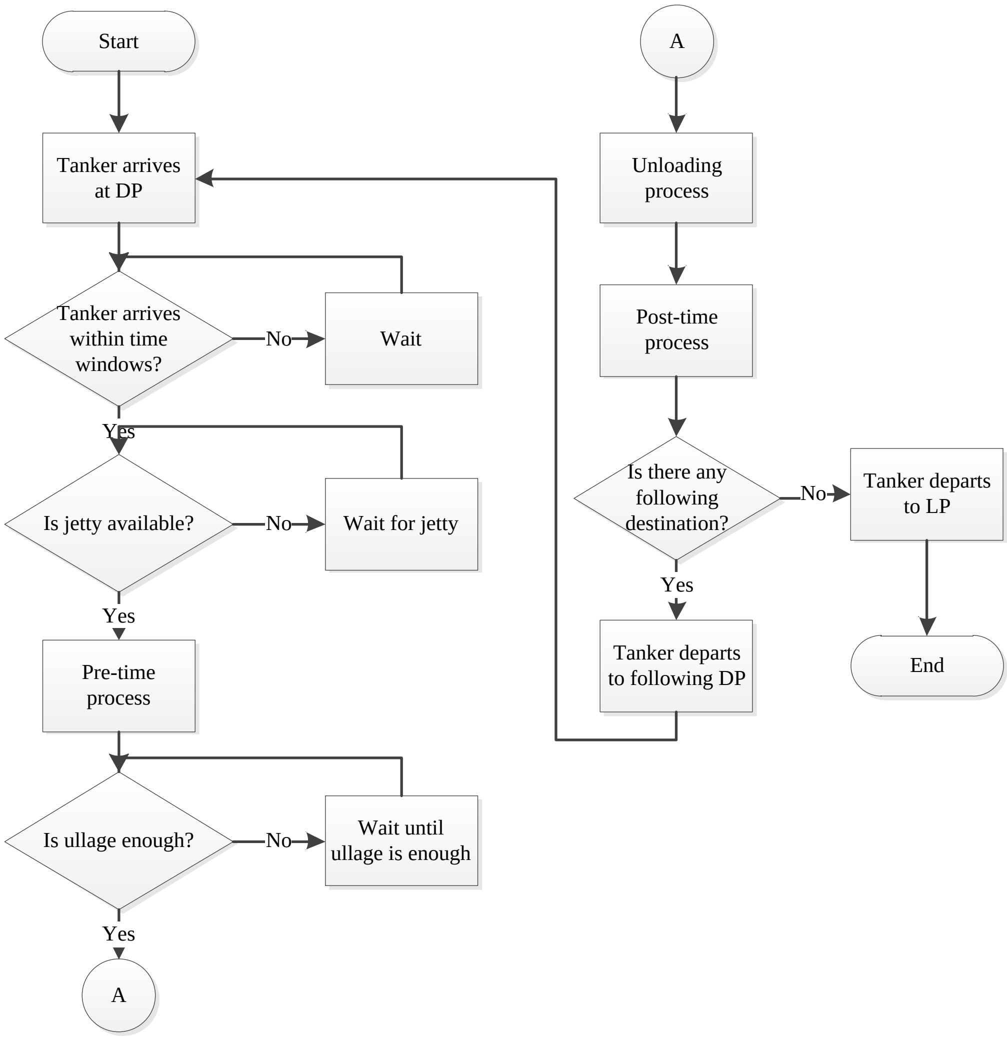

Figure 5. 6 Conceptual Model of Unloading Mechanism

1. Tanker Arrives at Discharge Port (DP)

   Tanker will arrive at discharge ports which are located in Ampenan, Benoa (Bali), Bima, Ende, Kupang, Maumere, Surabaya, Waigapu, Tanjung Manggis, and Kalbut. Tanjung Manggis and STS Kalbut are mentioned as discharge port and loading port since those are transit terminal.
2. Check Time Windows

   When tanker arrives at discharge port, make sure tanker arrives within time windows, or else, tanker has to wait until the time reaches time windows.
3. Check The Availability of Jetty

   Before entering discharge port, the availability of jetty is checked whether it is occupied or not. If it is occupied, tanker has to wait until status of jetty is idle. Then, tanker can enter the port.
4. Pre-time process

   There will be pre-time process for tanker before unloading avtur. This process is series of events which occurred during tanker enters port and before loading process, such as waiting for cargo calculation, waiting for lab analysis, waiting for line of avtur, waiting for bad weather, and waiting for order from port officer.
5. Check Ullage of Storage Tank

   Ullage or available space in storage tank has to be check before unloading of avtur. If the volume of avtur that will be unloaded is larger than the ullage, then, tanker has to wait until the ullage is larger or equal to volume of avtur.
6. Unloading Process

   This process is performed to transfer avtur from tanker to storage tank of discharge port based on the volume of avtur that will be unloaded. Duration of unloading process is determined in formula as follows.

   $$unloading\ time = \frac{unloaded\ volume}{pump\ rate\ of\ tanker} \qquad (5.6)$$

7. Post-time Process

Post-time process is series of events which occurred after hose disconnect from tanker and before tanker departs from unloading port. For instance, cargo calculation, waiting for port pilot or officer, and waiting for tide.

8. Tanker Departs to Destination

   After that, tanker departs to another discharge port, if there is any, which has been determined before. With tanker speed of 10 knots, sailing time can be known from formula as follows.

   $$Sailing\ time = \frac{distance\ between\ ports}{tanker\ speed} \tag{5.7}$$

9. Tanker Sails to Loading Port

   If there is no other destination for tanker, it means that tanker has unloaded all of its capacity and ready to sails back to loading port. The selection of loading port is based on historical data of tanker route. For example, MT. Olyvia, under normal circumstances, can load avtur in among three loading ports: Balikpapan, STS Kalbut, and Tanjung Manggis. Allocation of visitation can be determined based on frequency of visitation from avtur gantt chart.

5.2 Simulation Model

Based on conceptual model in previous subchapter, simulation model is constructed in ARENA software. The simulation model consists of 7 sub models: time-windows modulation sub model, production rate sub model, tanker initial position sub model, discharge port sub model, loading port sub model, daily objective throughput sub model, and sailing back to loading port sub model.

5.2.1 Sub Model 1: Time Windows Modulation

Time windows modulation is implemented in the simulation system depicted in Figure 5.7. This sub model creates the time windows and modulates its opening and closing, using the variable *Time* to represent the state. All tankers can determine from the value of variable *Time* whether they can move into port. For example, a tanker can move into *Maumere Port* when the value of *Time* variable is *Time* > *6* and before *Time* < *16.00.*

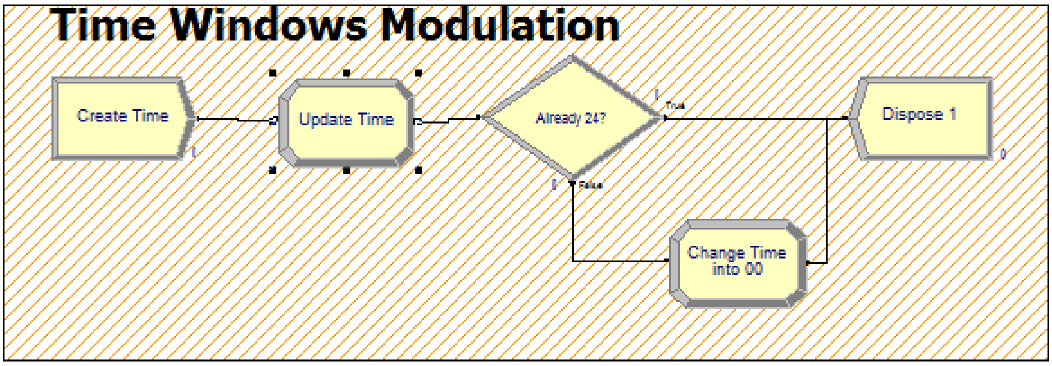

Figure 5. 7 Sub Model 1

A *Time* entity is created pre arrival for every hour at time 0 in the *Create* module, called *Creat Time.* The created *Time* entity enters the *Assign* module, called *Update Time.* Here, the variable of *Time* is set to *Time + 1.* Then, *Time* entity proceeds to *Decide* module to check whether the variable *Time* < 24. If *Time < 24, Time* entity proceeds to *Dispose* module. If it is not, then, *Time* entity proceeds to *Assign* module, called *Change Time into 00,* to change the value of *Time* variable into 0.

5.2.2 Sub Model 2: Production Rate

Sub model 2 which controls the production rate as supply in refinery unit is depicted in Figure 5.8. In avtur distribution system, it is assumed that stock of avtur in refinery unit is infinite. It means that there will be no stock out of avtur since any kind of disruption is ignored.

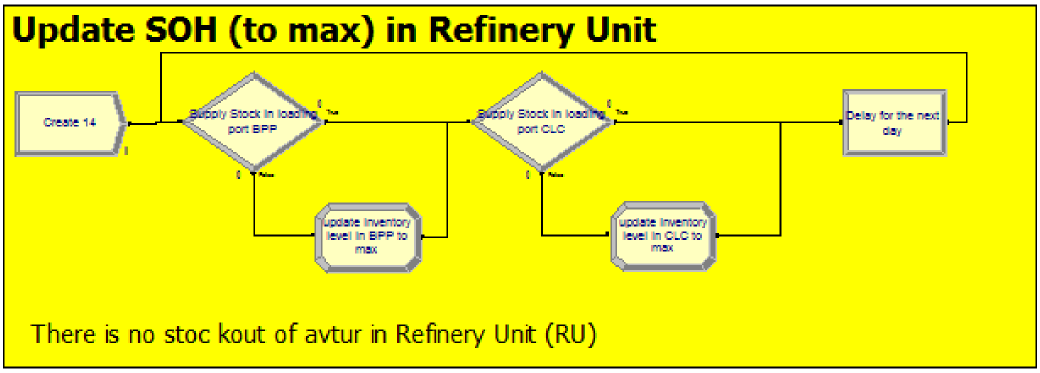

Figure 5. 8 Sub Model 2

An entity is created with maximum arrival of 1 in the *Create* module. Entity, then, proceeds to *Decide* module, called *Supply Stock in Loading Port Balikpapan,* to check whether the current stock of avtur in Balikpapan is equal or larger than minimum stock which has been determined by Pertamina before. If avtur stock is above the minimum level, entity will proceed to *Assign* module, called *Update Inventory Level in BPP to Max*, to add avtur stock up to maximum capacity of storage tank in refinery unit. If avtur stock in Balikpapan is in normal condition, entity will proceed to another *Decide* module to evaluate avtur stock in Cilacap refinery unit. In the end, the entity proceeds to *Delay* module, called *Delay for The Next Day*, to wait for a day before the entity is routed back to module *Decide* to repeat the cycle.

5.2.3 Sub Model 3: Tanker Initial Position

Sub model 3, which is depicted in Figure 5.9 is used to create and route a tanker to loading port. A tanker entity is created through *Create* module, then, proceeds to *Assign* module to put characteristics for each tanker: type of tanker, capacity of tanker, DWT of tanker, pump rate. Every tanker is created from one *Created* module and has its own *Assign* module because they are heterogeneous. After tanker entity is given characteristics, it is routed to one of four loading ports which are located in Balikpapan, Cilacap, STS Kalbut, and Tanjung Manggis.

