FINAL PROJECT – TI 141501

DISTRIBUTION OF SUBSIDIZED FERTILIZERS CONSIDERING TIME-WINDOWS AND STOCK CRITICALITY: A SIMULATION STUDY IN A FERTILIZER COMPANY

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APPROVAL SHEET

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FINAL PROJECT

Proposed as a Requisite to Graduate in Industrial Engineering Major and to Achieve a Bachelor Degree in Department of Industrial Engineering
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DISTRIBUTION OF SUBSIDIZED FERTILIZERS CONSIDERING TIME-WINDOWS AND STOCK CRITICALITY: A SIMULATION STUDY IN A FERTILIZER COMPANY

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ABSTRACT

PT. X is a subsidiary of state-owned company, PT. Pupuk Indonesia Holding Company, which produces and distributes fertilizers and non-fertilizer products to fulfill domestic and export market. As the biggest subsidiary company between other subsidiaries, PT. X has given a role to support the program of government to increase national agricultural product by producing and distributing subsidized fertilizers, such as Urea, ZA, SP-36, and Phonska.

In distributing the subsidized fertilizers, especially the land distribution to district warehouses in East Java, the common problem that the company facing is the imbalanced stock between different types of fertilizer products in the district warehouse, which makes the service level is not balanced. There are some product types that have very high amount of stock, while the others are having stock-out.

To overcome this problem, the author proposes this research to find the optimum fertilizer distribution decision to fulfill demand of multiple products in PT. X to test some improvement scenarios that adjust the delivery shift assignment rule to become considering time-windows, number of product types shipped in one truck, and dispatching rule considering the stock criticality. By implementing the selected scenario, which is to deliver two most critical product types in one truck and adjusting the delivery shift to consider the time-windows, it is found that the average service level becomes 77.34%, with the cost reduction of Rp 2,078,756,721 or 6% from the existing condition, to become Rp 30,936,138,279 in a year, due to joint-replenishment that is implemented.

Keywords : fertilizer, distribution, multiple products, stock criticality, ARENA, simulation, time windows

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The author recognizes that this is research needs further development. Therefore, a constructive suggestions and critics will be highly appreciated. May this research be useful for both academics and practical needs.

Surabaya, January 2018

Author

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CHAPTER I
INTRODUCTION

This chapter will explain about the background, problem formulation, and objectives of research, benefits, scope, and outline of the research

1.1 Background

As the population of Indonesian people increased every year, the need of primary food such as rice, corn, potato, and other agriculture products is also increased. This high demand of food needs and the high quality of the food can only be fulfilled by having a good quality of plant and soil. Fertilizer is one of the important products in agriculture sector that contribute to 20% of the successfulness in agricultural production increasing, and 15-30% to cost of agricultural enterprises, especially rice commodity. The Figure 1.1 shows the historical data about domestic sales of Urea, SP-36, ZA and NPK Fertilizers, which are mostly increasing in 2016 compared to the previous year. This fact supports the statement that the need of fertilizers to support national food security becomes the important issue that has to put on concern.

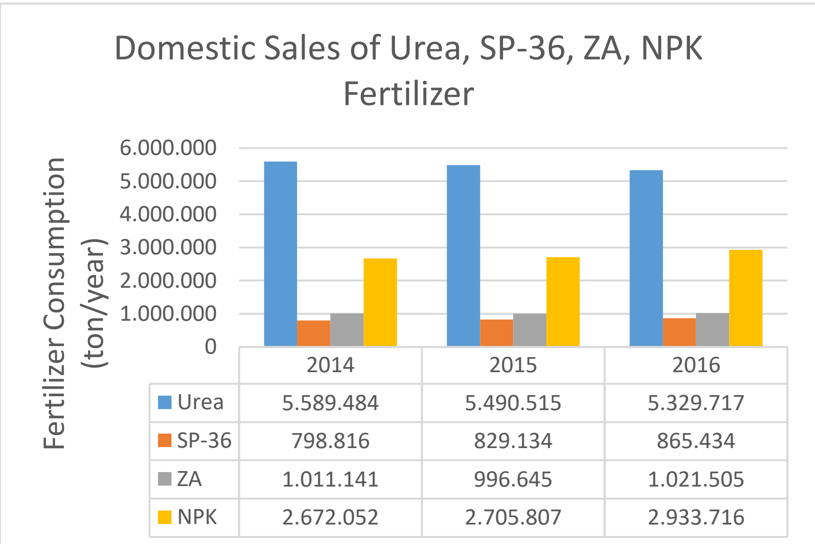

Figure 1.1 Fertilizer Consumption in 2014-2016 (Source: Association of Indonesian Fertilizer Producers)

Regarding to this situation, the government has made several policies to support national fertilizer industry growth, such as the one given to PT.X as the biggest fertilizer producer and distributor under PT. Pupuk Indonesia Holding Company. PT. X is a subsidiary of state-owned company that produces fertilizer and non-fertilizer products to fulfill domestic and export market. PT. X has given a role to support the program of the government to increase national agricultural product by producing and distributing subsidized fertilizers, such as Urea, NPK, Petroganik (Organic Fertilizer), SP-36, and ZA as it is stated on the Regulation of the Minister of Trade No.15 in 2013. In 2016, PT. X is given a responsibility to distribute 5.1 million tons of subsidized fertilizers from the overall national fertilizer needs of 9.55 million tons. Beside producing the subsidized fertilizers, PT. X also produces non subsidized fertilizers, customized fertilizers, and non-fertilizer products such as NPK Kebomas, ZK, DAP, KCL, Rock Phosphate, Petro Biofertil, etc.

To support this high demand of products, an effective and efficient strategy in all of the processes, such as the procurement, production planning, production, and distribution, is needed in order to get the most profitable result for the company, and also high customer satisfaction. One of the way to reach it is by making a good distribution network that is minimum in terms of cost and time consumed, but maximum in terms of market responsiveness and profit. According to Chopra & Meindl (2007), distribution refers to the steps taken to move and store product from supplier to customer that becomes the key driver of the overall profitability of a firm, because it affects both the supply chain cost and customer satisfaction directly.

PT. X has a principle of right place, right price, right amount, right quality, right type, and right time (6R) in doing the distribution activity. But in fact, the current condition in the distribution activity of Distribution Area 1, which is done using truck, still have some problems that affect their performance and make it unable to reach the 6R target. The truck delivers one type of fertilizers with the quantity of the allocated number that had been set by the government, to one district warehouse. Since the demand of one type of fertilizers in every district warehouse is high, it makes the distribution system unable to carry more than one type of fertilizers with the maximum quantity that has been set, due to the limitation of the truck capacity. Meanwhile, this condition makes the stock level in the district warehouse is only available for one type of products. This condition becomes a problem for the company, since mostly one agriculture commodity in an area needs more than one type of fertilizers. So, it is better if the distribution activity is done by carrying all type of products in one way of delivery, even though the quantity is not reaching the number of products allocated by the government yet. Later, the rest of the quantity will be fulfilled in the next delivery.

In the current condition, the trucks used in the land distribution of PT. X are taken from the third party logistics. So, every time the delivery wants to be done, PT. X will open the tender activity for the transportation provider to do the delivery. The delivery schedule for every destination is already set by PT. X by using their real-time land distribution application, so whenever there is an empty slot for delivery activity, the third party logistics can register to it. In the current distribution scheduling, each district warehouse, as the destination, is given three shifts of distribution activity, which are 07.00-15.00, 15.00-23.00, and 23.00-07.00. The hour in the shift indicates that the truck has to depart in the range of that hour. Even though PT. X already had a distribution scheduling, but this kind of scheduling is sometimes still prone to problem in delivery of the fertilizers. The problem in the delivery process may happen because the scheduling has not considered the time windows of the district warehouse and the distance from the factory to the district warehouse. Since there is high uncertainty in loading process time, travel time from factory to district warehouse, waiting time, unloading time, and other process time, it can lengthen the time needed by the truck to arrive to the district warehouse, which later becomes a problem if the truck arrives when the district warehouse is already closed. If this condition happens, the truck has to wait for the next day when the district warehouse opens, which can lead to a delay to other delivery activity done by that truck. By considering the discussion that has been stated, the development of a new distribution decision is needed in order to solve the current problems mentioned above, which is about to deliver the fertilizers to the district warehouse by considering the time windows, and the stock criticality of multiple products of subsidized fertilizers

By finding the optimum distribution strategy, it is expected that the distribution activity can deliver multiple products of subsidized fertilizers demanded, maintain the quantity in the desired level of stock that is able to fulfill the market demand, and also able to arrive in time. To develop the new distribution decision, a discrete-event simulation study can be done in this research because it can imitate the current condition of the system, and suitable for the behavior of the condition which has variability, interconnectedness between the components, and many occurrence of uncertainties due to its complex condition. Not only able to capture the condition of the system, simulation is also suitable for seeing the result of the proposed improvement scenario with less time consuming and cost.

The research is aimed to find the optimum fertilizer distribution decision to fulfill demand of multiple products in PT. X by using the method of discrete-event simulation study to test some improvement scenarios that change the delivery shift assignment rule to become considering time-windows, number of product types shipped in one truck, and dispatching rule considering the stock criticality.

1.2 Problem Formulation

The problem formulation that is going to be solved in this research is about to find the optimum distribution decision for the company to fulfill multiple products of subsidized fertilizers, but also keep the quantity in the desired number of stock and arrive on time, by considering the time windows and stock criticality. The output of the research will be about how these factors affect the cost and product availability. The cost components considered in this research are the transportation cost and holding cost. While for the product availability will be calculated by using the service level, which represents the probability of not having stock out in a replenishment cycle.

1.3 Objectives of Research

The objectives that are going to be achieved in this research are as follows:

1. To recommend improvements in distribution decision which considers the stock criticality of the multiple-products, time windows of the

district warehouse, and also assess the impact to the cost and product availability.

2. To compare the distribution cost and product availability between the existing condition and the proposed improvement scenario.

1.4 Benefits of Research

The benefits that are going to be obtained in this research are as follows:

1. The company will be able to know the distribution decision which considers the stock criticality of multiple subsidized fertilizers and time-windows in each district warehouse.
2. The company will be able to know the impact of adjusting the amount of load and multiple-products shipped, and also the delivery time that consider district warehouse time windows to the distribution cost and product availability.

1.5 Scope of Research

The scope used to describe the boundaries of this research is explained in the limitations and assumptions as follows:

1.5.1 Limitations

The limitation used in this research are as follows:

1. The research is focused on the distribution activity of subsidized fertilizers, which are Urea, ZA, SP-36, and Phonska.
2. The research is focused on the distribution activity shipped from Factory Warehouse in Gresik to Magetan, Lamongan1, Lamongan2, Tuban1, and Tuban2 District Warehouse by using truck of 30 ton.

1.5.2 Assumptions

The assumption used in this research are as follows:

1. The products are shipped only from one source, which is Gresik, to District Warehouse in East Java.
2. The resting time of the truck is already included in the overall trip time of the truck and there is no maintenance or breakdown time of the truck,

so the distribution activity can be done immediately after the truck arrived.

3. There is no product stock out problem in the factory, so the product stock is always available when it is needed.
4. The travel time and travel back time is using the same duration, by obtaining the result with approximation taken from Google Maps.

1.6 Outline of Research

This subchapter will explain about the research outline used in this research report, which is explained as follows

CHAPTER 1 INTRODUCTION

This subchapter will explain about the background of the research, the problem formulation of the research that will be solved in the research, the objective of the research that wants to be accomplished, the benefits of the research that are expected to be obtained, the limitation and assumption used in the research, and the research outline which explains the brief content of the research.

CHAPTER II LITERATURE REVIEW

This subchapter will explain about the theory used in doing the research. This theory will be used as a basis for the author to solve the research topic, and also to give a detail explanation to the reader about the concept used in the research. A supporting argument or opinion of the author regarding to the literature used is also needed, whether it is supporting the theory or defending the theory. The theory used is usually taken from books, previous researches, research paper, journal, and other qualified sources. The method or approach used by the author in the research also has to be explained in this chapter.