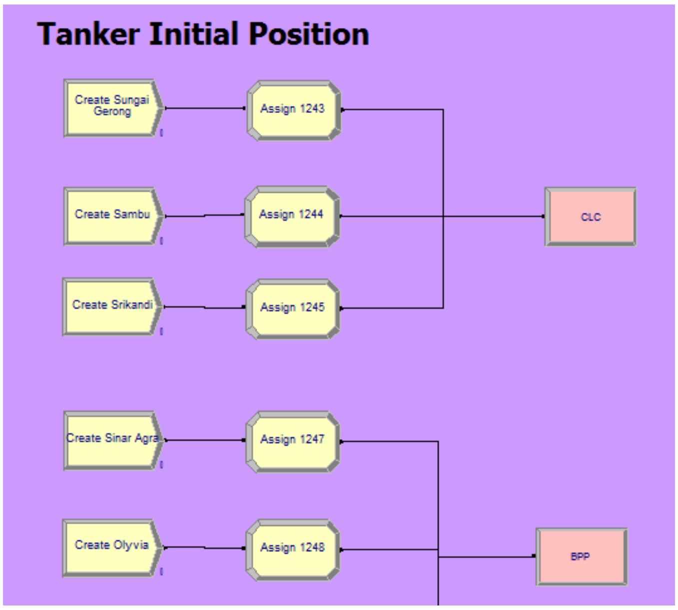

Figure 5. 9 Sub Model 3

5.2.4 Sub Model 4: Discharge Port

Sub model 4 explains the mechanism about discharging process in destination port. For this sub model, *Assign, Delay, Process, Hold,* and *Decide* modules are used to regulate the process. Figure 5.10 shows the sub model of discharge port.

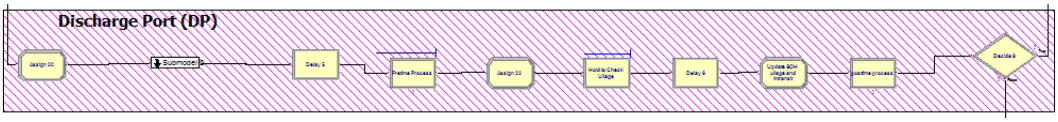

Figure 5. 10 Sub Model 4

From Figure 5.10, it is known that tanker entity sails from loading port to discharge port using *Delay* module. There is only one sub model to represent 10 discharge ports since all of activities are similar. Before entity starts being processed, tanker entity enters submodel 2 (Figure 5.11) in which tanker entity is plastered with attributes aimed to help sub model identify which discharge port this tanker should be processed in. *Decide* module identifies the destination of tanker based on *N-way condition.* After being plastered with identity in *Assign* module, tanker entity proceeds to *Hold* module. *Hold* module is used to retain tanker entity if tanker arrives outside time windows. Discharge port operates 24 hours if there is no *Hold* module after *Assign* module.

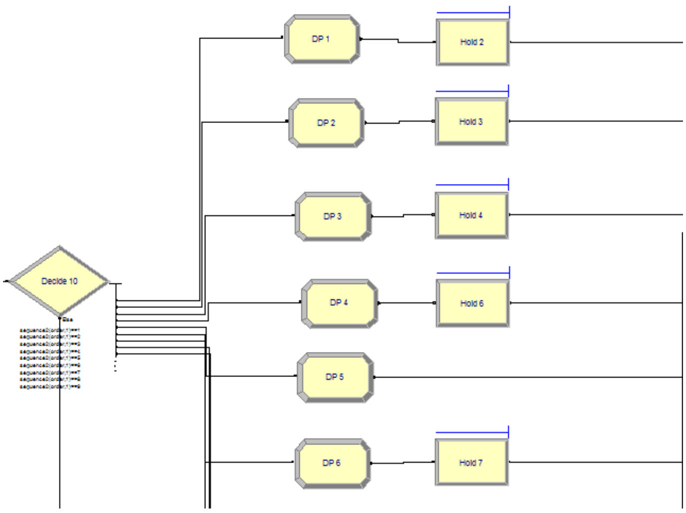

Figure 5. 11 Submodel in Sub Model 4

Tanker entity proceeds to *Delay* module to represent congestion or waiting process for available jetty. After tanker is released from *Hold* module, tanker entity enters *Process* module, called *Pre-time Process,* in which events such as wait for lab analysis, cargo calculation, wait for port officer, wait for daylight (time-windows) and other unexpected events such as wait for bad weather are occurred. *Pre-time Process* is recorded when tanker starts berthing in jetty until hose from port is connected with tanker. Thus, the *Process* module is set with *seize delay* action.

After *Pre-time Process,* tanker enters *Hold* module, called *Hold to Check Ullage,* in which space within storage tank is checked. Checking is performed in order to ensure unloaded cargo is smaller or equal to ullage or available space in storage tank. If unloaded cargo is larger than available space, tanker has to wait until storage tank can accommodate unloaded cargo. Once the condition is fulfilled, tanker entity enters *Delay* module to unload avtur with unloading duration is based on volume of unloaded cargo and speed of tanker pump rate.

After unloading process is completed, tanker enters another *Process* module, called *Post-time Process,* in which events after hose disconnected from tanker until tanker departs from jetty are recorded. Examples of those events are wait for cargo document, wait for port officer, and wait for the tide. Since tanker leaves jetty within *Post-time Process¸ Process* module is set with *delay release* action. After *Post-time Process,* tanker enters *Decide* module to determine its next destination. If tanker has another discharge port to be visited, then tanker enters *Delay* module to sails back to another discharge port. If tanker has finished its voyage, tanker enters *Route* module to go to loading port.

5.2.5 Sub Model 5: Loading Port

Sub model 5 regulates the mechanisms of loading process. To create simulation model of loading port, modules such as *Station, Assign, Hold, Delay, Process.* sub model 5 consists of four similar models to represent four loading port of avtur in MOR V. Figure 5.12 depicts simulation model of loading port.

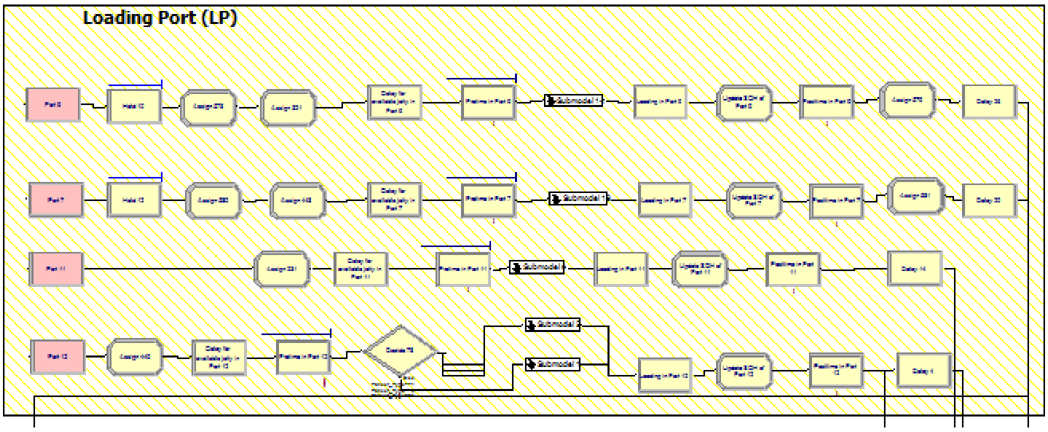

Figure 5. 12 Sub Model 5

Based on Figure 5.12, tanker entity will come thru *Station* module. *Delay* module is used to restrain tanker entity before seizing jetty since there might be entities, other than avtur tanker which are not presented in this system, are currently using the same jetty. Thus, *Delay* module is used instead of *Hold* module. After that, tanker will seize jetty thru *Process* module, called *Pre-time in Port*,

Before doing loading process into tanker's compartment, tanker entity proceeds to submodel to determine routing of tanker and volume allocation for each end depot – if a tanker visits multiple discharge ports. Figure 5.13 depicts submodel to determine route and volume allocation.

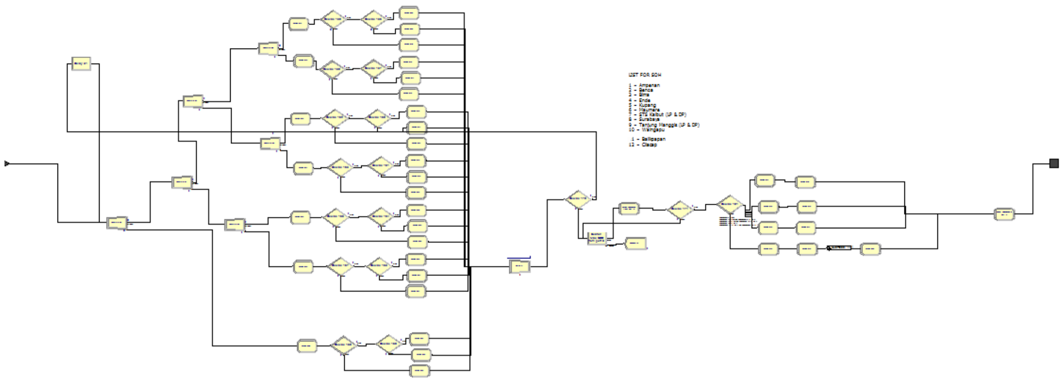

Figure 5. 13 Submodel for Route Determination and Volume Allocation

Basically, this submodel is used in both *Port 7* (STS Kalbut) and *Port 9* (Tanjung Manggis) since these loading ports cover the same area of destination. Meanwhile, for *Port 11* (Balikpapan) and *Port 12* (Cilacap), there are slight changes to adjust with condition of certain loading ports.

5.2.6 Sub Model 6: Daily Objective Throughput

Sub model 6 is used to explain the mechanism of reduced inventory level of avtur in 8 end depots and also used to calculate number of days under critical condition. Sub model 6 is depicted in Figure 5.14.

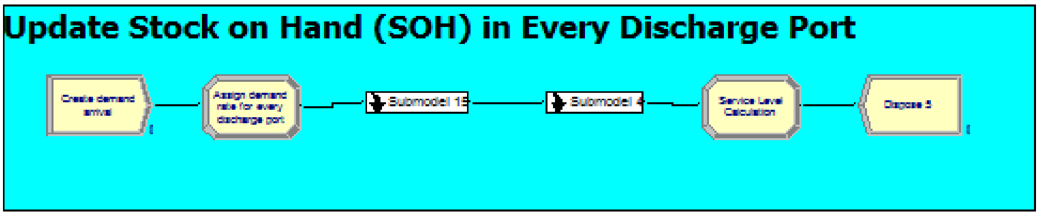

Figure 5. 14 Sub Model 6

The demand entity is created one per arrival per day since the obtained actual demand is recapitulated daily. Then, the demand entity proceeds to *Assign* module, called *Assign Demand Rate for Every Discharge Port*¸ to give the result of fitting distribution from actual demand on demand entity. The demand entity proceeds to *Sub Model 15* which is depicted inn Figure 5.15.

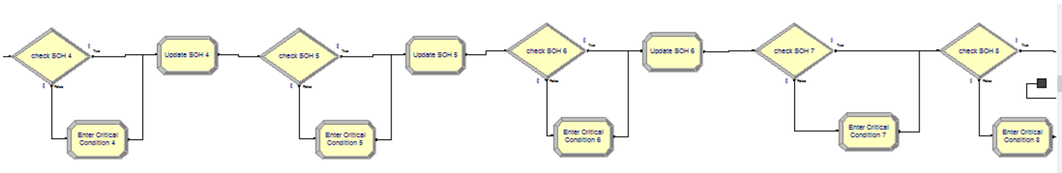

Figure 5. 15 Submodel 15 in Sub Model 6

Sub Model 15 is used to adjust demand and prevent negative value of SOH if demand exceeds stock on hand (SOH) of avtur in certain end depot. Demand entity proceeds to *Decide* module to check whether the current demand exceeds SOH. If it exceeds SOH, demand will be fulfilled by all of SOH.

Submodel 4 in sub model 6 is depicted in Figure 5.16. It is used to decrease SOH by demand and calculate how many days under critical conditions are. The demand entity proceeds to *Decide* module, called *Check SOH,* to check in which level SOH is when demand takes stock of avtur out. If demand comes when SOH is under safety stock level, demand entity enters *Assign* module, called *Enter*

Critical Condition, and the value of critical variable is updated. Then, demand entity proceeds to *Assign* module, called *Update SOH*, to change variable value of SOH.

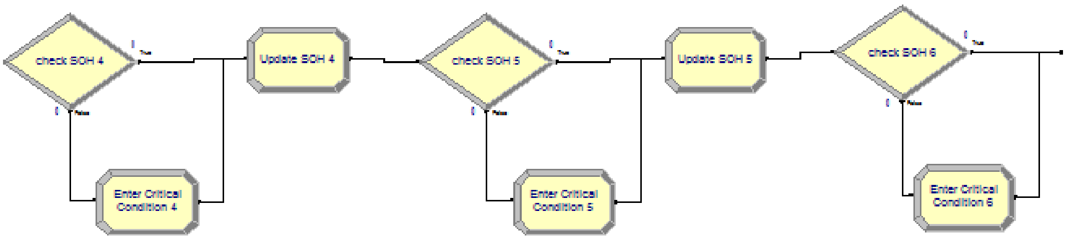

Figure 5. 16 Submodel 4 in Sub Model 6

5.2.7 *Sub Model 7: Sailing Back to Loading Port*

Sub model 7 is used to determine routing of tanker to loading port, once tanker has finished its voyage. The determination of loading port is based on historical data of tanker voyage. Sub model 7 is depicted in Figure 5.17.

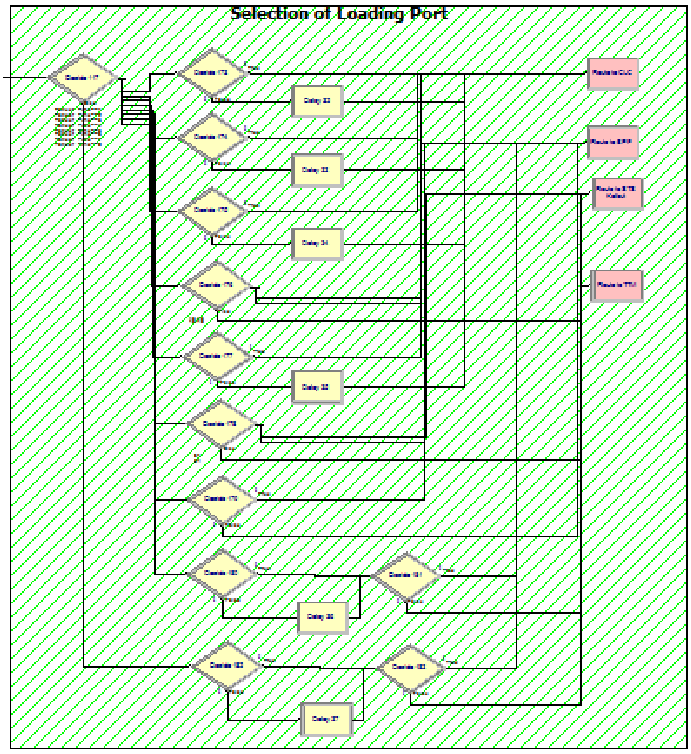

Figure 5. 17 Sub Model 7

The modules used in this sub model are *Decide*, *Hold,* and *Route* modules. *Decide* module is used to determine the destination of tanker, whether tanker sails within or out of system. If tanker sails out of system, tanker will be held in *Delay* module for several days, depend on where tanker is going to. If tanker entity passes through *Delay* module, tanker entity sails within system to loading port through *Route* module.

5.3 Calculation Number of Replication

Replication is performed in order to yield output of simulation model that can represent actual population. Replication is iteration process under same condition in an experiment to get high accuracy. This is occurred because ARENA system uses random input and random output (RIRO). Table 5.1 shows result of running simulation model with five replication.

Table 5. 1 Result of Five Replication

Replication	Total of Distributed Avtur
1	778800
2	699300
3	713500
4	640800
5	718600
average	710200
stdev.s	49301.57198

After average and standard deviation is obtained, then, calculation of half-width is performed with degree of confidence as much as 90%.

$$h_o = h_w = t_{n-1,\frac{\propto}{2}}\sqrt{\frac{s^2}{n}}$$

With:

$\propto = 0.1$

$n_o = 5$

$s = 49301.57198$

$t_{n-1,\frac{\propto}{2}} = t_{4,0.05} = 1.5332$ (obtained from t-table distribution)

$z_{\frac{\propto}{2}} = z_{\frac{0.1}{2}} = 1.645$

Then,

$$h_w = t_{4,0.05}\sqrt{\frac{(49301.57198)^2}{5}}$$

$$h_w = 33{,}804.11$$

From calculation, the value of hw is 33,804.11 KL or only about 4% from the average output of simulation. The hw value is relatively small compared to average of total distributed avtur. Thus, it can be concluded that 5 replications are enough to represent the system population.

5.4 Verification and Validation

5.4.1 Model Verification

Verification process is performed to test whether there are semantic error and syntax error in simulation model. Syntax error verification can be proofed by debugging in ARENA software. Figure 5.18 shows that there is no syntax error in simulation model.

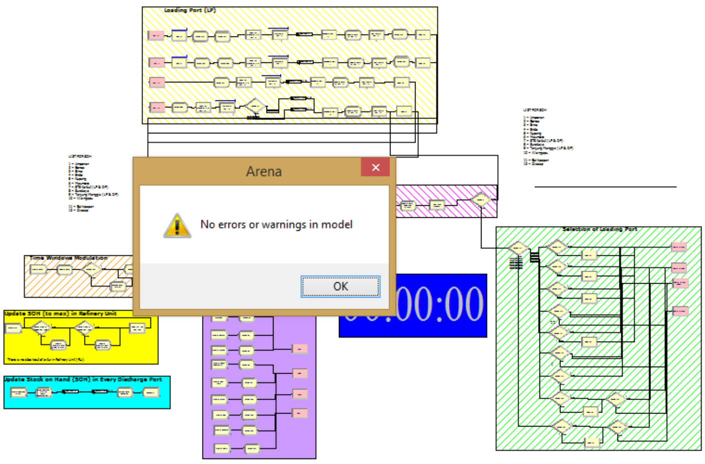

Figure 5. 18 Syntax Error Verification in ARENA

Besides syntax error, semantic error is also performed to test whether the logics in simulation model has followed intended logics of real system.

5.4.1.1 Verification of Time Windows

Time windows or daylight in every discharge port is different in range between 6 AM to 4 PM and several discharge port operates 24 hours. If tanker arrives outside the range of time-windows, tanker has to wait outside of port. To verify whether simulation model has fulfilled time-windows constraint or not, then, it can be checked by noticing *Hold* module when system time shows time outside 6 AM – 4 PM. There should be several tankers wait in *Hold* module.

In this simulation model, stopped tanker cannot be seen clearly in *Hold* module. However, when tanker entity reaches *Hold for Daylight* module out of time windows, clock will change its time into range of time windows when tanker entity exits *Hold* module.

5.4.1.2 Verification of Stock on Hand (SOH) in Discharge Ports

The full capacity (safe capacity) of storage tank consists of three components: stock on hand (SOH), ullage or available space within storage tank, and intransit volume or assigned volume which has not arrived yet in discharge port. Formula to elaborate safe capacity (SC) is shown as follows.

$$SC = SOH + Ullage + intransit$$

An interface to simplify verification for this aspect is shown in Figure 5.19. Figure 5.19 is used to check whether logic to calculate SOH is correct or not.

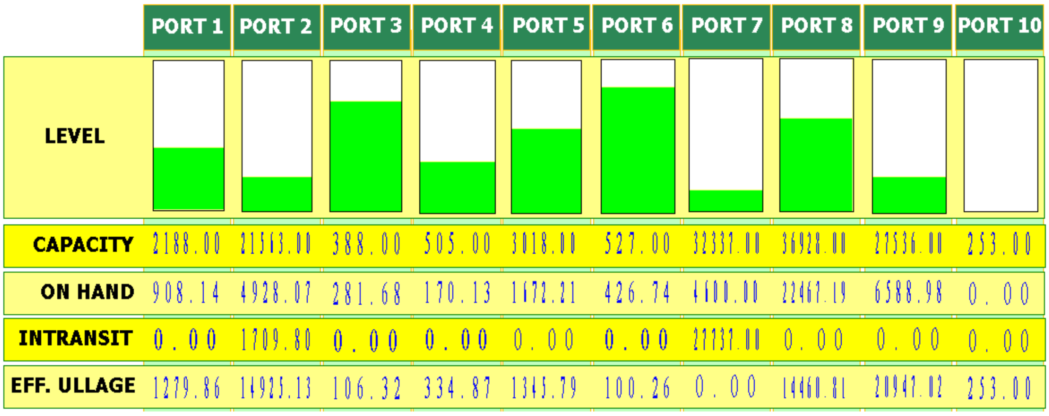

Figure 5. 19 Verification of SOH

Based on Figure 5.19, it can be concluded that the simulation model has followed correct logic to calculate SOH.

5.4.1.3 Verification of Allocated Volume

When a tanker has to do multiple discharge in one voyage (milk-run), capacity of tanker has to be divided into several parts. Volume allocation for each discharge ports may be varied, depends on criticality order and remaining ullage. Figure 5.20 shows verification for allocated volume which is obtained from *Read Write* module.

Tanker Type	Tanker Capacity	sequence 1 (LP)	Order	Sequence						Volume Allocation (in KL)					
				2	3	4	5	6	7	2	3	4	5	6	7
3	4100	12	5	10	4	5	6	3	2	0	0	0	388.905434009996	326.180883954866	962.681433053479
7	4100	7	2	10	4	5	6	3	2	253	100.951345226293	728.016995639409	60.5616448153741	43.7220038681236	2913.7480104508
6	7400	7	2	1	2	0	0	0	0	2188	7400	0	0	0	0
7	4100	7	3	10	4	5	6	3	2	0	100.951345226293	728.016995639409	60.5616448153741	43.7220038681236	2913.7480104508
3	4100	12	6	10	4	5	6	3	2	0	0	0	0	326.180883954866	962.681433053479
7	4100	7	4	10	4	5	6	3	2	0	0	728.016995639409	60.5616448153741	43.7220038681236	2913.7480104508
6	7400	7	3	1	2	0	0	0	0	0	7400	0	0	0	0
3	4100	12	7	10	4	5	6	3	2	0	0	0	0	0	962.681433053479
4	11400	11	2	2	0	0	0	0	0	11400	0	0	0	0	0
7	4100	7	5	10	4	5	6	3	2	0	0	0	60.5616448153741	43.7220038681236	2913.7480104508
7	4100	7	6	10	4	5	6	3	2	0	0	0	0	43.7220038681236	2913.7480104508
7	4100	7	7	10	4	5	6	3	2	0	0	0	0	0	2913.7480104508

Figure 5. 20 Verification of Allocated Volume for Milk-Run Case

From Figure 5.20, rows with pink highlight show the route for a voyage of tanker type 7 with capacity of 4100 KL. Column *Sequence 1* locates the loading port and columns *Sequence* show that destinations of tanker type 7, from the beginning to the end, are discharge *Port 10 (Waingapu), Port 4 (Ende), Port 5*

(Kupang), Port 6 (Maumere), Port 3 (Bima), and Port 2 (Benoa). Column *Order* shows which sequence is currently being visited. Allocated volume is mentioned in *Volume Allocation* column. Total of volume allocation in Figure 5.20 is equal to tanker capacity, which is 4100 KL.