CHAPTER III RESEARCH METHODOLOGY

This subchapter will explain about the steps used in doing the research, from the beginning to the end. The steps will give a comprehensive understanding to the reader about the research procedure.

CHAPTER IV DATA COLLECTING & PROCESSING

This subchapter will explain about data collected regarding to the research that is done. The data can be gathered in the form of primary data from observation, or secondary data. All of the data then will become the input of the research, which will be proceed by using the research method or approach, in order to solve the problem and find the right solution for it.

CHAPTER V ANALYSIS & INTERPRETATION

This subchapter will explain about the analysis and further explanation about the result of data processing that has been done before.

CHAPTER VI CONCLUSION & SUGGESTION

This subchapter will explain about the conclusion that can be obtained from the result of the data processing, and the proposed suggestion for the research object and the next research.

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CHAPTER II
LITERATURE REVIEW

This chapter will explain about the theories, concepts, and knowledge obtained from the literature source that have been elaborated and used to support the research work.

2.1 Distribution and Transportation Management

Distribution and transportation management includes both the physical activity such as product storing and delivering, and also non-physical activity such as information sharing, and customer service providing. Basically, the purpose of doing distribution and transportation management is to provide a good service to satisfy the customer that can be assessed by seeing the service level obtained, delivery speed or market responsiveness, the quality of the product received by the customers, and a good after-sales service. An efficient distribution and transportation management in supply chain is important, since it affects the performance of the company in terms of market responsiveness. According to (Pujawan & Mahendrawathi, 2010), to obtain this goal, the management has to do some functions as follows.

1. Do the segmentation and set the targeted service level.
2. Decide transportation mode that will be used.
3. Do the information and delivery consolidation.
4. Do the transportation scheduling and routing.
5. Give the value-added service.
6. Manage the stock of inventory.
7. Manage the product return policy.

2.1.1 Distribution Management

Referred from Chopra & Meindl (2007), distribution refers to the steps taken to move and store a product from the supplier stage to a customer stage, which occurs between every pair of stage in supply chain. Distribution becomes a key driver of the overall profitability of a firm because it affects both the supply chain cost and customer experience directly.

Referred from Pujawan & Mahendrawathi (2010), there are three strategies of product distribution from the factory to the market, which are listed as follows

1. Direct Shipment

   The shipment is done directly from the factory to the customer, without the existence of warehouse, or other support facility, between them. This strategy is suitable for product with the characteristic of short lifetime, perishable, and easy to damage in the loading-unloading process. The benefit of using this strategy is the time to market will be faster and more responsive, less inventory in supply chain, and no cost spent on renting or building warehouse. On the other hand, it also has some impacts such as the increase in transportation cost due to the widened scope of the delivery activity, no economies of scale, and also the increase in risk possibility of supply and demand uncertainty.

2. Shipment via Warehouse

   The shipment is done by delivering the product from factory to support facility or warehouse first, before it finally delivers the product from support facility or warehouse to the customer. This strategy is suitable for products with high uncertainty of supply and demand, and also have relatively long lifetime (durable product). The existence of support facility also can be used to consolidate the products from different suppliers before delivering it to customers, so that the economies of scale can be reached. Support facility also can be used as a solution to overcome the imbalanced product supply and demand. Meanwhile, there will be also an increase of cost in support facility, time to market compared to direct shipment strategy, and in probability of damaged product due to the higher frequency of loading and unloading process.

3. Cross-Docking

   This shipment is combining the benefits of the two previous strategies, in which the shipment is done by having cross-dock facility between the factory and customers. In the cross-dock facility, it may receive some products from different factories and consolidate it when delivering it to the customers to reach the economies of scale. What makes it different from the

Warehouse Shipment strategy is in cross-docking, there will be no inventory kept in the facilities. But instead, the products will be just consolidated there and then shipped right after it. By using this strategy, the time to market will be faster, and the economies of scale will also able to be reached because of the consolidation. Moreover, the handling activity and inventory will be decreasing. On the other hand, this strategy needs a high investment to create a good information system and coordination between the company and customer.

2.1.2 Transportation Management

Transportation refers to the movement of product from one location to another as it makes its way from the beginning of a supply chain to the customer (Chopra & Meindl, 2007). Transportation usually represents the most important single element in logistics cost for most firms. Based on the research done by Davis, et al (2002), freight movement has been observed to contribute to one-third and two-third of total logistics costs. Thus, an efficient transportation system can give a beneficial impact of greater competition in the marketplace, greater economies of scale in production, and reduced cost. It is obvious that to make decision about designing and efficient transportation management, a good coordination between shipper, the party that requires the movement of products in supply chain, and the carrier, the party who is responsible in moving or transporting the products. Referred from Ballou (2003), here are some characteristics of transportation that have to be considered by the shipper when making decision about the transportation selection:

1. Price

   The cost of transportation activity, and also can be added by other related cost, such as the wage of loading/unloading workers, the cost of fuel, etc.

2. Average transit time

   The average time it takes for a shipment to move from its origin point to destination.

3. Transit time variability

   The usual differences occur between the shipments with the same origin and destination that happen due to weather, traffic congestion, number of stop offs, consolidate shipment time, and other uncertain performance.

4. Loss and damage

   Each transportation mode has its own characteristic, which results in the difference in ability to move freight without loss and damage. The fewer the claims against a carrier, the more favorable the service appears to the user.

After selecting the most suitable transportation mode for doing the shipment, there are also some strategies that can be done to reach the most efficient way in setting the transportation management referred from Chopra & Meindl (2007), which are:

1. Align transportation strategy with competitive strategy

   Manager should make sure that the company's transportation strategy supports its competitive strategy. The company should evaluate the transportation function based on a combination of transportation cost, inventory cost, and the level of responsiveness achieved with customers.

2. Consider both in-house and outsourced transportation

   Manager should consider an appropriate combination of company-owned and outsourced transportation, based on the company's ability to handle transportation profitably as well as the strategic importance of transportation to the success of the firm.

3. Use technology to improve transportation performance

   Manager must use information technology as a platform of integrating information among the shipper, carrier, and customers in the context of shipment activity. The use of information technology can help the company to do transportation planning, modal selection, and build delivery routes and schedules so that the costs can be lowered and the market responsiveness can be improved.

4. Design flexibility into the transportation network

   Manager should consider the uncertainty conditions that may happen in demand, transportation ability, and others, so that the company will use more flexible transportation mode. The cost may seem higher than the inflexible one, but the flexible transportation mode allows the company to reduce the overall cost of providing high level of responsiveness.

2.2 Product Availability

Referred from Chopra & Meindl (2007), product availability refers to a firm's ability to fill a customer order out of available inventory. When the demand of the customer is not fulfilled, a stock-out will occur. There are several ways to measure product availability. Some of the measurement methods are as listed next.

1. Product fill rate (fr) is the fraction of product demand that is satisfied from product in inventory. By using this approach, it is better to do the replenishment review over specified inventory stock of demand rather than time.
2. Order fill rate is fraction of orders that are filled from available inventory. Order fill rate also should be reviewed over a specified number of orders rather than time.
3. Cycle Service Level (CSL) is a fraction of replenishment cycles that end with all the customer demand being met. The value of CSL is equal to the probability of not having stock out in a replenishment cycle.

2.3 Information Visibility in Supply Chain

Information becomes the lifeline of business, driving effective decisions and actions especially in supply chain (Langley, et al., 2008). Information provides insights and visibility into the supply chain activities taking place from the inbound to outbound. The visibility of customer demand, customer order, delivery status, inventory stock levels, production schedules, and other supporting data help the manager to make efficient supply chain strategy and appropriate response regarding to the condition. According to Lee & Whang (2000), Kulp (2002) Yu, et al.(2001) and Cristina (2014), by having a good information visibility in the supply chain, it will improve the performance of some elements in supply chain as listed next.

1. Cost

Since the key dimension of supply chain visibility is the real-time transparency of ongoing process, it makes the planning of all supply chain-related activities become more controlled, including the cost planning. Significant savings, especially by eliminating unnecessary expenses, also can occur by having information visibility in supply chain. Here the costs related are distribution cost, inventory holding cost, procurement cost, stock-out cost, and other component costs (Kantari, 2017)

2. Quality

Visibility in supply chain also can lead to a beneficial impact in terms of quality, when it involves the performance of the supplier and manufacturer. By having an information visibility, the coordination between the elements inside the company and also the supplier can be improved, which can lead to a better product quality.

3. Service Level

Visibility is helpful for identifying potential disruptions in advance and taking immediate action, especially when it comes to service level agreements, promised lead times, on-time delivery, product availability, and customer response time (AEB, 2015). By maintaining the service level in a desired level, therefore the company can receive higher customer satisfaction.

4. Flexibility

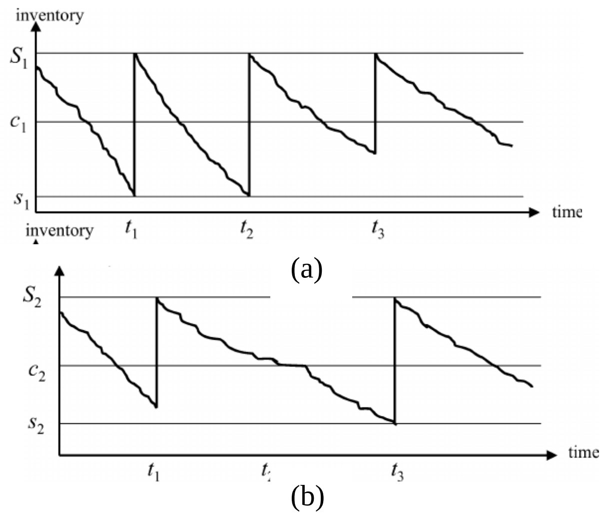
The challenge of managing complex supply chain is about how to deal with its volatile environment (Greene & Caragher, 2015). Thus, a well-managed and flexible supply chain is needed in order to reach the company competitive advantage and profitability. The flexibility can be seen in how the company or supplier can adjust the production or the order based on the uncertain demand and customer's desire.

5. Time

Information visibility in supply chain allows all the elements inside the supply chain to get the real-time condition of each of them, which makes them can interact better regarding to the condition so that the time needed can be reduced. Here the example is distribution cycle time, time to market, production lead time, and some others.

2.4 Can-Order Policy

Can-order policy or (s,c,S) policy is one of the classification of joint replenishment policy, in which the inventory is not controlled individually for every single item, but it is controlled simultaneously instead. The grouping of some different items in doing the replenishment is usually done in the item that is originated from the same source or supplier. According to Silver (1974), can-order policy has three different parameters used, such as order-up-to level (S), can-order level (c), and must-order level or reorder level (s). If the stock of one item reaches the level below s as the reorder level, then a delivery has to be done toward that item until it reaches the level of S. While delivering the product one that has been selected, can-order policy method is able to choose the second product to be delivered with the first product, so that the delivery process will be able to reach economies of scale. Figure 2.1 shows the example of replenishment for two different products using can-order policy. Figure 2.1(a) explains about the s,c,S level of the first product type. In the figure, is seen that the product is restocked when it reaches the reorder level (s) until the stock is in the level of S as the order-up-to level. Figure 2.1(b) explains about the s,c,S level of second product type. In the figure, it is seen that the product is restocked when it reaches the can-order level (c) until the stock is in the level of S as the order-up-to level.



(a)

(b)

Figure 2.1 Can-order Policy Method

Actually, calculation by using some formulas are needed to find the parameter of can-order policy, which are must-order level or reorder level (s), can-order level (c), and order-up-to level (S). But, in this research, some adjustments are made in order to make it more relatable with the current condition in the company. Here the reorder level (s) is using the Stock to Demand Ratio (SDR) value that has been set and considered critical by the company, valued 14 days, which makes the item has to be replenished as soon as possible. This value means that the stock item is considered critical if the stock is only able to cover the need for 14 days. While for the can-order level (c) is set to be the SDR critical value of the company plus 1 day, which makes it become 15 days. For the S level as the order-up-to level, the value is set to be the delivery target of each product. To compare every product type whether the product type is critical, the SDR value of each product type in all the district warehouse has to be calculated by using the Equation 2.1

$$Stock\ to\ Demand\ Ratio = \frac{On\ hand\ Inventory + Intransit\ Inventory}{Average\ Demand\ x\ Lead\ Time} \quad (2.1)$$

After the SDR each of the product type has been calculated, then these values have to be compared with the company SDR critical value to find the first critical product to be shipped. Then, the second product shipped can be selected by comparing the SDR value with the can-order level that has been set before.