5.4.2 Model Validation

Validation process is a simulation model testing toward real world system. This process is performed by comparing output of simulation model to real world system. Model is stated as valid when the result of running simulation model does not have any significance differences toward the real system. Data used for validation testing are stock on hand (SOH) in several depots within system. Table 5.2 shows SOH data based on existing and simulation.

Table 5. 2 Simulation Output of Stock on hand (SOH) in Several Depots

Replication	**SOH 3**		**SOH 5**		**SOH 4**		**SOH 7**		**SOH 8**	
	Simulation	**Existing**	**Simulation**	**Existing**	**Simulation**	**Existing**	**Simulation**	**Existing**	**Simulation**	**Existing**
1	212.47	173	1611.56	1455	265.4	255	14675.89	15218	14292.09	15214
2	208.61	173	1746.88	1455	277.52	255	11473.1	15218	13115.42	15214
3	171.21	173	1433.82	1455	248.34	255	14027.19	15218	11909.01	15214
4	165.6	173	1463.09	1455	196.79	255	15747.56	15218	15607.72	15214
5	173.48	173	1642.78	1455	258.33	255	15254.21	15218	14633.26	15214

One of method used for performing validation testing is *Anova: Single Factor*. *Null hypothesis* (H_0) is used to state there is no significance difference between output result of simulation and existing system. On the other hand, *alternative hypothesis* (H_A) is used to state that there is significance difference between average output of simulation and existing system.

$$H_0 : \mu 1 = \mu 2$$

There is no significance difference between two population

$$H_A : \mu 1 \neq \mu 2$$

There is significance difference between two population

Table 5. 3 Validation Testing of SOH 3

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	5	931.37	186.274	500.788
Column 2	5	865	173	0

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	440.4977	1	440.4977	1.759218	0.221335	5.317655
Within Groups	2003.152	8	250.394			
Total	2443.65	9				

Table 5.3 shows that *F* value of SOH 3 is smaller than *F crit,* which means do not reject H_0. There is no significance difference between existing condition and simulation model. Thus, it can be concluded that simulation model represents existing condition of avtur distribution system in MOR V. Result for other SOH are in Appendix B.

5.5 Experiment

Experiment is performed to alternatives courses of action which have been determined before. Determined alternative courses of action consist of base scenarios and combination scenario. There are two base scenarios:

1. Determine number of tanker based on existing condition in simulation model. The output of every combination of tanker are service level and total distribution cost. Delivery frequency is also put into consideration for choosing the combination of tanker which has fulfilled the KPI,
2. Add new supply point which is closer to Benoa (Bali) and determine number of tanker with consideration of new TBBM existence

5.5.1 *Scenario 1: Determining Number of Operating Tanker*

Scenario 1 is performed by trial-and-error, finding the combination of tanker which satisfies performance measures: service level and total distribution cost. There is no analytical approach used to determine base number of tanker in this simulation model since tanker mostly does multiple discharge instead of direct shipment. Thus, combination of tanker is developed solely based on result of existing simulation model. Table 5.4 shows the average service level, after five replication, from Port 1 to Port 10 (Port 7 and Port 9 are excluded from consideration since those ports are transshipment point or TBBM). Combination of tanker used in existing condition and in scenarios are shown in Table 5.4 which is followed by Table 5.5 that shows simulation result for existing and scenarios. The detail result of running simulation model with five replications can be accessed in Appendix C.

From Table 5.5, it is known that the existing condition of service level in Benoa (Bali) is the lowest among other ports by 52.8% and followed by Ende by 85.9%. Thus, adding or subtracting number of tankers are performed in order to increase the service level in Benoa and Ende, resulting four scenarios of tanker combination.

Table 5. 4 Combination of Tanker in Existing and Scenario Model

Number of Tanker in Use								
Tanker Combination	**S. gerong**	**Sambu**	**Srikandi**	**Sinar Agra**	**Olyvia**	**Plaju**	**Dewayani**	**Shinta**
Existing	1	1	1	1	1	1	1	1
1st Combination	1	1	1	1	2	1	1	1
2nd Combination	1	1	1	1	2	2	1	1
3rd Combination	1	1	2	1	2	2	1	1
4th Combination	1	1	2	1	2	2	1	2

Table 5. 5 Simulation Output of Existing and Scenario

Tanker Combination	Service Level (%)								Number of Delivery							
	1	**2**	**3**	**4**	**5**	**6**	**8**	**10**	**1**	**2**	**3**	**4**	**5**	**6**	**8**	**10**
Existing	92.49	57.70	99.95	93.92	98.85	100.00	94.71	100.00	21	127	23	24	24	23	26	24
1st Combination	94.36	65.92	99.84	95.56	99.95	100.00	95.75	100.00	22	134	25	25	25	25	28	25
2nd combination	95.18	67.89	99.45	93.75	99.23	100.00	96.73	100.00	23	132	24	25	24	24	26	25
3rd Combination	96.55	71.18	100.00	94.79	99.18	100.00	95.66	100.00	22	133	24	25	25	25	27	25
4th Combination	97.04	72.22	99.62	96.60	99.95	100.00	96.99	100.00	23	137	24	26	25	25	24	25

5.5.2 Scenario 2: Determining Number of Operating Tanker by Adding New Supply Point (TBBM)

Second scenario is performed in order to find out whether Pertamina's plan to add new supply point to increase service level of Benoa is effective or not. Another reason TBBM Tuban for avtur is being considered is because Cilacap has high jetty occupancy leading to long duration of waiting time. Thus, TBBM is needed to redirect supply pattern.

The proposed-TBBM is located in Tuban, East Java. Avtur stock in Tuban will be supplied from Cilacap and is assumed to be always ready stock. Service level of avtur in Port 8, Surabaya, will be assumed 100% since Surabaya will be supplied from TBBM Tuban, through pipeline. There will be diversion of route for *Srikandi* tanker once TBBM Tuban is built. *Srikandi* will load avtur in Tuban instead of Cilacap. It is expected to reduce waiting time for *Srikandi,* increasing service level in general, and reducing of total distribution cost.

Since the result of tanker combination in *Scenario 1* has not yielded minimum prescribed service level, which is 90% in Benoa, another scenario is developed to fulfil the target. *Scenario 2* is proposed by combining *Scenario 1* and *Scenario 2.* The objective of *Scenario 2* is to determine number of tanker for supply and distribution of avtur in MOR V by considering new TBBM in Tuban.

5.5.4 Significance Testing

Significance testing is performed to find out whether combination of tanker and existence of new TBBM in Tuban affect service level significantly. Significance testing is performed through two-way Anova. Table

Table 5. 6 Two-way Anova Table for Service Level

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Sample	342.14553	3	114.04851	18.906954	3.07874E-07	2.263452
Columns	16506.638	1	16506.638	2736.4693	1.4286E-32	2.869259
Interaction	56.699288	3	18.899762	3.1332013	0.039032228	2.263452
Within	193.026985	32	6.032093			
Total	17098.510	39				

Result of *two-way Anova* concludes that combination of tanker and existence of new TBBM as transshipment point affect service level of DPPUs in MOR V significantly. Significant effect can be proofed by comparing *F* value to *F crit*. *F* value is bigger than *F crit* which means $\mu1 \neq \mu2$, there is significant effect to service level.

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CHAPTER 6
SIMULATION MODEL ANALYSIS

6.1 Analysis of Scenario 1

Evaluation of the best scenario produces number of tanker needed which satisfies performance measurement. The best combination is selected when the combination can improve service level in Benoa (Bali) and Ende and the combination can still maintain service level of other ports which have obtained service level above 95%. However, for Bali, the minimum target of service level is 90%.

Out of eight type of tankers, adding number of tanker will be revolved in four types of tanker: *Plaju*, *Shinta*, *Olyvia,* and *Srikandi.* These tankers are chosen since the coverage area of those four tankers include Bali and Ende. Number of tankers will be added gradually in order to observe the change in terms of service level and total distribution cost. *Dewayani* is out of option since it is owned-tanker by Pertamina and if number of *Dewayani* is increased, investment cost for procuring additional tanker should be calculated, and it is out of scope of this research.

Based on Table 5.5, the best tanker combination is *4th Combination*. *4th Combination* is chosen because the overall service level of *4th Combination* has reached targeted level, which is 95%. Figure 6.1 shows the effect of tanker combination to service level of DPPUs in MOR V. The average service level is increased as number of tanker is increased since it will increase number of delivery. Total distribution cost is also increased since adding new tanker will increase fixed cost and variable cost. Figure 6.2 shows the effect of tanker combination in Benoa. Additional number of delivery increases variable cost, even though, the increment is not as expensive as additional number of tanker.

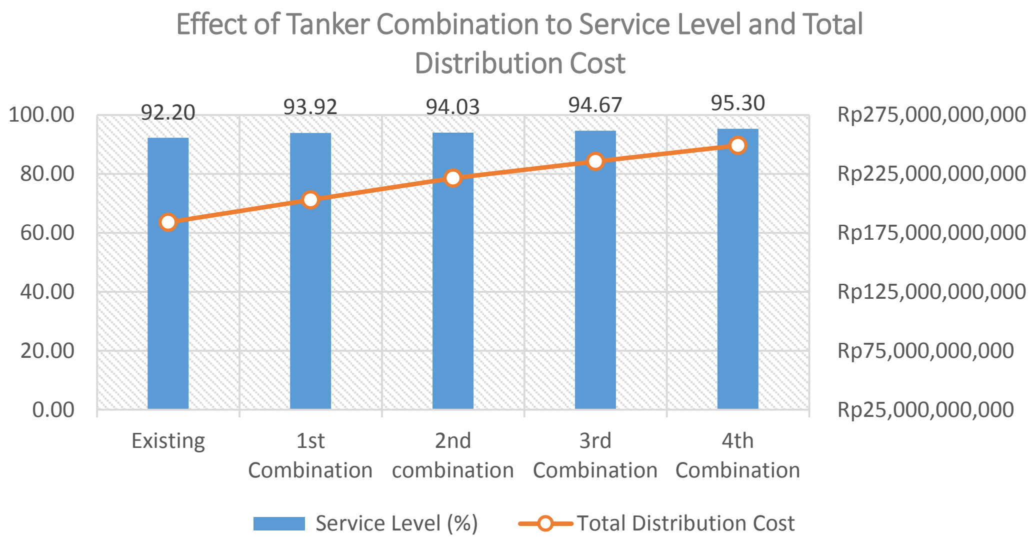

Figure 6. 1 Summary of Tanker Combination to Service Level and Total Distribution Cost

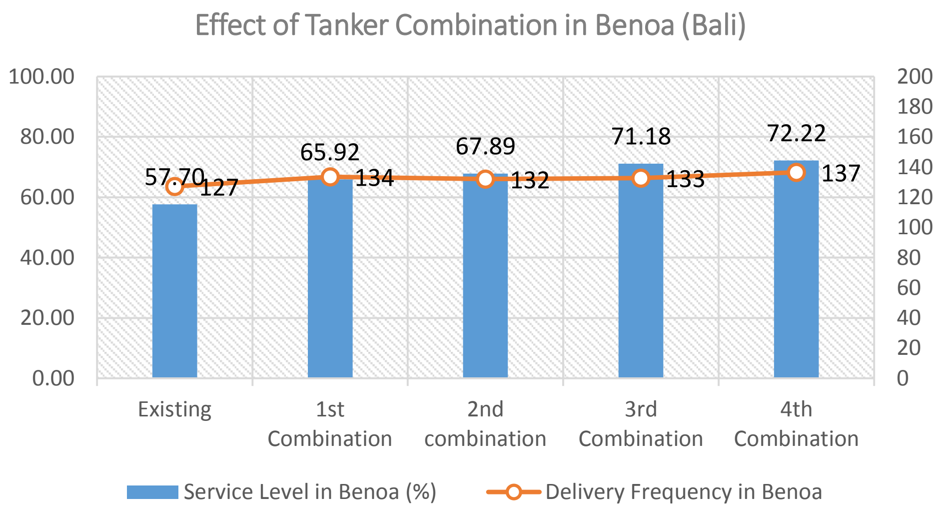

Figure 6. 2 Effect of Tanker Combination in Benoa

6.2 Analysis of Scenario 2

From the best tanker combination of *Scenario 1: 4th Tanker Combination*, it offers the best average service level over other combinations. However, if service level is observed individually for every DPPUs, service level in Benoa is still poor and far from target. Thus, combination of tanker combination and existence of new TBBM is proposed with expectation that result will give better result than before. Full table of replication for *Scenario 2* can be seen in Appendix D.