Can-order policy is implemented in multiple product replenishment in order to get lower overall cost by combining some different products in the replenishment activity. In this research, the combination of the product types is set based on the criticality of stock.

2.5 System Modeling

System is defined as a collection of elements that function together to achieve a desired goal (Blanchard, 2012). While model is a simple representation of a system, either quantitative or qualitative, that represents the real condition about the process and describes the interaction between elements that are observed (Kelton, et al., 2002)

2.5.1 Elements of System

There are some elements of a system, which are entities, activities, resources, and controls in a simulation perspective. These elements define who, what, where, when, and how of entity processing (Harrel, et al., 2004). The details of each element will be explained as follows

1. Entities

   Entities are items processed through the system, such as products, customers, patients, materials, etc. Each entity has its own attribute, or local variables, and variable, or global variables (Kurniawati, 2017). Attribute is something relatedly attached to the entity that becomes the characteristic which can differs between one entities to another. While variable is an information that reflects some characteristics in a system.

2. Resource

   Resource is the means by which activities are performed, which provides the supporting facilities, equipment, and personnel for doing the activities. The examples of resource in a system is worker, equipment, or facility. Each of the resource has characteristics such as capacity, speed, cycle time, and reliability (Harrel, et al., 2004).

3. Activities

   Activities are the tasks performed in the system, which are either directly or indirectly involved in the processing of entities. It can be classified as entity processing, entity and resource movement, and resource adjustments.

4. Controls

   Control defines how, when, and where the activities are performed. It can be in the form of schedule, plans, policy, written procedures that rule the movement of the system and provide information for how the system should operate.

2.5.2 Variables of System

There are three types of variables that involved in the system, especially in simulation model, which are explained as follows.

1. Decision Variable

   Decision variable is an independent variable in an experiment which is stated. Thus, it can affect the system if this variable is changed.

2. Response Variable

   Response variable, which is usually called performance or output variable, is variable that measures the performance of the system in response to particular decision variable that has been set before.

3. State Variable

   State variable indicates the status of the system at any specific point in time, for example the current number of entities queuing in one process.

2.6 Simulation

Simulation is the imitation of a dynamic system using a computer model in order to evaluate and improve system performance (Schriber, 1987). Taken from another source, simulation refers to a broad collection of methods and applications to mimic the behavior of real system, usually on a computer with appropriate software (Kelton, et al., 2002). By seeing the definition given, it can be said that from a practical viewpoint, simulation, especially the computerized one, is a process of designing and creating a computerized model of a real or proposed system for the purpose of conducting numerical experiments, in order to have a better understanding of the system performance and behavior. The real power of this tool is to model a complex dynamic system, in which in this research the complex and dynamic condition happen due to the uncertainty, and predict the performance. The use of simulation is beneficial, since it provides a way to validate whether the best decisions are being made. It is also able to avoid expensive, time-consuming, and disruptive proposed scenarios that may occur when directly implementing it in the real system or following the nature of traditional trial-and-error techniques. Nevertheless, since many real systems are affected by uncontrollable and random inputs, the simulation models may involve random or stochastic input components that leads to a random output. Even though the simulation output may be uncertain, the user can deal with, quantify, and reduce this uncertainty by making a lot of over-simplifying assumptions about the system.

2.6.1 Simulation Model

Obtained from Kelton, et al. (2002), there are some classifications of simulation models listed as follows:

1. Static vs. Dynamic

   Static simulation is one that is not based on time. It involves drawing random samples to generate a statistical outcome. While dynamic simulation includes the passage of time.

2. Continuous vs. Discrete

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

3. Deterministic vs. Stochastic

   Deterministic simulation has constant input and produce constant output as well, which means there is no random variables. While stochastic simulation has random variables as the input, and therefore produces random output.

2.6.2 Simulation using Discrete-Event Simulation Method

In this research, the discrete-event simulation is done by using ARENA software. This software is able to solve discrete-event simulation problem, and combine between analytic and graphic simulation.

There are some steps have to be done to do simulation by using ARENA, which are listed as follows:

1. Collect the data.

   The first step starts with collecting the data that are going to be the input of the simulation model

2. Do fitting distribution of data that have been obtained.

   The data that are already obtained have to be processed in the Input Analyzer in ARENA to get the distribution fitting data. These distribution-fitted data will later become the input for the simulation model.

3. Create ARENA simulation model based on the existing condition

   After the distribution fitting process has been done, the process can continue to the building of simulation model of the existing condition. The simulation model has to reflect the real condition, or the conceptual model that has been made before.

4. Define the number of replication needed

   After the ARENA simulation model has been made, then the calculation of replication needed has to be done. By doing so, it is expected that the result will be more accurate, since the amount of data result obtained will be higher so it can reflect the condition better.

5. Do the verification of ARENA simulation model.

   Verification is a process to check the suitability of the simulation with the conceptual model that has been made before, by doing software debug examination to check the syntax and semantic error, and checking the behavior of the simulation whether it is already reflecting the real condition

6. Do the validation of ARENA simulation model

   According to Law & Kelton (1991), validation is the process of determining whether the simulation model is really an accurate representation of the real system being modeled. A model is said to be valid when it does not have a significant difference with the actual system observed either from its characteristics or from its behavior. Validation can be done using a statistical test tool that includes a uniform test of output data, two-equity test, two-variance equality test and distribution match test.

7. Design the experiments

   In this research, the author attempts to find the right scenario to reach the research goal. In this research, the scenario will adjust the distribution decision rule considering the time-windows of district warehouse and the amount of load in each delivery that carry multiple products of subsidized fertilizers considering stock criticality

8. Analysis of Result

   The result of the scenario will later be analyzed further by using Analysis of Variance (ANOVA) statistical test. ANOVA test is conducted to evaluate the impact of each factor that becomes the adjusted variable in the scenario, to the performance measure. By using ANOVA test, it can be determined whether the result of the improved scenario has given a statistically different result from the existing condition

2.7 Previous Research

There has been several researches discussing about distribution system of a company. The summary of those researches are explained in the Table 2.1

Table 2.1 Preceeding Research Comparison

Title	Author	Objective	Condition	Method	Output
Previous Research					
Simulasi Distribusi Produk Semen dengan Skenario Kepastian Tenggang Waktu Pengiriman	Winda Puspadimiati (2016)	Determine the due date certainty and its effect to on-time delivery, truck utilization, and packer utilization	Single product, multi destination	Discrete-event Simulation	• Due date certainty rule • Number of trucks allocated in distribution
Simulasi Sistem Distribusi Pupuk Urea In-bag Bersubsidi (Studi Kasus Perusahan Pupuk di Indonesia)	Stefan Adhie Nugroho (2016)	Determine the effect of • Dedicated loading line policy • Segmentation of delivery time to cycle time • Number of truck needed	Single product, multi destination	Discrete-event Simulation	• The decision of using dedicated loading line • New segmentation of delivery time
Simulation Study of Cement Distribution Considering Stock Criticality and Shipment Due Date	Lala Ayu Kantari (2017)	Determine the effect of • Considering stock criticality • Number of truck allocated to order fill rate, truck utilization, and on-time delivery	Single product, multi-destination	Discrete-event Simulation	• New dispatching rule considering the stock criticality • Number of trucks allocated
This Research					
Distribution of Subsidized Fertilizers Considering Time-Windows and Stock Criticality: A Simulation Study In A Fertilizer Company	This research (2017)	Determine the effect of • Considering stock criticality • Adjusting delivery schedule shift considering time-windows • Distributing multiple product types in one delivery	Multi-product, multi-destination	Discrete-event Simulation	• New dispatching rule considering stock criticality • New delivery shift assignment considering time-windows • New distribution decision of shipping multiple products in one truck

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CHAPTER III
RESEARCH METHODOLOGY

This chapter explains about the methodology used in this research. The explanations are structured based on the step of the process, which are study of the system, data collecting, data processing, conceptual model building, existing simulation model building, verification and validation, design of experiment, and scenario model building.

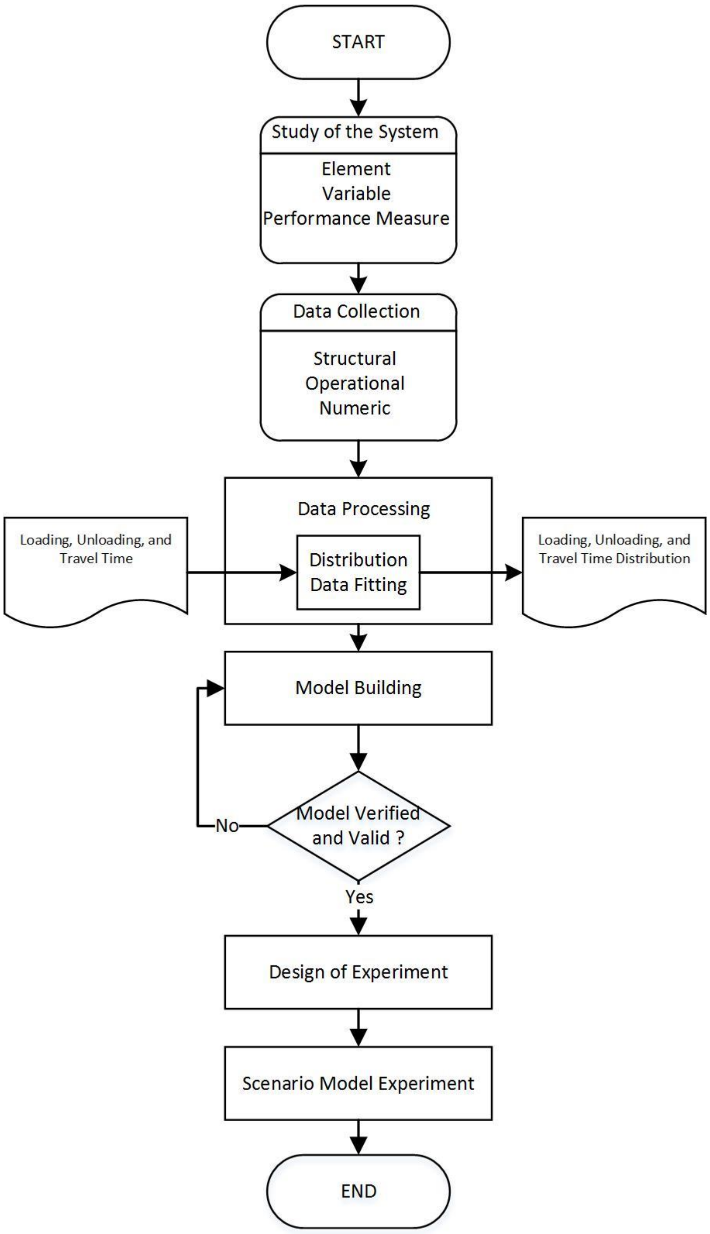

Figure 3.1 Flowchart of Methodology

3.1 Study of the System

The identification of the system is done by elaborating the elements, variables, and performance measures.

3.1.1 Elements of System

The elements of system consist of entity, activity, resource, and control, which are elaborated in the explanation below.

1. Entity

   The entity in the system is products delivered. Here the products have some types of variance, which are Urea, Phonska, SP-36, and ZA Fertilizer. Each of the product has the same dimension and weight to each other that is 50 kg.

2. Activity

   The activity in the system is the whole cycle of the truck from in the factory, until it is back again to the factory, such as traveling to transportation area to product loading area, waiting to be loaded, loading the load, weighing the load, preparing for departure, traveling to destination, waiting to be unloaded in the destination, unloading, and traveling back to the factory.

3. Resource

   The resources in the system are the truck, loading worker in the factory warehouse, unloading worker in the destination warehouse, administration checker, and weight-checking worker.

4. Control

   The control used in the system is the standard operating procedure for doing the distribution process in the company, and the operational hour of the district warehouse.

3.1.2 Variables of System

The variables in the system consist of decision variable, response variable, and state variable. Decision variables are the variables that are going to be adjusted to see the expected result of the response variable. While the state variable is the current status of system, whether it is busy or idle. The detailed examples are shown in the Table 3.1

Table 3.1 Variables of System

Decision Variable	Response Variable	State Variable
• Distribution schedule shift allocation • Variance of product delivered in one trip • Dispatching rule (Stock Criticality)	• Distribution cost • Product availability	• State of the truck (busy/idle) • State of the loading worker (available/not) • State of the unloading worker (available/not) • State of the weight-checker worker (available/not) • State of the administration checker (available/not)

3.1.3 Performance Measures

The performance measures are used to assess the performance of the system regarding to achieving the objectives. In this research, the performance measures used are the cost and service level.

1. Cost

   The cost can be calculated by using the Equation 3.1

$$Cost = Distribution\ Cost + Holding\ Cost$$

$$Cost = (LoadingRate + Transportation\ Cost + Unloading\ Rate) + (25\%\ x\ Total\ Price\ of\ Average\ Daily\ Inventory) \quad (3.1)$$

2. Service level

   Service level shows the ratio between the days of not having stock out and the total planning horizon, which shows the probability of the cycle of not having stock-out (Ballou, 2003)

$$\text{Service Level} = \left(1 - \frac{\text{Total number day stockout}}{\text{Total planning horizon}}\right) \text{x } 100\% \quad (3.2)$$

3.2 Data Collection

In this phase, the data collecting process is done in order to capture the real system. The data is later used as the input of the simulation model. There are three types of data, which are structural data, operational data, and numerical data. The lists of each category are provided in Table 3.2.

Table 3.2 Data Collection

General	Company (Manufacturer)	District Warehouse (Destination)
Structural Data		
• Types of Product	• Company location	• District Warehouse location
Operational Data		
• Distribution mechanism/procedure	• Time windows	• Time windows
Numerical Data		
• Speed of truck • Travel time • Capacity of truck • Transportation rate	• Loading time • Weight-checking time • Maximum amount of loading in a day • Number of loading worker • Number of weight-check worker • Cost of loading per ton	• Demand rate • Unloading time • Distance from origin to destination • Capacity of warehouse v • Consumption rate • Inventory level • Number of unloading worker • Maximum amount of unloading in a day • Cost of unloading per ton

3.3 Data Processing

The data processing phase is done by doing the distribution data fitting. This process is done in order to get the input data for the simulation model. The raw data obtained will be processed by using Input Analyzer in ARENA to get the distribution of the data. The data that need to be fitted to distribution are the loading time in the factory warehouse, travel time from factory warehouse to district warehouse as the destination, unloading time in the destination, and the consumption rate in each district warehouse.

3.4 Conceptual Model

In this phase, the conceptual model is made in the form of logic flow diagram to express the real condition of the system. The conceptual model will be used as a reference in making the simulation model later.

3.5 Simulation Model

By using the distribution data fitting result and conceptual model that have been made before, then the simulation model in ARENA can be made. The distribution data fitting result becomes the input data for the simulation model, while the conceptual model becomes the guidance of the model thinking representing result. By doing so, it is expected that the result will be more accurate, flow.

3.6 Calculation of Minimum Number of Replication Needed

In this phase, the calculation to find the minimum number of replication needed is done. Knowing the minimum number of replication needed is important in order to get the model with the sufficient replication and more reality- since the amount of data result obtained will be higher so it can reflect the condition better. According to Harrel et al. (2004), the formula to calculate number of replication is shown in Equation 3.3 and Equation 3.4 , by first finding the half width

$$\mathrm{hw} = \frac{\mathrm{t}_{\left(\mathrm{n}-1\,\frac{\alpha}{2}\right)} \ \mathrm{x}\ \mathrm{std}}{\sqrt{\mathrm{n}}} \qquad (3.3)$$

$$\mathrm{n}' = \left[\frac{\mathrm{z}\left(\frac{\alpha}{2}\right)\mathrm{x}\ \mathrm{std}}{\mathrm{hw}}\right]^2 \qquad (3.4)$$

with:

α = Rate of Error

n = number of replication

std = standard deviation

t = t-distribution value

hw = half width

n’ = number of replication needed

3.7 Verification and Validation

After building the model, it has to be checked whether the model is already verified and valid. Verification is a process to check whether that the simulation model that has been made is correctly reflecting the conceptual model. Verification is done by using trace and debug checking in the software, and watching the behavior of the system.

Validation is a process to check whether the model has represented the real system correctly, by comparing the result of the simulation model with the real data in the system (Kelton, et al., 2002). A model can be said to be valid when it does not have a significant difference with the actual system observed either from its characteristics or from its behavior. In this research, the validation process can be done by using statistical test to determine whether there is a significant difference between the output in the real system and in the model.

3.8 Design of Experiment

After the existing model is verified and valid, then the scenario model can be start to be developed. This research is trying to look for a distribution decision that can give an improvement in the research performance measures, such as distribution cost and product availability. Regarding to this condition, the author has set three factors that possibly can give improvement to the performance measures, namely:

3.8.1 Delivery Scheduling Time

The current truck delivery schedule, which has not considered the time-windows of district warehouse, is set in 3 shift for each day and each destination, which are 00.00-07.00, 07.00-15.00, and 15.00-00.00. Here the transportation providers can freely choose the shift based on their availability. The current condition implementing this schedule has shown that the current schedule is still prone to delay in the arrival to the district warehouse. It is still possible that the truck arrives in the district warehouse in a longer time than usual due to the travel uncertainty, and the truck has to wait for the next day to unload the product since the district warehouse is already closed.

Thus, to overcome this problem, the author suggests the new delivery scheduling that defines the delivery based on the distance, which are short, moderate, and long distance. The delivery with short distance has to be done in the earlier shift, moderate distance done in middle shift, and the long distance done in the last shift. This adjustment is done in order to prevent the truck from arriving in the closing hour of the destination. By using the proposed scheduling, it is expected that it can give a better performance for the distribution.

3.8.2 Variance of Products Shipped in One Delivery to One Destination

The current method of distribution, when one delivery is only carrying one type of products, makes the stock availability of each product type is not balanced between each other. There are some periods that have only one product type has abundance of stock, while the others are having stock-out. This imbalanced stock between different product types is not suitable with the market demand that often need several types of products at once. The proposed scenario to overcome this problem is to deliver multiple-products of subsidized fertilizers in one delivery activity to one destination instead of one type of fertilizers only. The method to do the prioritization of the product type that is going to be delivered is by using can-order policy.

3.8.3 Dispatching Rule

The current dispatching rule in the company is done based on the earliest order from the district warehouse, instead of considering the criticality. Thus, in this research, the author tries to propose a new dispatching rule that is considering the stock criticality of each product type. Thus, the critical product will be prioritized to be delivered. The stock criticality can be defined by using formula of Stock to Demand Ratio (SDR). Stock to Demand Ratio (SDR) is able to express the criticality of a stock by considering the current inventory, in-transit inventory, and the average demand in particular delivery lead time. The lower the value, the more critical the stock is, which means it needs to prioritized to do the replenishment. The formula of SDR is shown in the Equation (2.1).

Table 3.3 shows the experimental design which summarizes the factors considered in developing the scenario and the levels of each factors.

Table 3.3 Experimental Design

Factors	Level 1	Level 2
Delivery scheduling time	No time-windows constraint	Considering district warehouse time windows (All short travel distance is allocated in Shift 1)
Variance of products shipped in one delivery to one destination	Single product	Multiple products per delivery
Dispatching Rule	Earliest delivery order released	Prioritizing stock criticality

After design of experiment to define the scenario has been done, the phase can be continued to scenario model building, which is to execute the scenario model plan to the simulation model. Based on the result of design of experiment, the scenario that are used in this research are explained in Table 3.4 as follows.

Table 3.4 Scenario Determination

No	Scenario	Delivery Scheduling Time	Variance of Products Shipped	Dispatching Rule	Decision of Scenario Determination
1	Scenario 0 (Existing)	No time-windows constraint	Single product	Earliest delivery order released	Selected
2	Scenario 1 (Improvement)	Considering warehouse time windows	Multiple products per delivery. One truck can carry two different product types	Prioritize the type of product based on Stock to Demand Ratio (SDR)	Selected
3	Scenario 2 (Improvement)	Considering warehouse time windows	Multiple products per delivery. One truck can carry three different product types	Prioritize the type of product based on Stock to Demand Ratio (SDR)	Selected

CHAPTER IV
DATA COLLECTION AND DATA PROCESSING

This chapter provides the information about the data collection and data processing done during the research project. These data will later be useful in building the simulation and scenario experiment.

4.1 Data Collection

This subchapter explains about the result of the data collection process done to support this research project. The explanation is divided based on the source or the step of the process.

4.1.1 Distribution Process in PT. X

PT. X delivers the number of demand for each district warehouse that has been set before by the government. As it is stated on the Regulation of the Ministry of Trade No.15 in 2013, PT. X is given a role to fulfill the monthly demand set by the government. The Figure 4.1 shows the distribution flow of PT. X.

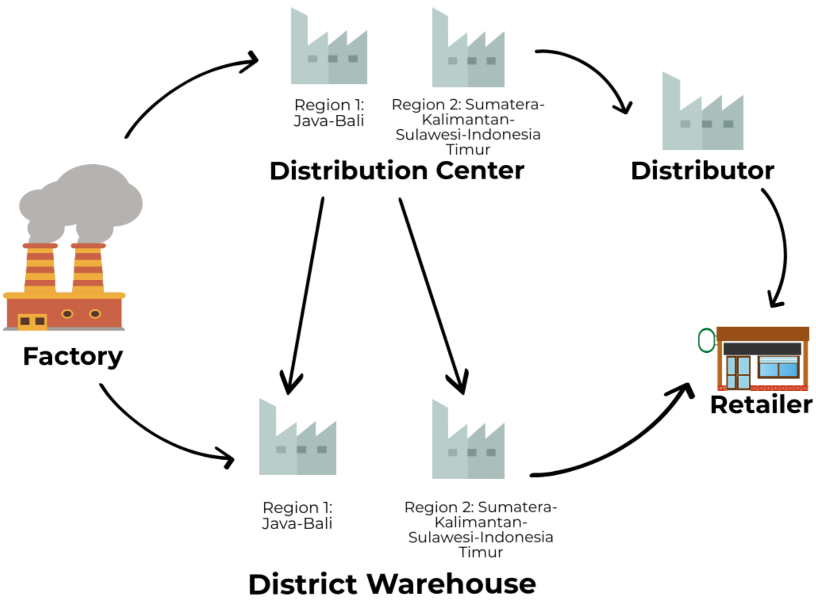

Figure 4.1 Distribution Flow of PT. X

The distribution process are classified into two different scopes, which are land for region Java and Bali, and maritime distribution for region Sumatera, Kalimantan, and East Indonesia. Meanwhile, in this research, the research scope is more focused on the land distribution process from the factory to the district warehouse.

In the current distribution system, each of the truck only carries one type of fertilizers with one destination of district warehouse. In the beginning of the process, PT. X opens the tender activity for the transportation provider to do the delivery. The delivery schedule for every destination is already set by PT. X by using their real-time online distribution monitoring website, so whenever there is an empty slot for delivery activity, the third party logistics can register to it. There is also a maximum amount of load shipped by the truck for each product to one district warehouse in a shift, which makes the products cannot be delivered all at once if the amount is high.