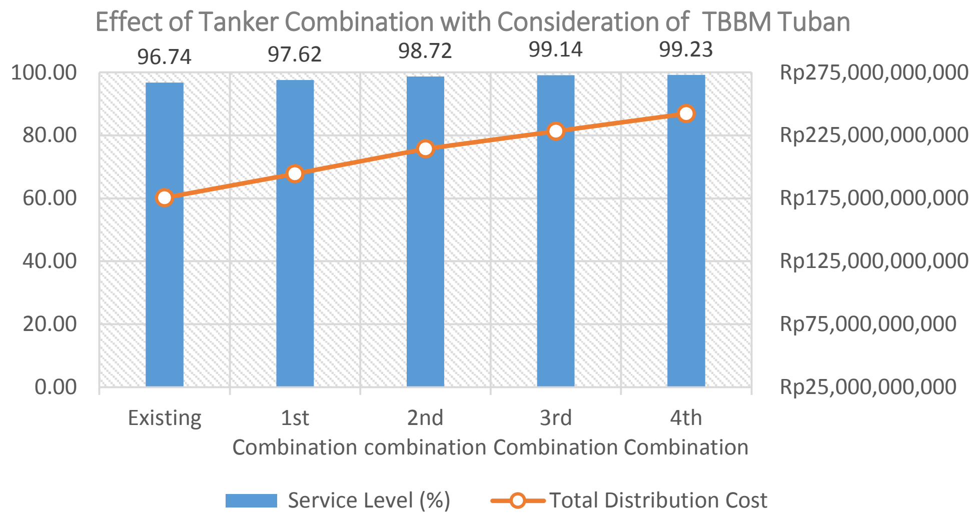

Figure 6. 3 Effect of Tanker Combination with Consideration of BBM Tuban

Figure 6.3 summarizes the change in service level and total distribution cost caused by combination of tanker and existence of new TBBM. *3rd Combination* becomes the selected option in *Scenario 2* instead of *4th Combination* since by using 11 tankers the overall and Benoa service level have reached targeted level. Figure 6.4 exhibits the effect of tanker combination in *Scenario 2.*

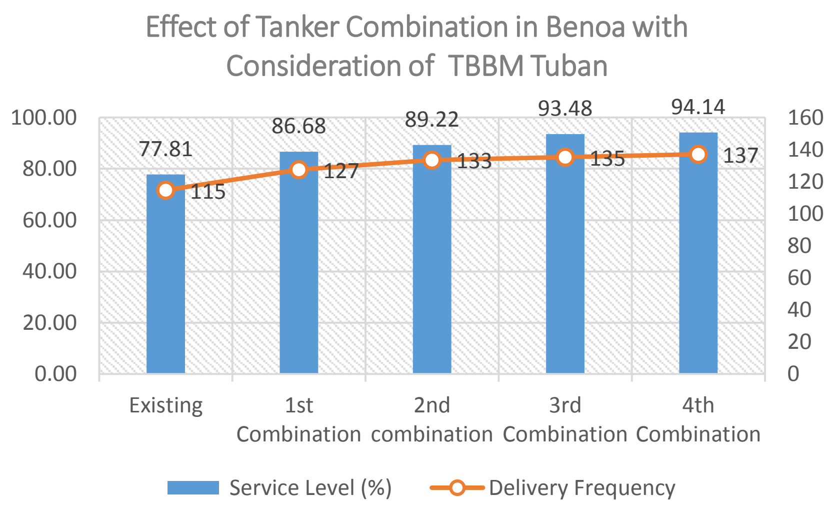

Figure 6. 4 Effect of Tanker Combination to Service Level and Delivery Frequency in *Scenario 2*

6.3 Effect of Waiting Time in Loading Port to Service Level

This experiment will change the duration of waiting time in four initial loading ports. There will be two type of experiment. First experiment is changing the duration of waiting time in loading port using initial number of tanker:

1. Reduce duration of waiting time by 10%
2. Reduce duration of waiting time by 50%
3. Reduce duration of waiting time by 66.67%
4. Increase duration of waiting time by 50%

Option 1 can be implemented by enhancing the pump rate to make loading process faster. The change of rule for queuing from first in first out (FIFO) to priority can be one of ways to reduce duration of waiting time. Option 2 and option 3 can be implemented by adding new jetty. Details regarding to duration of waiting time and replication can be seen in Appendix E. Figure 6.5 summarizes the effect of waiting time in loading ports to average of service level in MOR V.

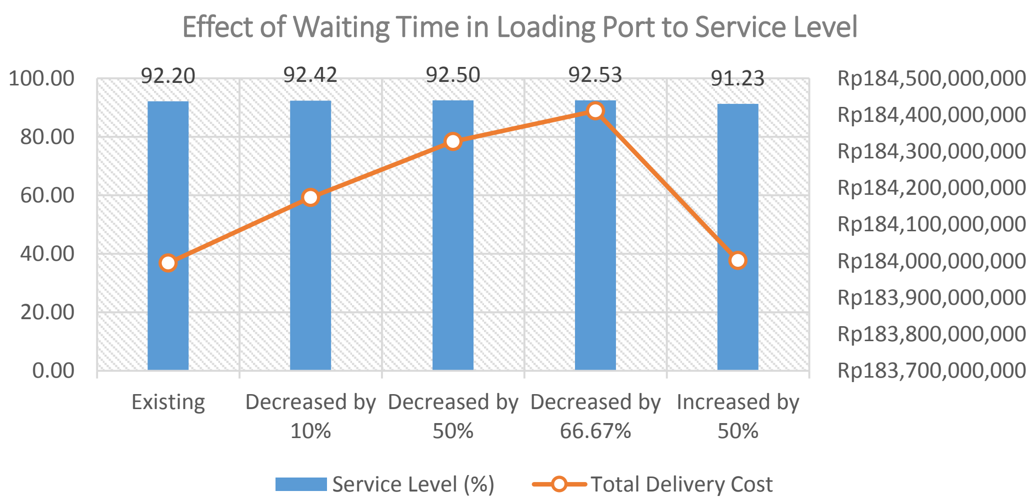

Figure 6. 5 Effect of Waiting Time in Loading Port to Service Level

The reduction of duration of waiting in loading ports increases the service level since it also increases the number of delivery. However, service level and total distribution cost show different result when duration of waiting time in all loading ports are increased by 50%. The overall service level decreased into 91.23%. Total distribution cost is also decreased due to fewer number of delivery.

Second experiment is reducing duration of waiting time by 50%, then, determining number of tankers is performed. The purpose of experiment is to find out whether reducing duration of waiting time up to 50% can result in different tanker combination. Detail replication for second experiment can be seen in Appendix F. Figure 6.6 summarizes the effect of tanker combination to service level if duration of waiting time in loading ports is reduced by 50%. The result is the selected number of tanker combination lies in the *3rd Combination.* Reduction of waiting time affects decision of choosing tanker combination since the result has been shifted from *4th Combination* to *3rd Combination.*

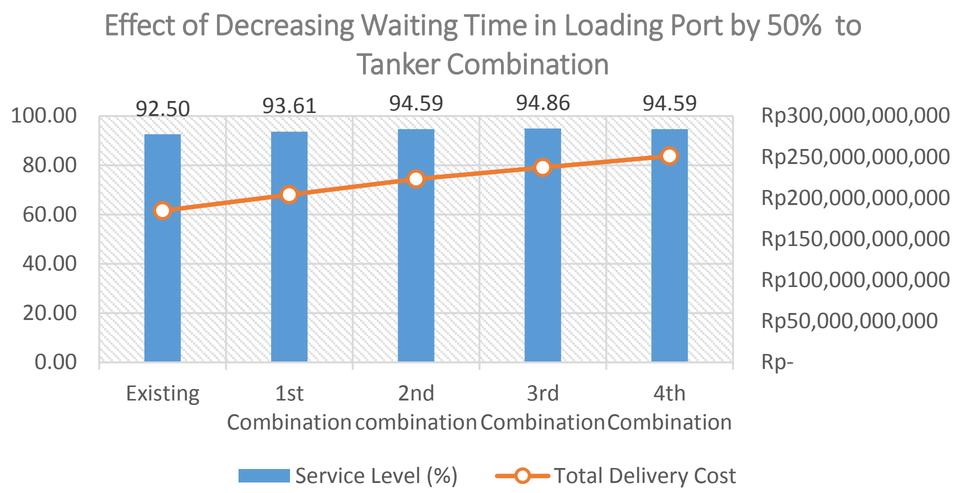

Figure 6. 6 Effect of Decreasing Waiting Time in Loading Port by 50% to Tanker Combination

6.4 Effect of TBBM Location to Service Level

This experiment will be performed by locating the new TBBM closer or further from initial location, which is Tuban. The base condition used in this experiment is the chosen combination from *Scenario 2* in which the number of tanker is determined with consideration the existence of new TBBM. Detail replication of this experiment can be found in Appendix G.