In the current distribution scheduling, each district warehouse, as the destination, is given three shift of distribution activity, which are 07.00-15.00, 15.00-23.00, and 23.00-07.00. The hour in the shift indicates that the truck has to depart in the range of that hour. After the truck has been assigned to the load of demand, then the loader does the loading activity of the fertilizer products. After the loading process, then the truck is being weighed and checked for the administration needs. Then, the process is continued with the dispatching process of truck to each of the district warehouse. The traveling time from the factory to the district warehouse varies due to the different distance between district warehouse, and the uncertainties that may happen during the traveling process such as traffic congestion.

The district warehouse has the operational hour of 08.00-16.00 from Monday-Friday, and 08.00-13.00 for Saturday only. When the truck arrives in that range of time, it means the truck can proceed to the next process, which is unloading process. If the truck arrives not in that period of time, the truck has to wait until the district warehouse is open in the next day. This condition can make the distribution process is delayed, and may also give a delay impact to the following distribution process.

After the unloading process in the district warehouse is done, then the truck travels back to the factory to do the other delivery activities. Overall, the time to do the distribution process may vary, due to the uncertainties that may happen in the loading time, unloading time, travel time, and other processing time inside the distribution activity.

4.1.2 Distribution Activity Data

The delivery process includes the process to distribute the products from the factory to the district warehouse, which needs some supporting data related to factory warehouse as the origin, truck as the transportation mode of the distribution, and district warehouse as the destination of the distribution process.

The factory warehouse data includes the data that are especially related to the loading process in the factory, which loads the products from the warehouse to the truck. In the existing condition, the company has both dedicated factory warehouse, in which one warehouse is only available to store one type of products and load one type of product, and also multiple-product factory warehouse to store many types of products in one warehouse. Thus, in the proposed scenario discussed later, it is assumed that all of the delivery activity will be will be originated from the multiple-product warehouse. Here the data related are the number of trucks can be loaded in one loading line, and the operational hour of factory warehouse.

Truck activity data includes all the data related to the truck activity from it arrives to the factory to begin the distribution activity to the district warehouse, until it travels back to the factory. All of the trucks used are outsourced from transportation providers, which makes the number is limited and the company has to wait until the truck is available. The district warehouse data includes the number of products of each types that has to be delivered to the district warehouse. Each of the district warehouse has its own monthly demand on each type of product. This data will later be used for comparing the actual number of products delivered and the expected number of products delivered. Historical data about rate of product demand are also used to obtain the product demand rate of the products per day.

There are also some costs incurred during the distribution process, in which it becomes the component of the cost calculation in this research. The costs considered in this research are the distribution cost and holding cost. The distribution cost consists of the transportation cost set by the transportation provider, loading cost, and unloading cost. The transportation cost is obtained by considering the distance and the fuel cost occurred during the traveling process, which makes each warehouse has different transportation cost except for warehouses in Tuban that have the same cost with each other. There are also loading and unloading cost which is burdened to PT. X to pay for the loading and unloading worker. The cost of transportation, loading cost, and unloading cost are provided in the Table 4.1 and Table 4.2.

Table 4.1 Cost of Transportation

Transportation Cost	**Cost (Rp/ton)**
Magetan	Rp 84,030
Lamongan1	Rp 39,636
Lamongan2	Rp 46,288
Tuban1	Rp 55,415
Tuban2	Rp 55,415

Table 4.2 Loading and Unloading Cost

Activity	**Cost (Rp/ton)**
Loading cost	Rp 6,000
Unloading cost	Rp 7,500

The holding cost is set to be 25% of the total price of average inventory per day. Thus, the average inventory per day, which is known in the unit of ton, has to be calculated with the unit price of each product type. The unit price of each product type in the unit of Rp/ton is shown in the Table 4.3.

Table 4.3 Unit Price of Product per Ton

Product Type	**Cost (Rp/ton)**
Urea	Rp 1.800.000
ZA	Rp 1.400.000
SP36	Rp 2.000.000
Phonska	Rp 2.300.000

4.2 Data Processing

This subchapter discusses about the result of the data processing from the data explained in the previous subchapter.

4.2.1 Distribution Activity Data

The data collecting and processing results are provided and explained based on the sequence of the distribution activity, which are shown in the explanation below

1. Assign truck to the delivery order

   In this process, the system is waiting for the truck from outsourcing transportation party to register for transporting the delivery order available. There are 3 shifts available for the truck to do the delivery process, which are from 07.00-15.00, 15.00-23.00, and 23.00-07.00. Each of the shift has the maximum capacity of load, which means if one shift has been assigned to the trucks and already reached the maximum load capacity per shift, then the other trucks have to assign for the next shift. In this research, the maximum load capacity for each shift is provided in the Table 4.4.In this research, it is assumed that all of the district warehouses are following the same standard of maximum load capacity per shift.

   Table 4.4 Maximum Amount of Load per Shift

No	Type of Fertilizer	Maximum Load per Shift (ton)
1.	Urea	600
2	ZA	733
3.	Phonska	2000
4.	SP-36	500

   After the truck is assigned to particular shift, then it has a lead time of 1 day to prepare the truck for the delivery process. In this case, the truck observed has the capacity of 30 tons.

2. Truck Processed in the Loading Line

   After the truck is arrived to the factory, it is processed in the loading line which has the capacity of processing 5 trucks at a single time. So, if there are already 5 trucks in the loading line, the truck has to queue until there is an idle space.

3. Loading process

The load of the truck is shipped from the factory warehouse to the truck. The processing time of the loading activity has a distribution of UNIF(3.48e+003, 4.48e+003) seconds for every 30 tons of fertilizer products. The amount of load shipped depends on the delivery target of each warehouse, which also differs between one types of product to another.

4. Weight and administration checking

After all the fertilizers have been loaded to the truck, then the truck is being weighed and checked for the administration needs before finally it departs from the factory warehouse. This process has a distribution time of 43.5 + 60 * BETA(0.411, 0.402) seconds.

5. Travel to destination

The truck is then depart from the factory warehouse and travel to the destination. The travel time depends on the distance of the destination to the factory warehouse, with approximation of truck velocity to be 40 km/hour. The destinations observed in this project are listed in the Table 4.5.

Table 4.5 District Warehouse Observed

No	District Warehouse Observed	Capacity	Warehouse Outsource Party	Address	Travel Time (Minutes)
1	Magetan - Maospati	10.000	PT BGR	Desa Sugih Waras, Kec. Maospati Kab. Magetan	200 + 110 * BETA(0.452, 0.542)
2	Tuban 1 - Jenu	8.000	PT AJG	Jl. Raya Tuban-Semarang, Desa Sugihwaras, Kec.Jenu, Kab.Tuban.	99.5 + 61 * BETA(0.441, 0.581)
3	Tuban 2 - Palang	5.000	PT AJG	Jl. Desa Morosemo, Kec. Plumpang, Kab.Tuban.	69.5 + 61 * BETA(0.663, 1.05)
4	Lamongan 1 - Kota	5.000	PT Graha SG	Jl. Jaksa Agung Suprapto 74, Lamongan	39.5 + 36 * BETA(0.482, 0.874)
5	Lamongan 2- Pucuk	3.200	PT Graha SG	Jl. Raya Sukodadi, Babat KM.17, Kec. Pucuk, Kab. Lamongan	39.5 + LOGN(18.3, 23.4)

6. Unloading process

After the truck is arrived in the district warehouse as the destination, then it has to be checked whether the warehouse is open. The operational hour for the district warehouse is 08.00-16.00 for Monday-Friday, and 08.00-13.00 for Saturday. If the warehouse is open, the truck is proceed to the unloading process. The unloading line has a capacity of processing 4 trucks in a moment, so if all the loading line are still occupied, the truck has to wait for the empty loading line. The unloading process time is following distribution of UNIF(0.999, 2) hours.

7. Travel back to the factory warehouse

After all the fertilizers shipped by the truck are already being unloaded to the factory warehouse, then the product stock in the district warehouse is updated, and the truck travels back to the factory warehouse. The backhauling process time is assumed to be the same with the departing travel time

4.2.2 Demand Rate for District Warehouse Data

This part explains about the demand rate data in the unit of product per day, in which can be used to determine the number of products sold per day. The number of on hand inventory will later has to be reduced with this demand rate to obtain the result of the on hand inventory after the sales. Table 4.6 shows the distribution fitting result of the demand rate per day in a month for every product type in each district warehouse, in the unit of product per day.

Table 4.6 Demand Rate Distribution Fitting Result

Destination	Type of Product	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Magetan	Urea	TRIA(24,30,36)	TRIA(50,63,76)	TRIA(54,68,82)	TRIA(75,94,113)	TRIA(21,26,31)	TRIA(42,53,64)	TRIA(41,51,61)	TRIA(62,78,94)	TRIA(26,33,40)	TRIA(58,72,86)	TRIA(90,112,134)	TRIA(59,74,89)
	ZA	TRIA(29,36,43)	TRIA(18,22,26)	TRIA(30,38,46)	TRIA(45,56,67)	TRIA(16,20,24)	TRIA(27,34,41)	TRIA(30,38,46)	TRIA(40,50,60)	TRIA(32,40,48)	TRIA(74,93,112)	TRIA(71,89,107)	TRIA(50,63,76)
	SP36	TRIA(10,13,16)	TRIA(6,8,10)	TRIA(9,11,13)	TRIA(14,18,22)	TRIA(4,5,6)	TRIA(7,9,11)	TRIA(10,12,14)	TRIA(10,13,16)	TRIA(2,3,4)	TRIA(11,14,17)	TRIA(21,26,31)	TRIA(10,13,16)
	Phonska	TRIA(22,27,32)	TRIA(22,28,34)	TRIA(43,54,65)	TRIA(70,87,104)	TRIA(19,24,29)	TRIA(26,33,40)	TRIA(44,55,66)	TRIA(61,76,91)	TRIA(32,40,48)	TRIA(70,87,104)	TRIA(100,125,150)	TRIA(68,85,102)
Lamongan1	Urea	TRIA(82,102,122)	TRIA(58,72,86)	TRIA(80,100,120)	TRIA(94,118,142)	TRIA(57,71,85)	TRIA(62,77,92)	TRIA(27,34,41)	TRIA(38,48,58)	TRIA(42,53,64)	TRIA(113,141,169)	TRIA(135,169,203)	TRIA(106,133,160)
	ZA	TRIA(42,52,62)	TRIA(22,28,34)	TRIA(20,25,30)	TRIA(32,40,48)	TRIA(16,20,24)	TRIA(17,21,25)	TRIA(10,12,14)	TRIA(15,19,23)	TRIA(18,22,26)	TRIA(39,49,59)	TRIA(39,49,59)	TRIA(19,24,29)
	SP36	TRIA(35,44,53)	TRIA(22,28,34)	TRIA(34,43,52)	TRIA(28,35,42)	TRIA(18,23,28)	TRIA(14,18,22)	TRIA(7,9,11)	TRIA(4,5,6)	TRIA(8,10,12)	TRIA(29,36,43)	TRIA(14,17,20)	TRIA(16,20,24)
	Phonska	TRIA(63,79,95)	TRIA(30,37,44)	TRIA(54,67,80)	TRIA(67,84,101)	TRIA(39,49,59)	TRIA(41,51,61)	TRIA(28,35,42)	TRIA(36,45,54)	TRIA(35,44,53)	TRIA(95,119,143)	TRIA(91,114,137)	TRIA(10,13,16)
Lamongan2	Urea	TRIA(46,57,68)	TRIA(34,42,50)	TRIA(26,33,40)	TRIA(78,98,118)	TRIA(62,78,94)	TRIA(33,41,49)	TRIA(32,40,48	TRIA(38,48,58)	TRIA(31,39,47)	TRIA(76,95,114)	TRIA(95,119,143)	TRIA(83,104,125)
	ZA	TRIA(12,15,18)	TRIA(7,9,11)	TRIA(19,24,29)	TRIA(19,24,29)	TRIA(14,18,22)	TRIA(8,10,12)	TRIA(10,12,14)	TRIA(9,11,13)	TRIA(3,4,5)	TRIA(18,22,26)	TRIA(19,24,29)	TRIA(9,11,13)
	SP36	TRIA(20,25,30)	TRIA(13,16,19)	TRIA(10,13,16)	TRIA(21,26,31)	TRIA(18,22,26)	TRIA(12,15,18)	TRIA(9,11,13)	TRIA(8,10,12)	TRIA(6,7,8)	TRIA(22,28,34)	TRIA(14,18,22)	TRIA(12,15,18)
	Phonska	TRIA(32,40,48)	TRIA(7,9,11)	TRIA(21,26,31)	TRIA(44,55,66)	TRIA(36,45,54)	TRIA(20,25,30)	TRIA(19,24,29)	TRIA(25,31,37)	TRIA(15,19,23)	TRIA(51,64,77)	TRIA(40,50,60)	TRIA(17,21,25)
Tuban1	Urea	TRIA(64,80,96)	TRIA(89,111,133)	TRIA(46,58,70)	TRIA(84,105,126)	TRIA(76,95,114)	TRIA(82,102,122)	TRIA(45,56,67)	TRIA(55,69,83)	TRIA(68,85,102)	TRIA(94,118,142)	TRIA(109,136,163)	TRIA(70,88,106)
	ZA	TRIA(13,16,19)	TRIA(21,26,31)	TRIA(7,9,11)	TRIA(10,12,14)	TRIA(12,15,18)	TRIA(10,13,16)	TRIA(6,7,8)	TRIA(7,9,11)	TRIA(7,9,11)	TRIA(21,26,31)	TRIA(32,40,48)	TRIA(20,25,30)
	SP36	TRIA(22,27,32)	TRIA(25,31,37)	TRIA(13,16,19)	TRIA(16,20,24)	TRIA(22,27,32)	TRIA(19,24,29)	TRIA(18,22,26)	TRIA(14,18,22)	TRIA(14,18,22)	TRIA(18,23,28)	TRIA(16,20,24)	TRIA(6,7,8)
	Phonska	TRIA(50,63,76)	TRIA(55,69,83)	TRIA(30,38,46)	TRIA(66,82,98)	TRIA(58,73,88)	TRIA(40,50,60)	TRIA(35,44,53)	TRIA(32,40,48)	TRIA(42,53,64)	TRIA(68,85,102)	TRIA(47,59,71)	TRIA(26,32,38)
Tuban2	Urea	TRIA(37,46,55)	TRIA(22,28,34)	TRIA(26,32,38)	TRIA(40,50,60)	TRIA(26,32,38)	TRIA(17,21,25)	TRIA(10,12,14)	TRIA(31,39,47)	TRIA(44,55,66)	TRIA(74,93,112)	TRIA(91,114,137)	TRIA(62,77,92)
	ZA	TRIA(3,4,5)	TRIA(4,5,6)	TRIA(4,5,6)	TRIA(3,4,5)	TRIA(6,7,8)	TRIA(2,2,2)	TRIA(2,2,2)	TRIA(4,5,6)	TRIA(2,3,4)	TRIA(10,12,14)	TRIA(22,28,34)	TRIA(16,20,24)
	SP36	TRIA(10,13,16)	TRIA(11,14,17)	TRIA(4,5,6)	TRIA(7,9,11)	TRIA(8,10,12)	TRIA(2,3,4)	TRIA(2,3,4)	TRIA(6,7,8)	TRIA(6,8,10)	TRIA(18,23,28)	TRIA(30,37,44)	TRIA(4,5,6)
	Phonska	TRIA(26,32,38)	TRIA(18,23,28)	TRIA(20,25,30)	TRIA(34,42,50)	TRIA(21,26,31)	TRIA(14,17,20)	TRIA(8,10,12)	TRIA(25,31,37)	TRIA(27,34,41)	TRIA(46,57,68)	TRIA(43,54,65)	TRIA(20,25,30)

4.3 Conceptual Model

This chapter explains about the conceptual model of the existing condition and proposed improvement of the system. The conceptual model will later become the basis in making the simulation model in ARENA.

4.3.1 Conceptual Model of Existing Condition

Figure 4.2 shows the conceptual model of existing distribution activity in PT. X, which is specifically only used for one process of delivery that has one destination and one type of products shipped. The dispatching rule is based on the earliest delivery order request entered by the district warehouse to the company. The delivery shift assignment is depends on the current time when the truck is ready to do the distribution activity. But, there is also possibility that the truck is not assigned in the current time shift due to the maximum load capacity in one shift, which makes the truck has to be allocated in the next shift when the maximum load capacity in one shift has not been reached yet.

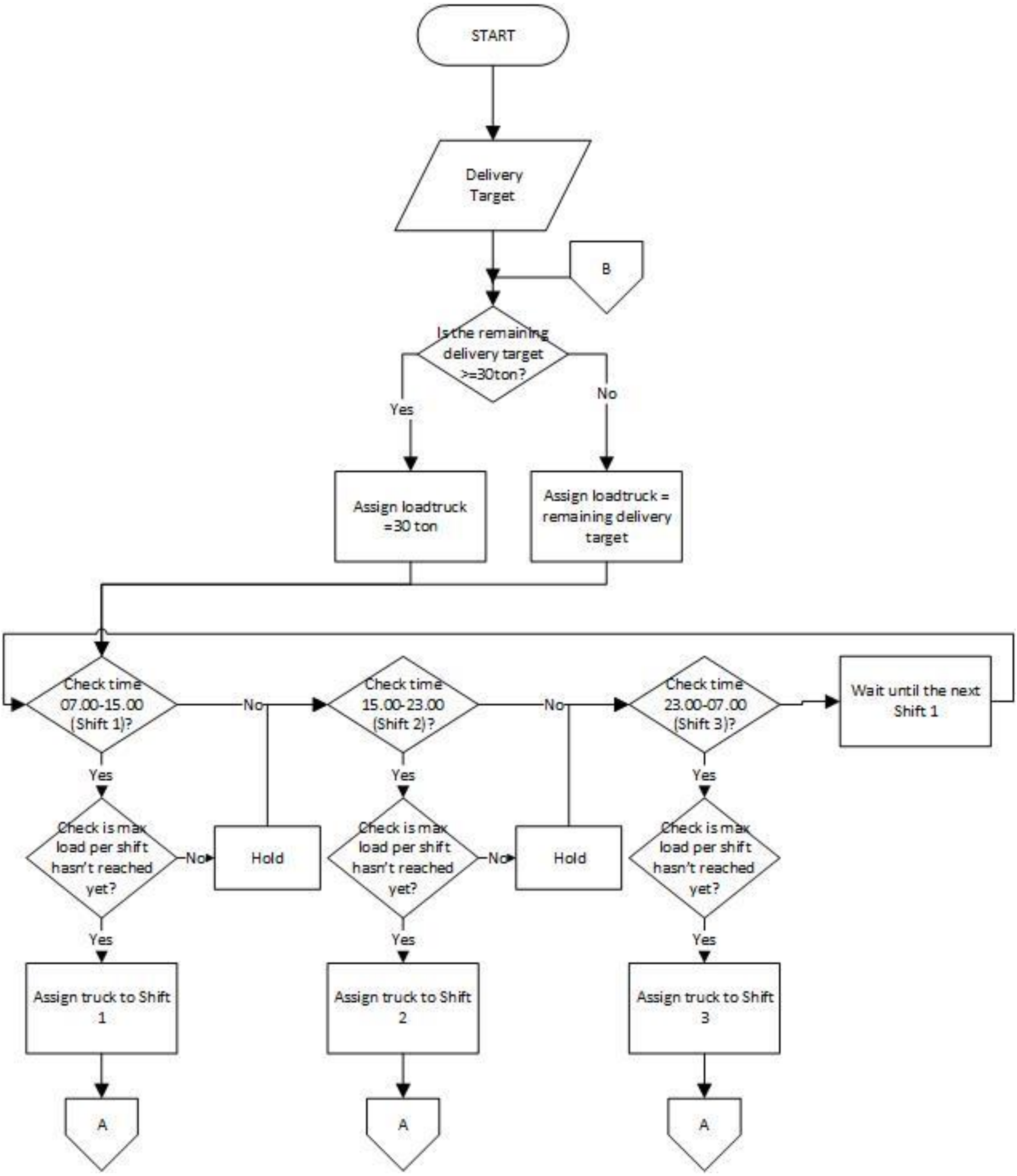

Figure 4.2 Conceptual Model of Existing Distribution Process (1)

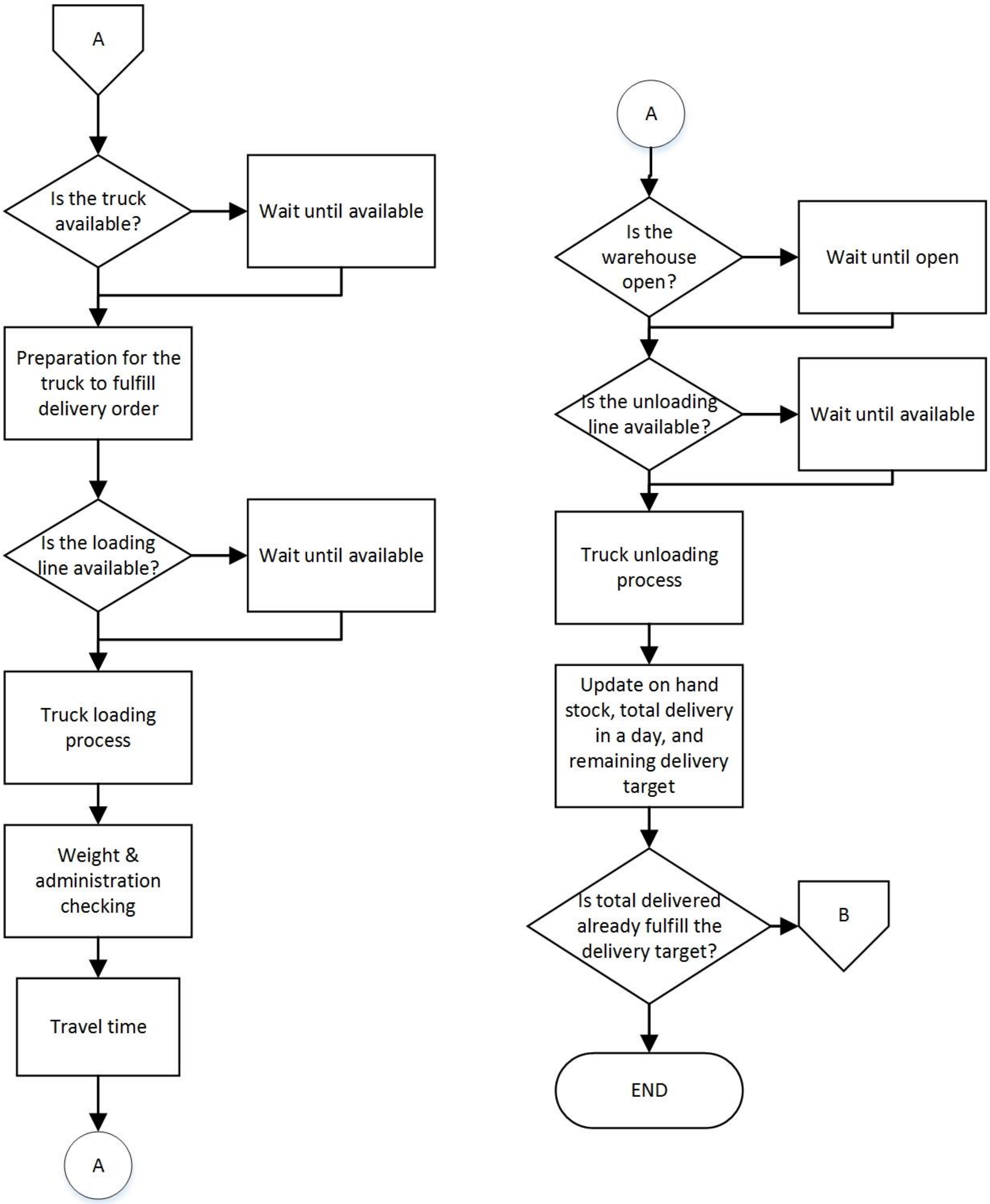

Figure 4.2 Conceptual Model of Existing Distribution Process (2)

Figure 4.3 shows the conceptual model of daily total delivery updater. Since there is a maximum load shipped for each destination in one shift, this makes a calculation of total delivery in a day per product in a day in one shift is necessary. This number will later automatically updated to 0 when the day changes. In this research, it is assumed that the calculation result will be restarted to 0 in every 07.00.