Table 6. 1 Change of Location of New TBBM

Description	DPPU						
Lead Time (in days)	1	2	3	4	5	6	10
Existing	1.21	1.42	1.79	2.67	3.17	2.67	2.40

Description	DPPU						
Lead Time (in days)	**1**	**2**	**3**	**4**	**5**	**6**	**10**
TBBM is located closer to discharge ports	0.60	0.71	0.90	1.33	1.58	1.33	1.20
TBBM is located further to discharge ports	1.81	2.13	2.69	4.00	4.75	4.00	3.60

Table 6. 2 Closer Location of TBBM Compared to Other Loading ports

	DPPU							
Supply Point	in Days	**1**	**2**	**3**	**4**	**5**	**6**	**10**
	TBBM is located closer to discharge ports	0.60	0.71	0.90	1.33	1.58	1.33	1.20
	12	1.92	1.75	2.75	3.29	3.75	3.58	3.04
	11	1.92	2.13	1.88	2.67	3.71	2.33	2.42
	7	0.71	0.92	1.38	2.25	2.71	2.21	1.96
	9	0.33	0.25	1.75	3.42	4.25	3.67	3.75

Table 6. 3 Further Location of TBBM Compared to Other Loading Ports

	DPPU							
Supply Point	in Days	**1**	**2**	**3**	**4**	**5**	**6**	**10**
	TBBM is located further to discharge ports	1.81	2.13	2.69	4.00	4.75	4.00	3.60
	12	1.92	1.75	2.75	3.29	3.75	3.58	3.04
	11	1.92	2.13	1.88	2.67	3.71	2.33	2.42
	7	0.71	0.92	1.38	2.25	2.71	2.21	1.96
	9	0.33	0.25	1.75	3.42	4.25	3.67	3.75

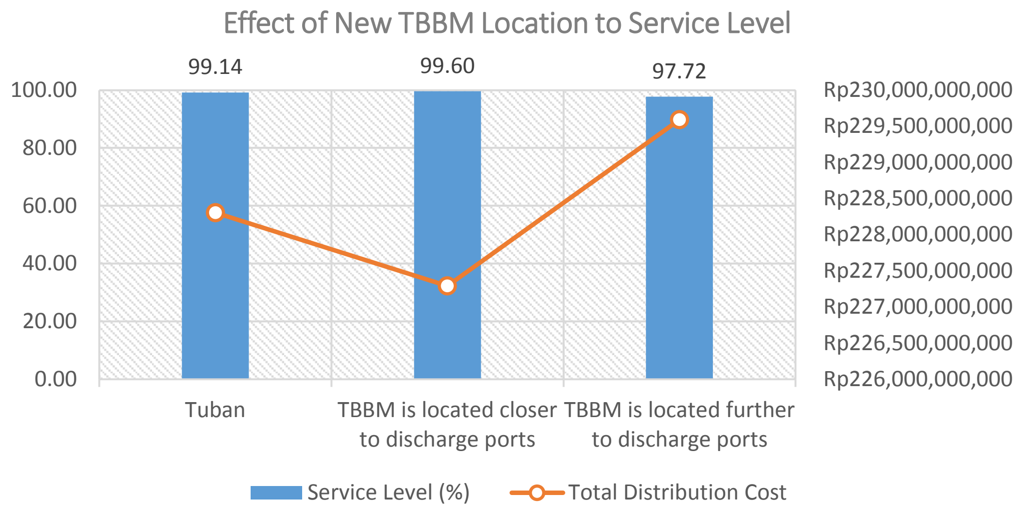

Figure 6. 7 Effect of Location of New TBBM to Service Level

Figure 6.7 summarizes the experiment for this subchapter. When new TBBM is built closer to DPPUs than initial location, tankers tempt to load avtur from the new TBBM since the stock of avtur is always ready – compared to STS Kalbut or Tanjung Manggis in which sometimes tanker has to wait for next supply from Cilacap when the capacity of tanker is bigger than stock-on-hand in those transshipment points. It can be concluded that the closer new TBBM gets, the cheaper total distribution cost becomes due to fewer bunker consumption.

TBBM that is closer than initial location proposes better result because, based on Table 6.2 through Table 6.4, initial location (Tuban) is quite far from DPPUs compared to STS Kalbut and Tanjung Manggis. Thus, tankers will keep loading from STS Kalbut and Tanjung Manggis instead of Tuban. TBBM in Tuban will help reducing jetty occupancy in Cilacap by redirecting *Srikandi* into TBBM Tuban.

6.5 Effect of Waiting Time in New TBBM to Service Level

This experiment is similar with experiment in subchapter 6.2. However, in this experiment, the changed parameter is only duration of waiting time in new TBBM. The base scenario is the chosen tanker combination of *Scenario 2* to find out whether the current number of tanker can handle the change of parameter of duration waiting time:

1. Reduce duration of waiting time by 10%
2. Reduce duration of waiting time by 33.33%
3. Reduce duration of waiting time by 50%
4. Increase duration of waiting time by 50%

Details of replication and output summary for this experiment can be found in Appendix H.

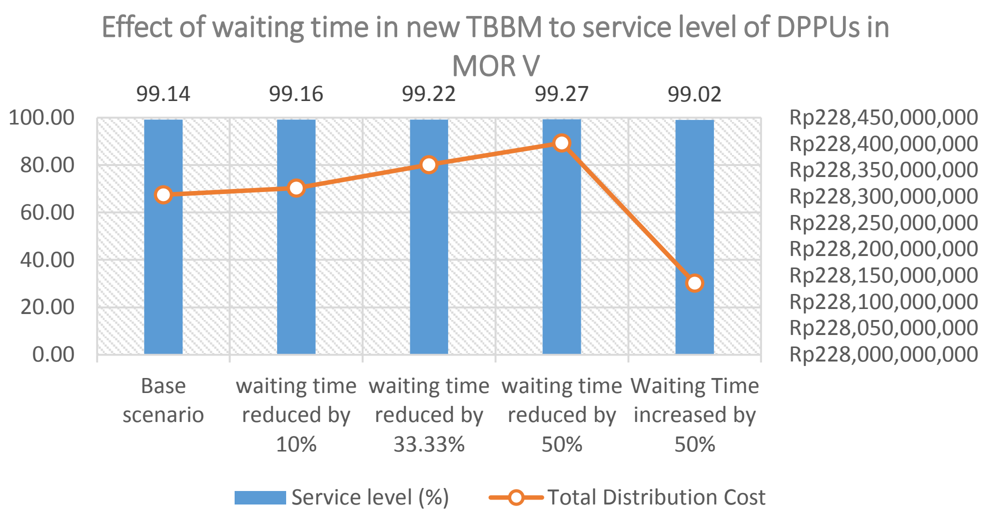

Figure 6. 8 Effect of Waiting Time in New TBBM to Service Level of DPPUs in MOR V

The summary of this experiment is exhibited by Figure 6.7. The reduction of waiting time in TBBM Tuban does not give significant result since the overall service level in base scenario has reached 99%. It can be concluded that the recommended tankers will perform fine without any significant disturbance in service level when average waiting time is longer than (up to 50%) the predicted time.

6.6 Effect of Changing Capacity of Storage Tank to Tanker Combination when Capacity of Storage Tank is increased by 50%

This experiment is development of *Scenario 1: 4th Combination* since based on Table 5.5, service level of Benoa has not reached 90%. Current storage tank capacity in Benoa can only cover less than 10 days of demand. This is too risky since if tankers are late, even only once, it would cause critical condition in Benoa. Thus, this experiment tries to upsize the storage tank capacity by 50% and, at the same time, to increase number of tankers in order to increase the number of delivery. To perform this experiment, some conditions are set:

1. The base scenario for this experiment is *4th Combination* from *Scenario 1*.
2. Capacity of storage tank in Benoa will be increased by 50% of initial capacity (minimum requirement if capacity of storage tank is planned to be upsized.
3. Composition of tanker combination in this experiment is different from previous experiments since this involves more tanker (Table 6.5)
4. The experiment uses initial DOT

Table 6. 4 Tanker Combination when Storage Capacity is Upsized

Number of Tanker in Use								
Tanker Combination	**S. gerong**	**Sambu**	**Srikandi**	**Sinar Agra**	**Olyvia**	**Plaju**	**Dewayani**	**Shinta**
Existing	1	1	1	1	2	2	2	2
1st Combination	1	1	1	1	3	2	2	2
2nd combination	1	1	1	2	4	4	3	3
3rd Combination	1	1	1	3	5	5	3	4
4th Combination	1	1	1	4	5	5	3	5

Details of replication and simulation output for this experiment can be found in Appendix I. Figure 6.9 summarizes the effect of tanker combination when storage tank capacity in Benoa is upsized to overall service level and to service level in Benoa (Figure 6.10). *4th Combination* is selected since the overall service level has reached 95% and the service level in Benoa has reached 90%.

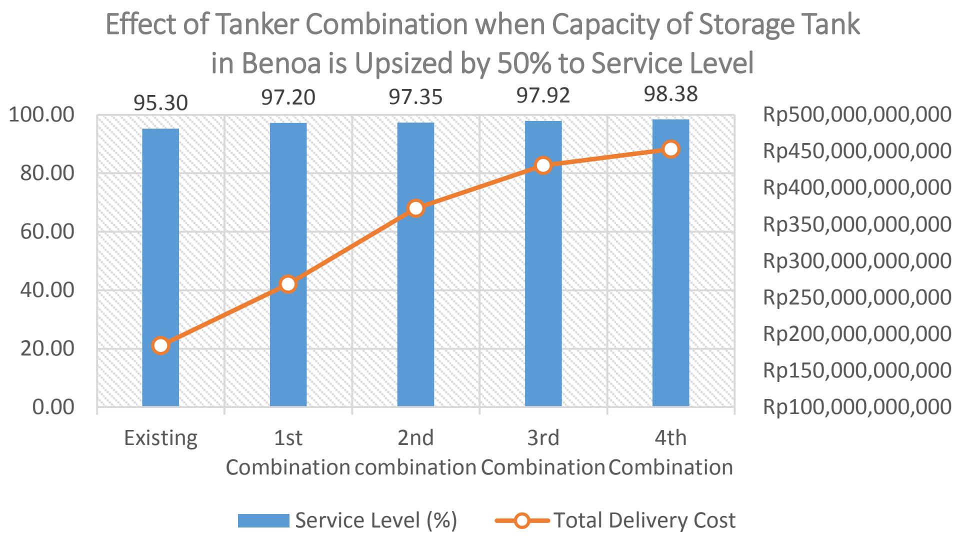

Figure 6. 9 Effect of Upsizing Storage Tank Capacity to Service Level

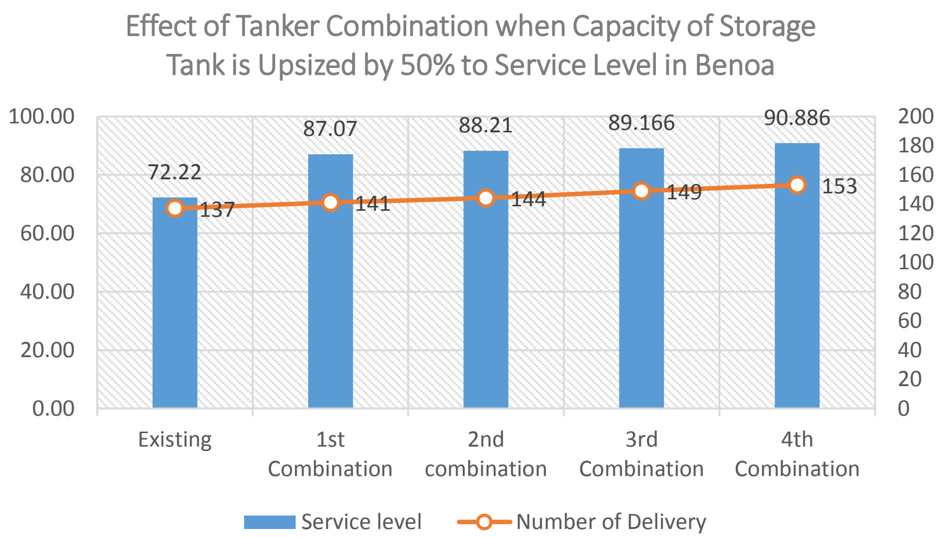

Figure 6. 10 Effect of Upsizing Storage Tank Capacity to Service Level in Benoa

CHAPTER 7
CONCLUSION

7.1 Conclusion

The conclusion to this research are:

1. A conceptual and simulation models has been developed to be used for determining the number of tankers required to reach the desired service level in two conditions: the current one, and when a new TBBM is added in Tuban as a supply point/loading port. The model can accommodate the experimentation considering several conditions when there is: a change of waiting time duration in initial loading ports, a change of waiting time in the new TBBM, a change of storage tank capacity, and a change of new TBBM location.
2. Experiment is performed under two scenarios:
   a. Experiment with the model of current condition found that 12 tankers are required. This combination will result in a total annual distribution cost of IDR 249,220,600,000.
   b. When a new TBBM is added, the recommended number of tankers is 11. The combination will result in a total annual distribution cost of IDR 228,303,600,000.
3. A sensitivity analysis has been performed by changing the value of the following variables: waiting time duration in the loading ports, waiting time in the new TBBM, and the capacity of storage tank in DPPU Bali. Based on the performed sensitivity analysis:
   a. The recommended tankers in point (2.b) will perform fine without any significant disturbance in service level when average waiting time is longer than (up to 50%) the predicted time.
   b. If duration of waiting time in initial loading ports can be reduced as much as 50%, the recommended tankers combination in point (2.a) can

be changed to that in point (2.b). It also means a saving of IDR 13,828,800,000.

c. If the new TBBM location is closer to the destination, there will be a meaningful reduction to the total distribution cost due to fewer consumption of bunker cost and higher service level than that resulted in point (2.b).
d. Upsizing the capacity of storage tank in Benoa will significantly affects the required tankers combination to reach a service level of 90%.

7.2 Suggestion

The suggestions for this research are:

1. Financial analysis should be done thoroughly to support the selection of experiments. Furthermore, it will provide a stronger reason for decision maker.
2. When data is available or possible to be collected, other types of disruption such as natural disaster and breakdown of tanker should be included in the model.
3. More data should be used as model input. The minimum data required for a year prediction, at least is a one-year data. That way, it will be sufficient to provide information about system behavior throughout the year.

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APPENDIX

Appendix A: Lead Time Matrix (in days)

From/To	Ampenan	Benoa	Bima	Ende	Kupang	Maumere	STS Kalbut	Surabaya	Manggis	Waingapu	Balikpapan	Cilacap
Ampenan		0.25	0.83	1.75	2.21	1.79	0.71	1.04	0.17	1.50	1.92	1.92
Benoa	0.25		1.13	1.71	2.17	2.00	0.92	0.00	0.13	1.46	2.13	1.75
Bima	0.83	1.13		0.83	1.29	0.96	1.38	1.58	0.88	0.83	1.88	2.75
Ende	1.75	1.71	0.83		0.58	0.88	2.25	2.33	1.71	0.46	2.67	3.29
Kupang	2.21	2.17	1.29	0.58		1.75	2.71	2.79	2.13	0.96	3.71	3.75
Maumere	1.79	2.00	0.96	0.88	1.75		2.21	2.50	1.83	1.29	2.33	3.58
STS Kalbut	0.71	0.92	1.38	2.25	2.71	2.21		0.33	0.00	1.96	0.00	2.50
Surabaya	1.04	0.00	1.58	2.33	2.79	2.50	0.33		0.92	1.96	2.04	2.96
Manggis	0.17	0.13	0.88	1.71	2.13	1.83	0.00	0.92		1.88	1.96	1.88
Waingapu	1.50	1.46	0.83	0.46	0.96	1.29	1.96	1.96	1.88		2.42	3.04
Balikpapan	1.92	2.13	1.88	2.67	3.71	2.33	0.00	2.04	1.96	2.42		3.71
Cilacap	1.92	1.75	2.75	3.29	3.75	3.58	2.50	2.96	1.88	3.04	3.71	

Appendix B : Validation, One-Way Anova

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	5	931.37	186.274	500.788
Column 2	5	865	173	0

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	440.4977	1	440.4977	1.759218	0.221335	5.317655
Within Groups	2003.152	8	250.394			
Total	2443.65	9				

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	5	1246.38	249.276	973.8345
Column 2	5	1275	255	0

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	81.91044	1	81.91044	0.168223	0.692460411	5.317655
Within Groups	3895.33812	8	486.917265			
Total	3977.24856	9				

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	5	7898.13	1579.626	16955.53
Column 2	5	7275	1455	0

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	38829.1	1	38829.1	4.580109	0.064764	5.317655
Within Groups	67822.14	8	8477.767			

Total	106651.2	9				

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	5	71177.95	14235.59	2798071
Column 2	5	76090	15218	0

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	2412823.52	1	2412823.52	1.724633	0.225511372	5.317655
Within Groups	11192285.64	8	1399035.704			
Total	13605109.16	9				

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	5	69557.5	13911.5	2046665
Column 2	5	76070	15214	0

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	4241266	1	4241266	4.144564	0.076166	5.317655
Within Groups	8186658	8	1023332			
Total	12427924	9				

Appendix C: Simulation Output for *Scenario 1*

Existing Replication	Service Level (%)							
	1	2	3	4	5	6	8	10
1	93.97	62.47	99.73	90.68	98.08	100.00	97.40	100.00
2	96.16	60.00	100.00	96.71	99.45	100.00	94.11	100.00
3	92.33	61.10	100.00	95.89	100.00	100.00	95.48	100.00
4	91.78	53.15	100.00	91.23	97.26	100.00	93.56	100.00
5	88.22	51.78	100.00	95.07	99.45	100.00	93.01	100.00

Replication	Service Level (%)							
	1	2	3	4	5	6	8	10
1	92.054	63.835	99.178	94.52	100	100	96.643	100
2	95.068	65.753	100	97.534	100	100	97.843	100
3	96.986	67.397	100	96.712	100	100	95.63	100
4	96.712	70.41	100	95.068	100	100	96.465	100
5	90.958	62.191	100	93.972	99.73	100	92.164	100

Replication	Service Level (%)							
	1	2	3	4	5	6	8	10
1	95.342	62.465	99.452	95.068	98.36	100	95.082	100
2	98.904	73.698	100	93.698	99.45	100	97.123	100

Replication	Service Level (%)							
	1	2	3	4	5	6	8	10
3	91.78	65.479	99.178	94.794	100	100	98.287	100
4	97.26	70.958	100	94.52	100	100	96.835	100
5	92.602	66.849	98.63	90.684	98.36	100	96.301	100

Replication	Service Level (%)							
	1	2	3	4	5	6	8	10
1	96.712	74.246	100	95.616	100	100	93.561	100
2	95.616	66.301	100	95.342	100	100	96.356	100
3	95.89	72.328	100	97.808	100	100	95.383	100
4	96.712	71.78	100	90.136	96.99	100	96	100
5	97.808	71.232	100	95.068	98.9	100	97.013	100

Replication	Service Level (%)							
	1	2	3	4	5	6	8	10
1	96.99	72.33	99.73	96.16	100.00	100	95.92	100
2	96.99	69.86	100.00	94.52	99.73	100	97.10	100
3	95.34	67.40	100.00	97.26	100.00	100	97.56	100
4	98.63	78.63	98.36	97.53	100.00	100	97.38	100
5	97.26	72.88	100.00	97.53	100.00	100	95..465	100

Tanker Combination	Service Level (%)								Number of Delivery							
	1	2	3	4	5	6	8	10	1	2	3	4	5	6	8	10
Existing	92.49	57.70	99.95	93.92	98.85	100.00	94.71	100.00	21	127	23	24	24	23	26	24
1st Combination	94.36	65.92	99.84	95.56	99.95	100.00	95.75	100.00	22	134	25	25	25	25	28	25
2nd combination	95.18	67.89	99.45	93.75	99.23	100.00	96.73	100.00	23	132	24	25	24	24	26	25
3rd Combination	96.55	71.18	100.00	94.79	99.18	100.00	95.66	100.00	22	133	24	25	25	25	27	25
4th Combination	97.04	72.22	99.62	96.60	99.95	100.00	96.99	100.00	23	137	24	26	25	25	24	25

Appendix D: Simulation Output for *Scenario 2*

Existing Replication	Service Level (%)							
	1	2	3	4	5	6	8	10
1	100	68.219	100	91.78	99.726	100	100	100
2	100	78.082	99.452	96.986	100	100	100	100
3	100	84.383	100	100	100	100	100	100
4	100	73.424	97.808	95.342	99.452	100	100	100
5	100	84.931	100	100	100	100	100	100

Replication	Service Level (%)							
	1	2	3	4	5	6	8	10
1	100	86.301	100	92.602	100	100	100	100
2	100	88.767	100	98.63	100	100	100	100
3	100	83.835	100	89.315	98.904	100	100	100
4	100	89.041	100	99.178	100	100	100	100
5	100	85.479	99.726	93.15	100	100	100	100

Replication	Service Level (%)							
	1	2	3	4	5	6	8	10
1	100	92.328	100	99.178	100	100	100	100
2	100	90.136	100	94.794	100	100	100	100

Replication	Service Level (%)							
	1	**2**	**3**	**4**	**5**	**6**	**8**	**10**
3	100	92.328	100	99.726	100	100	100	100
4	100	92.054	100	95.342	100	100	100	100
5	100	94.246	100	98.63	100	100	100	100

Replication	Service Level (%)							
	1	**2**	**3**	**4**	**5**	**6**	**8**	**10**
1	100	92.328	99.726	99.726	100	100	100	100
2	100	92.054	100	99.178	100	100	100	100
3	100	93.424	100	100	100	100	100	100
4	100	93.972	100	99.726	100	100	100	100
5	100	95.616	100	100	100	100	100	100

Replication	Service Level (%)							
	1	**2**	**3**	**4**	**5**	**6**	**8**	**10**
1	100	93.15	100	100	100	100	100	100
2	100	94.246	100	100	100	100	100	100
3	100	92.876	100	99.178	100	100	100	100
4	100	93.698	100	99.452	100	100	100	100
5	100	96.712	100	100	100	100	100	100

Tanker Combination	Service Level (%)								Number of Delivery							
	1	2	3	4	5	6	8	10	1	2	3	4	5	6	8	10
Existing	100.00	77.81	99.45	96.82	99.84	100.00	100.00	100.00	18	115	25	25	25	25	0	25
1st Combination	100.00	86.68	99.95	94.58	99.78	100.00	100.00	100.00	21	127	24	25	25	24	0	25
2nd combination	100.00	92.22	100.00	97.53	100.00	100.00	100.00	100.00	23	133	25	26	25	25	0	26
3rd Combination	100.00	93.48	99.95	99.73	100.00	100.00	100.00	100.00	22	135	27	28	28	28	0	28
4th Combination	100.00	94.14	100.00	99.73	100.00	100.00	100.00	100.00	22	137	28	29	28	28	0	29

Appendix E: Simulation Output of Experiment 1.a

Existing Condition								
Existing Replication	Service Level (%)							
	1	2	3	4	5	6	8	10
1	93.97	62.47	99.73	90.68	98.08	100.00	97.40	100.00
2	96.16	60.00	100.00	96.71	99.45	100.00	94.11	100.00
3	92.33	61.10	100.00	95.89	100.00	100.00	95.48	100.00
4	91.78	53.15	100.00	91.23	97.26	100.00	93.56	100.00
5	88.22	51.78	100.00	95.07	99.45	100.00	93.01	100.00

Existing Condition, waiting time decreased by 10%								
Replication	Service Level (%)							
	1	2	3	4	5	6	8	10
1	94.25	56.45	98.63	95.34	100.00	100.00	97.67	100.00
2	92.33	57.84	100.00	93.42	99.45	100.00	97.40	100.00
3	90.14	59.45	100.00	92.33	98.36	100.00	95.21	100.00
4	91.23	55.68	99.45	94.25	98.08	100.00	95.64	100.00
5	93.97	59.18	98.63	97.26	99.18	100.00	96.18	100.00

Existing Condition, waiting time decreased by 50%								
Replication	**Service Level (%)**							
	1	**2**	**3**	**4**	**5**	**6**	**8**	**10**
1	94.25	60.55	99.45	93.97	99.45	100.00	95.38	100.00
2	94.52	59.18	100.00	97.81	100.00	100.00	92.47	100.00
3	90.41	57.53	100.00	94.79	99.45	100.00	96.58	100.00
4	93.42	56.99	99.45	94.79	97.81	100.00	95.21	100.00
5	90.68	54.52	100.00	95.89	99.45	100.00	96.03	100.00