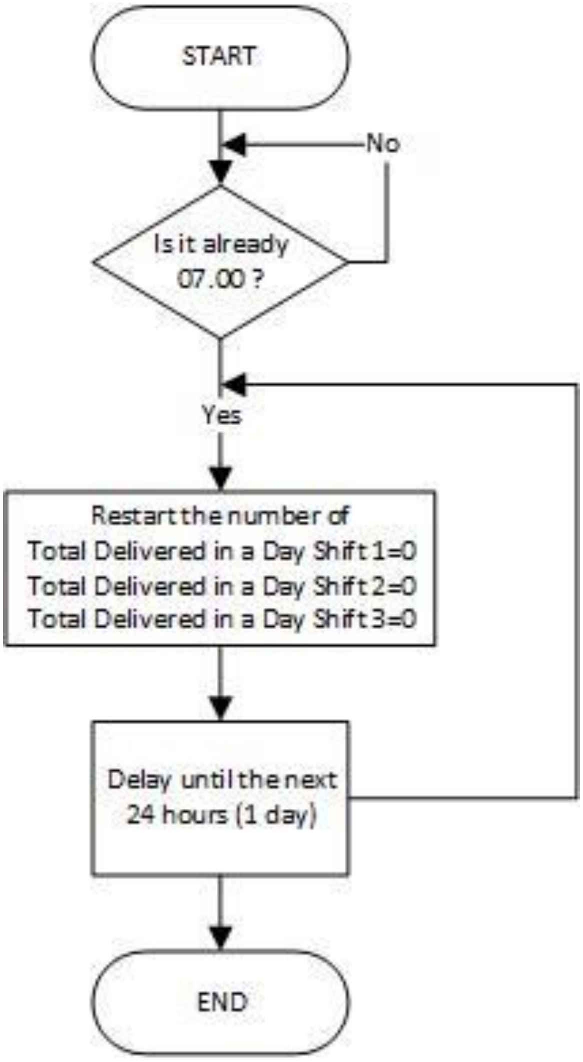

Figure 4.3 Conceptual Model of Daily Total Delivery Updater

Figure 4.4 shows the conceptual model of the updater of district warehouse operational hour, or the time-windows of the district warehouse. In this project, the district warehouse opens on Monday-Friday at 08.00-16.00, and Saturday at 08.00-13.00. This logic is to indicate whether the district warehouse is open so that the unloading process can be done there. If the truck arrives outside the operational hour of the district warehouse, the truck has to wait until the operational hour start.

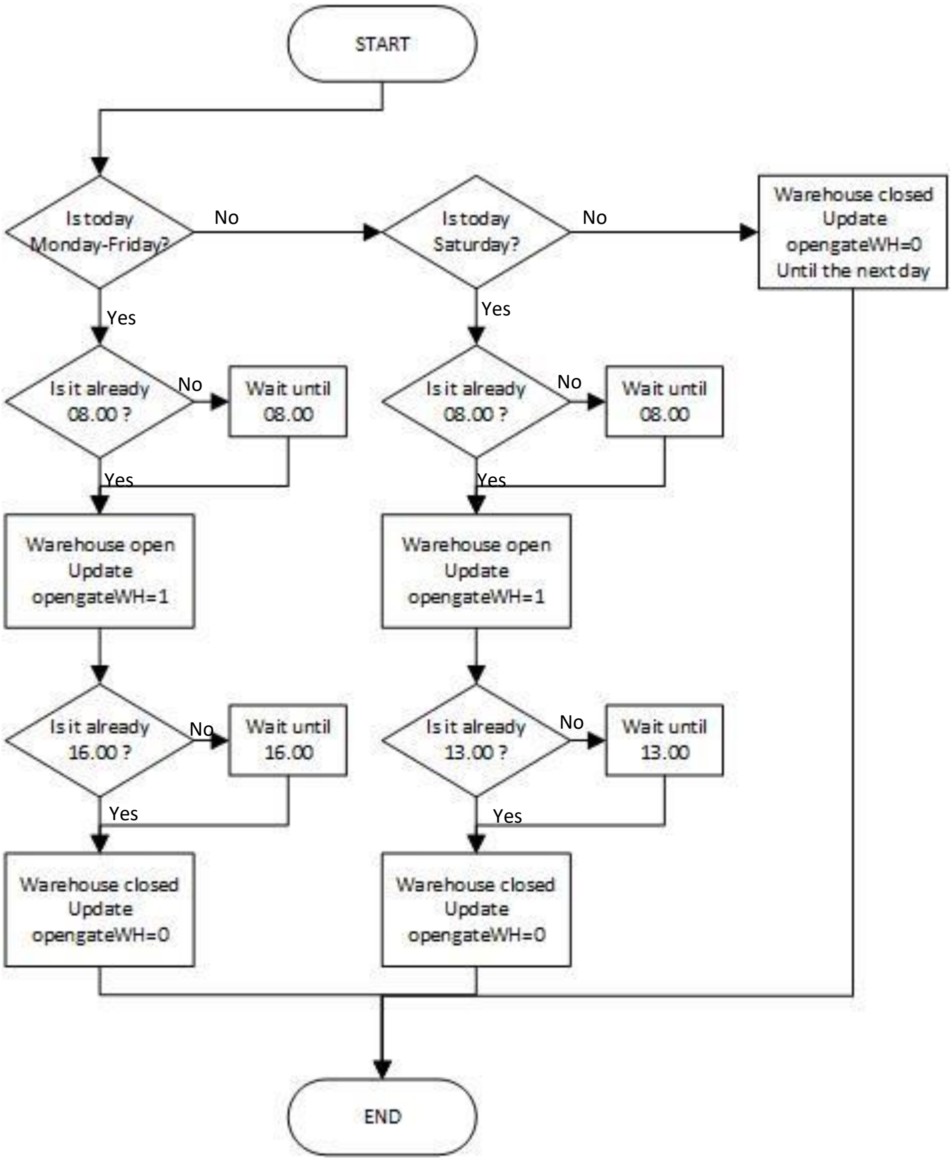

Figure 4.4 Conceptual Model of District Warehouse Operational Hour Updater

4.3.2 Conceptual Model of Proposed Scenario

The proposed scenario has some different logic compared to the existing condition, especially for the dispatching rule. The existing dispatching rule is following the earliest delivery order entered in the system, which depends on when the requests are made by the district warehouse and when the transportation provider register and sign to the allocated delivery process to particular destination and type of product. In the proposed scenario, this rule will be replaced by the dispatching rule that is considering the stock criticality of each product type.

There is also a difference in the variance of product loaded in one truck. In the existing condition, a truck is dedicated to carry only one type of product to deliver the product to the district warehouse. Meanwhile, in this proposed scenario, one truck can load more than one type of product in a truck depends on which type of product has critical amount of stock.

The explanation of the new distribution rule will be provided below.

1. District Warehouse Stock Update

   Before start delivering the product to the district warehouse, the number of stock available in each district warehouse has to be updated to see the current condition of the stock, so that the company can make the right decision about which type of product to deliver first. The amount of stock can be updated by summing all the number of products received by the district warehouse and reduce the number with the selling rate of each product type.
2. Calculate Stock to Demand Ratio (SDR)

   To know which product type that is critical, a calculation of stock to demand ratio has to be done in each product type. The calculation of stock to demand ratio considers the current number of on hand inventory, in-transit inventory, lead time, and average demand in the period of the lead time. In this research, the lead time is obtained from the travel time from the factory, as the origin, to the district warehouse as the destination
3. Prioritize the delivery of particular product type based on the criticality, which is selected by using can-order policy method.

The first product type shipped is chosen after prioritizing the most critical destination according to Stock to Demand Ratio calculation. After the stock to demand ratio of each product has been calculated, then this value is compared to the criticality standard owned by the company, which becomes the reorder point set by the company. The company has been stated that a stock is considered critical if the current stock is only able to cover 14 days of demand. Thus, the first type of product selected to be delivered is the one with SDR value closest to the criticality standard. If there is no critical stock, then the product type chosen is the one with the lowest value of SDR, meaning that this product type is the closest to the criticality.

Then, the second and third product type delivered is chosen by prioritizing the most critical destination according to can-order Policy. In this research, the value of can-order Level is obtained from value of Stock to Demand Ratio (SDR) plus 1, which is for 15 days. The second and third product type chosen is the one with the SDR value below can-order Level, or the one with the lowest value of SDR if there is no stock lies below the Can-order Level. So, here the s or the reorder level value is all set to be 14 days, the c or the can-order level is all set to be 15 days, and the S or order-up-to level is set to be equal to the target delivery of each product in each district warehouse.

4. Assign the amount of load of each product type

   There has to be an adjustment about how to allocate each number of products type, since the truck is only able to carry 30 tons. Meanwhile, each of the product type has its own delivery target. Thus, load allocation between each product is needed, by considering the proportion of remaining demand owned by each product type.

There is also a consideration about the time windows of the district warehouse as the destination. According to Cristina (2014), a delivery with time-windows constraint should be able to adjust the departure time so that it will arrive just in time, or in the period of time when the destination is still open. The adjustment can be done by using the approach of considering the distance and travel time needed to arrive to the destination. By using this method, the decision will make the shipment with the short distance that needs short travel time is assigned to the early or morning-to-day shift so that the truck can arrive back earlier to the origin. While for the destination with the long distance can be assigned to the night shift, so that the truck can arrive to the destination right in time when the district warehouse, as the destination, opens in the morning. But, since this research is only focused on the district warehouse that is considered possible to receive multiple-product distribution, it only resulting 5 warehouses explained in the Subchapter 4.2.1, which are Magetan Warehouse, Lamongan 1 Warehouse, Lamongan 2 Warehouse, Tuban 1 Warehouse, and Tuban 2 Warehouse. These warehouses have short distance and short travel time, which makes all of the distribution activity related to these warehouses will be assigned to the early morning-to-day shift (07.00-15.00) if the distribution rule is following the time-windows constraint. So, there will be an additional process to follow this rule, which is explained below

1. Allocate the delivery shift to Shift 1 (07.00-15.00) for the district warehouse with short distance and travel time
2. Check the maximum load shipped of each product in one shift. Each product type has the maximum load shipped from the factory in one shift. If the maximum load is already reached, the shipment has to be done in the next shift 1 in the next day

Based on the explanation provided above, it can be concluded that there will be an adjustment in two of the three decision variables, which are an adjustment in the aspect of dispatching rule, and the time-windows. According to these explanation, the conceptual model of each scenario will be provided in the Figure 4.5 for Scenario 1, and Figure 4.6 for Scenario 2. Scenario 1 will have two most critical product types shipped in one truck and considering time-windows in the delivery shift assignment, while Scenario 2 will have three most critical product types shipped in one truck and considering time-windows in the delivery shift assignment.