Existing Condition, waiting time decreased by 66.67%								
Replication	**Service Level (%)**							
	1	**2**	**3**	**4**	**5**	**6**	**8**	**10**
1	92.05	60.87	100.00	94.25	96.99	100.00	97.12	100.00
2	89.04	58.95	100.00	95.62	100.00	100.00	93.84	99.45
3	90.96	57.26	100.00	95.07	98.36	100.00	95.75	100.00
4	88.77	58.45	100.00	97.81	100.00	100.00	93.29	100.00
5	92.88	59.63	100.00	97.81	100.00	100.00	96.85	100.00

Existing Condition, waiting time increased by 50%								
Replication	**Service Level (%)**							
	1	**2**	**3**	**4**	**5**	**6**	**8**	**10**
1	93.97	61.92	100.00	95.62	99.73	100.00	96.47	100.00
2	87.67	53.97	99.18	90.41	99.73	100.00	95.47	100.00

Existing Condition, waiting time increased by 50%								
Replication	**Service Level (%)**							
	1	**2**	**3**	**4**	**5**	**6**	**8**	**10**
3	89.04	54.25	99.18	90.68	93.97	100.00	96.03	100.00
4	89.86	54.79	100.00	85.75	93.70	100.00	95.73	100.00
5	90.14	56.71	100.00	92.88	99.45	100.00	93.01	100.00

Tanker Combination	**Service Level (%)**							
	1	**2**	**3**	**4**	**5**	**6**	**8**	**10**
Existing	92.49	57.70	99.95	93.92	98.85	100.00	94.71	100.00
Decreased by 10%	92.3828	57.72	99.342	94.52	99.0136	100	96.4188	100
Decreased by 50%	92.66	57.75	99.78	95.45	99.23	100.00	95.13	100.00
Decreased by 66.67%	90.7392	59.032	100	96.1092	99.0684	100	95.3694	99.8904
Increased by 50%	90.14	56.33	99.67	91.07	97.31	100.00	95.34	100.00

Appendix F: Simulation Output of Experiment 1.b

Replication	Service Level (%)							
	1	2	3	4	5	6	8	10
1	95.068	66.027	99.178	92.328	99.726	100	96.027	100
2	92.602	67.945	100	96.164	99.726	100	93.561	99.452
3	93.424	66.301	99.726	95.89	100	100	92.465	100
4	93.698	66.575	100	93.15	95.616	100	93.561	100
5	97.534	67.123	100	94.246	98.63	100	98.767	100

Replication	Service Level (%)							
	1	2	3	4	5	6	8	10
1	96.438	69.315	99.452	90.41	98.63	100	92.547	100
2	98.082	74.52	99.452	95.068	100	100	96.849	100
3	91.506	72.328	100	95.068	100	100	95.835	100
4	99.178	74.246	100	95.342	100	100	96.301	100
5	95.616	68.767	100	93.972	99.726	100	94.821	100

Replication	Service Level (%)							
	1	2	3	4	5	6	8	10
1	97.808	71.506	100	91.232	98.082	100	94.109	100
2	95.89	70.958	100	98.356	100	100	97.123	100

Replication	Service Level (%)							
	1	2	3	4	5	6	8	10
3	95.616	71.506	100	96.712	100	100	93.287	100
4	96.986	67.945	100	95.068	98.63	100	96.027	100
5	99.178	74.52	100	98.904	100	100	95.095	100

Replication	Service Level (%)							
	1	2	3	4	5	6	8	10
1	97.808	67.945	100	94.794	100	100	94.013	100
2	95.068	67.671	100	96.438	100	100	95.835	100
3	94.52	74.246	100	98.082	98.356	100	96.739	100
4	94.246	72.054	100	93.972	99.726	100	95.109	100
5	97.534	69.315	100	96.712	100	100	93.383	100

Tanker Combination	Service Level (%)							
	1	2	3	4	5	6	8	10
Existing	92.66	57.75	99.78	95.45	99.23	100.00	95.13	100.00
1st Combination	94.47	66.79	99.78	94.36	98.74	100.00	94.88	99.89
2nd combination	96.16	71.84	99.78	93.97	99.67	100.00	95.27	100.00
3rd Combination	97.10	71.29	100.00	96.05	99.34	100.00	95.13	100.00
4th Combination	95.84	70.25	100.00	96.00	99.62	100.00	95.02	100.00

Appendix G: Simulation Output of Experiment 2

Replication	Service Level (%)							
	1	**2**	**3**	**4**	**5**	**6**	**8**	**10**
1	100	92.328	99.7	99.73	100	100	100	100
2	100	92.054	100	99.18	100	100	100	100
3	100	93.424	100	100	100	100	100	100
4	100	93.972	100	99.73	100	100	100	100
5	100	95.616	100	100	100	100	100	100

Distance reduced by 50%	Service Level (%)							
	1	**2**	**3**	**4**	**5**	**6**	**8**	**10**
1	100	97.96	100	100	100	100	100	100
2	100	95.97	100	100	100	100	100	100
3	100	95.60	100	100	100	100	100	100
4	100	98.62	100	100	100	100	100	100
5	100	95.79	100	100	100	100	100	100

Distance increased by 50%	Service Level (%)							
	1	**2**	**3**	**4**	**5**	**6**	**8**	**10**
1	100	83.972	100	98.63	100	100	100	100
2	100	82.876	100	100	100	100	100	100

Distance increased by 50%	**Service Level (%)**							
	1	**2**	**3**	**4**	**5**	**6**	**8**	**10**
3	98.63	82.328	100	98.8	99.86	100	100	100
4	98.89	85.068	100	98.93	100	100	100	100
5	99.05	84.246	98.47	100	98.98	100	100	100

Location Scenario	**Service Level (%)**							
	1	**2**	**3**	**4**	**5**	**6**	**8**	**10**
Tuban	100	93.479	99.9452	99.73	100	100	100	100
Distance reduced by 50%	100	96.788	100	100	100	100	100	100
Distance increased by 50%	99.31	83.698	99.694	99.27	99.768	100	100	100

Appendix H: Simulation Output of Experiment 3

Replication	Service Level (%)							
	1	2	3	4	5	6	8	10
1	100	92.328	99.726	99.726	100	100	100	100
2	100	92.054	100	99.178	100	100	100	100
3	100	93.424	100	100	100	100	100	100
4	100	93.972	100	99.726	100	100	100	100
5	100	95.616	100	100	100	100	100	100

waiting time reduced by 10%	Service Level (%)							
	1	2	3	4	5	6	8	10
1	100	94.79	100	100	100	100	100	100
2	100	94.79	100	99.726	99.726	100	100	100
3	100	93.42	99.726	99.45	100	100	100	100
4	100	93.42	100	100.00	100	100	100	100
5	100	91.51	100	100.00	100	100	100	100

waiting time reduced by 33.33%	Service Level (%)							
	1	2	3	4	5	6	8	10
1	100	92.88	99.726	100	100	100	100	100
2	100	94.78	100	99.452	100	100	100	100
3	100	93.97	100	100.00	100	100	100	100
4	100	93.70	100	100.00	100	100	100	100
5	100	94.25	100	100.00	100	100	100	100

waiting time reduced by 50%	Service Level (%)							
	1	2	3	4	5	6	8	10
1	100	91.78	100	100	100	100	100	100
2	100	94.70	100	100	100	100	100	100
3	100	95.40	100	99.50	100	100	100	100
4	100	95.59	100	99.73	100	100	100	100
5	100	94.52	100	99.45	100	100	100	100

Waiting Time increased by 50%	Service Level (%)							
	1	2	3	4	5	6	8	10
1	100	91.07	100	99.18	100	100	100	100
2	100	91.80	100	99.73	100	100	100	100
3	100	92.60	100	98.01	100	100	100	100
4	100	93.97	100	100.00	100	100	100	100
5	100	94.79	100	99.73	100	100	100	100

Tanker Combination	**Service Level (%)**							
	1	**2**	**3**	**4**	**5**	**6**	**8**	**10**
Tuban	100	93.48	99.9452	99.73	100	100	100	100
waiting time reduced by 10%	100	93.5884	99.9452	99.8356	99.9452	100	100	100
waiting time reduced by 33.33%	100	93.9144	99.9452	99.8904	100	100	100	100
waiting time reduced by 50%	100	94.40	100	99.74	100	100	100.00	100
Waiting Time increased by 50%	100	92.85	100	99.33	100	100	100	100

Appendix I: Simulation Output of Experiment 4

Replication	Service Level (%)							
	1	2	3	4	5	6	8	10
1	98.62	87.88	100	98.08	100	100	97.37	100
2	97.97	89.67	99.45	99.18	100	100	97.66	100
3	98.62	85.67	100	92.88	95.89	100	96.29	100
4	96.88	84.78	100	97.81	100	100	97.64	100
5	97.26	87.33	100	96.44	98.63	100	96.00	100

Replication	Service Level (%)							
	1	2	3	4	5	6	8	10
1	100	87.97	100	97.97	98.63	100	97.66	100
2	100	90.76	100	95.62	98.63	100	97.11	100
3	97.70	87.78	100	97.40	94.25	100	98.38	100
4	98.44	86.34	100	97.53	95.34	100	96.10	100
5	96.71	88.21	100	98.70	99.45	100	97.48	100

Replication	Service Level (%)							
	1	2	3	4	5	6	8	10
1	97.26	90.14	100	97.33	96.99	100	98.03	100
2	100	89.74	100	98.88	97.53	100	96.73	100

Replication	Service Level (%)							
	1	2	3	4	5	6	8	10
3	98.52	86.56	100	95.89	100	100	97.92	100
4	100	89.55	100	100	99.45	100	99.38	100
5	100	89.84	100	99.88	99.18	100	97.82	100

Replication	Service Level (%)							
	1	2	3	4	5	6	8	10
1	100	90.45	100	100	100	100	97.74	100
2	98.70	92.33	100	99.78	100	100	99.84	100
3	99.53	91.2	100	100	100	100	96.29	100
4	100	90.57	100	98.36	100	100	99.03	100
5	99.89	89.88	100	98.15	97.81	100	95.74	100

Tanker Combination	Service Level (%)							
	1	2	3	4	5	6	8	10
Existing	97.04	72.22	99.62	96.60	99.95	100	96.99	100
1st Combination	97.87	87.07	99.89	96.88	98.90	100	96.99	100
2nd combination	98.57	88.21	100	97.44	97.26	100	97.34	100
3rd Combination	99.16	89.17	100	98.39	98.63	100	97.98	100
4th Combination	99.62	90.89	100	99.26	99.56	100	97.73	100

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BIOGRAPHY

Hannah Febriani is the second daughter of Edy Heri Prasetyo and Juwairiah. The author was born in Jakarta, February 27th 1997. First started her formal school in SD Tunas Jakasampurna for the elementary school. Then, continued the study to SMP Labschool Jakarta for the junior high school. And SMAN 8 Jakarta for senior high school. The author went to college in 2014, entering Industrial Engineering Department of Institut Teknologi Sepuluh Nopember (ITS), Surabaya.

During the college years, the author was actively involved in several organizations. The author joined as staff of Pengembangan Sumber Daya Mahasiswa (PSDM) ITS in her second year (2015 – 2016). In the third year, the author joined as a volunteer of International Office (IO) ITS in Hospitality Division. In 2017, the author involved in a professional activity during her internship in PT Pertamina. For further discussion, the author can be reached through email: hannahhanun@gmail.com.