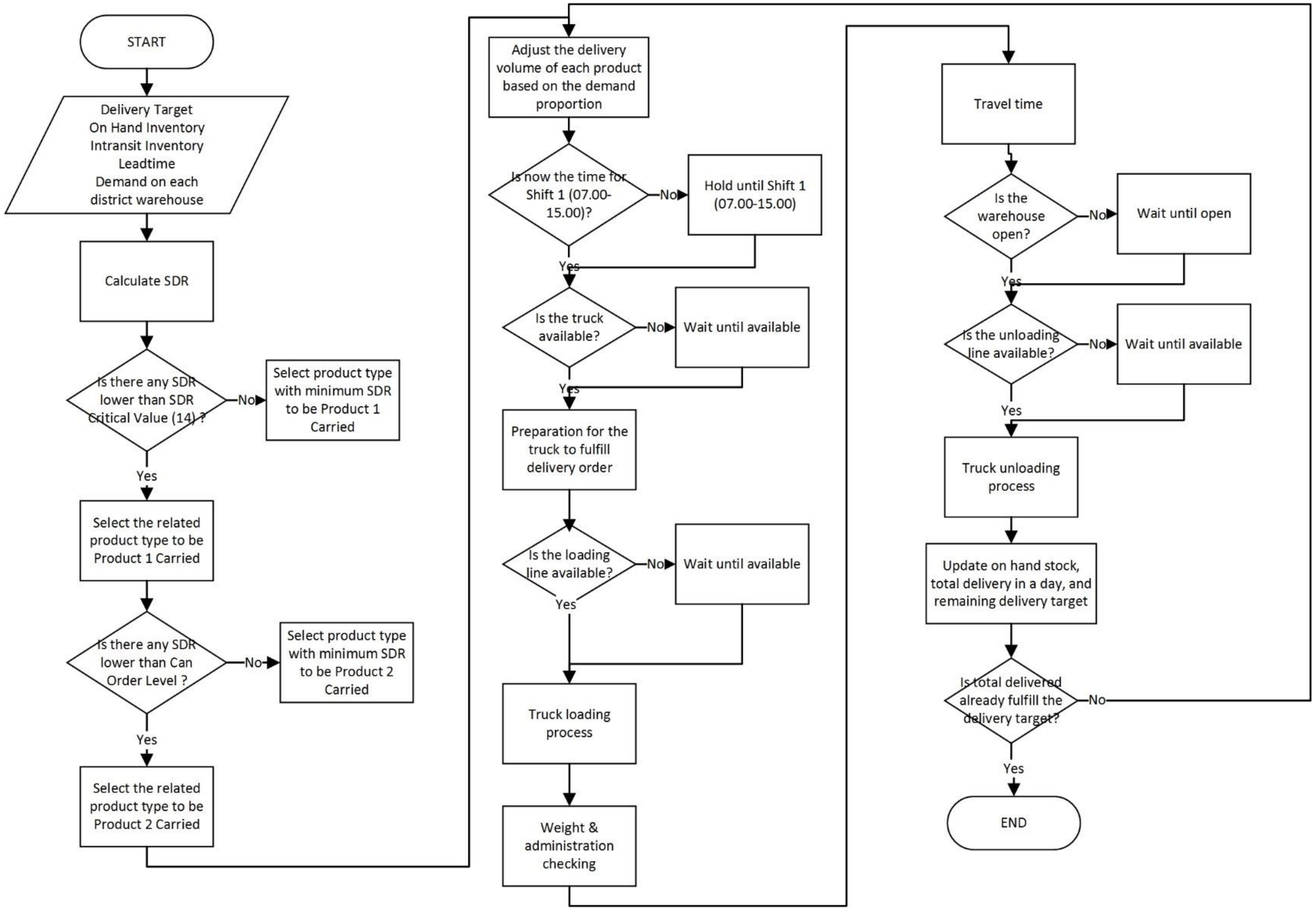

Figure 4.5 Conceptual Model of Scenario 1 (2 Product Types with Time Windows)

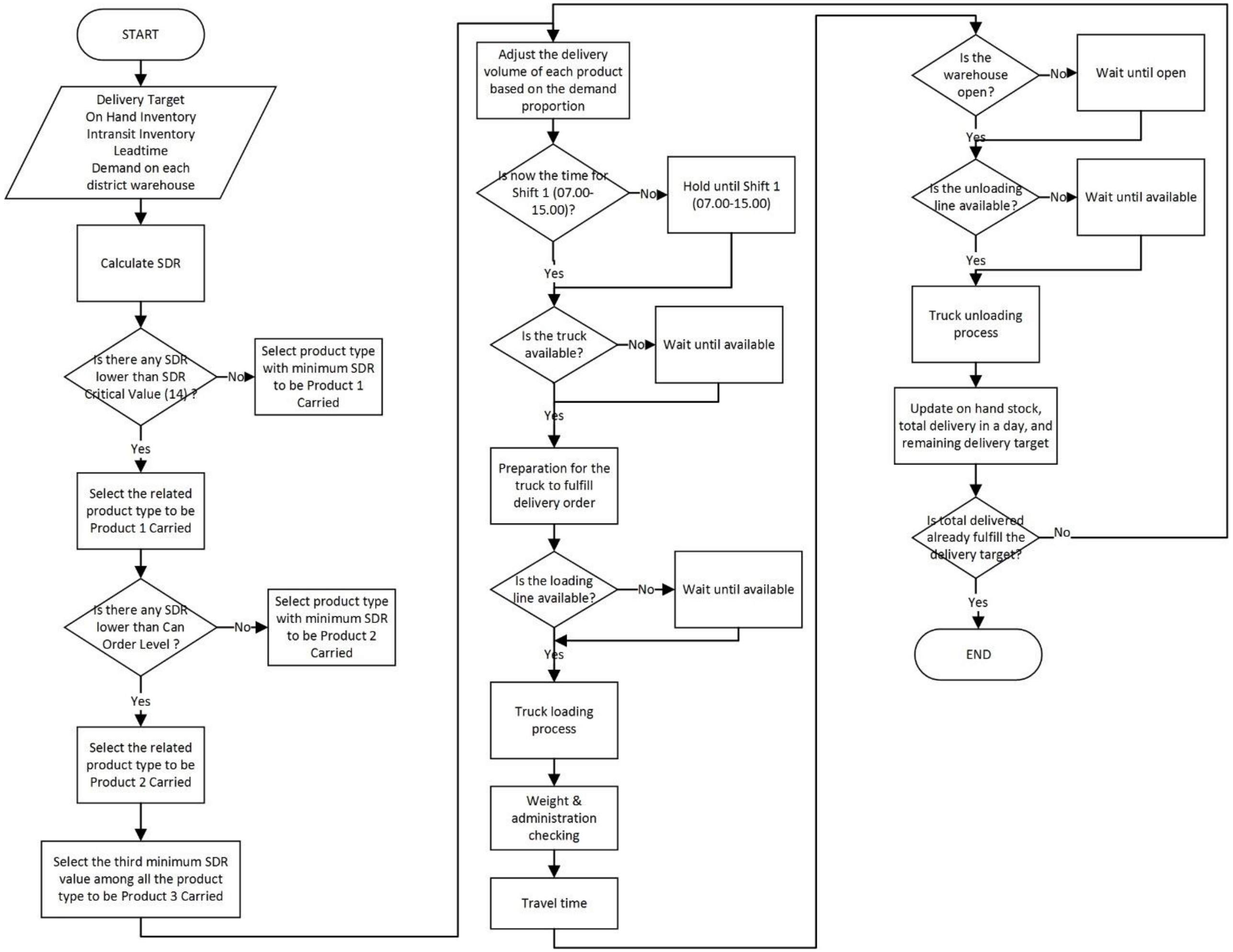

Figure 4.6 Conceptual Model of Scenario 2 (3 Product types with Time Windows)

4.4 Model Building

This chapter provides the explanation about the simulation model that has been made, by inputting the data and parameter needed and following the working processes that have been set in the conceptual model. The processes explained in this simulation model are focused on the main distribution activity, which starts from the loading process in the factory, until it arrives to the district warehouse. But, all of the constraints already consider the real regulation and policy applied in the company.

The simulation is made using ARENA 14 Software, with total simulation time of 1 year or equal to 365 days, with 1 day equal to 24 hours. The existing simulation interface is shown in the Figure 4.7.

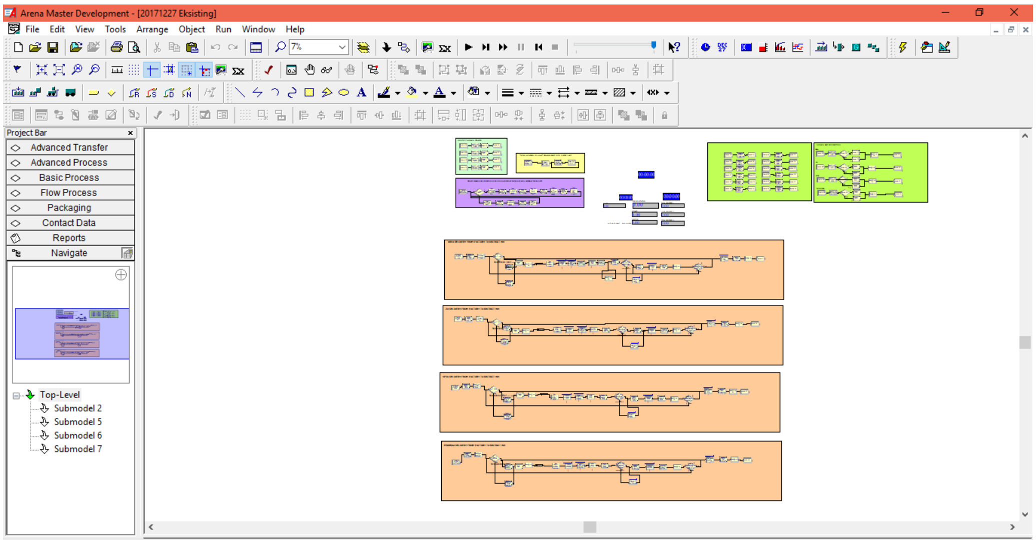

Figure 4.7 Existing Simulation Interface

The existing model consists of some different parts, which overall explain the distribution process from the beginning until the end. The explanation of each model part is provided below

4.4.1 Existing Condition Model

This subchapter provides the explanation of every sub-model made in the simulation model of existing condition, which are classified into two different parts named general sub-model and distribution process sub-model

4.4.1.1 General Sub-model

The general sub-model generated in the existing condition model includes the model of monthly demand updater, district warehouse operational hour updater, total delivered in a day reset, and on hand stock after updated by selling rate. The sub-model of monthly demand updater has the function to update the monthly demand of each product type. The information are obtained from the excel file recalled by the module. Here the entity is set to be the demand, so the time between arrivals is set to be in every month, with maximum arrival of 12 to reflect 12 months. In the file that has been read by the module, there are 12 data of monthly demand, which is automatically updated every month in the system.

There is also a sub-model for updating the operational hours of the district warehouse, which later give the signal to the main distribution process model to indicate whether the district warehouse is open. The district warehouse has the operational hour of 08.00-16.00 on Monday-Friday, 08.00-13.00 on Saturday, and closed on Sunday. A sub-model for resetting the amount of total delivered in day is also made, since there is a constraint of maximum load delivered in every one shift for every product. So, resetting the number to become 0 at the end of the shift is necessary to keep the number updated.

To update the number of on hand stock after it is reduced by the daily demand in the district warehouse, a sub-model for calculating the number of on hand stock is made. Each product has its own demand rate and also differs between each month. There is also a calculation of amount of stock out whenever the on hand stock is below the demand rate. If there is no on hand stock left to cover the selling needs or the demand, the calculation of the stock out will be automatically updated. But if there is any on hand stock that is able to cover the demand, the on hand stock number will be reduced.

4.4.1.2 Distribution Process Sub-model of Existing Condition

This part explains about the sub-model of distribution process from the beginning in the factory until it arrives to the district warehouse. The system reads the monthly delivery target that has been assigned before, and then determines the amount of load truck shipped by considering the monthly remaining target that has not been fulfilled yet. If the monthly delivery target is higher than the truck capacity, which is 30 tons, the truck load shipped is set to be 30 tons. Meanwhile, if the monthly delivery target is lower than the truck capacity, then the truck load shipped is set to be the exact number of the target delivery load.

After that, it is continued to the delivery shift assignment. The logic of the model is assigning the delivery order to the shift that is currently running. But, if the maximum amount of load of every product type in that shift has been reached, then it can be allocated to the next shift until it does not exceed the maximum load capacity per shift.

After the truck has been assigned to particular shift, there will be a delay for the truck to do preparation for 1 day before it finally starts to do the loading process in the factory warehouse. Then, it has some processes inside the factory warehouse after loading process which are weight and administration checking, until it finally departs from the factory to the district warehouse. After the truck arrived in the district warehouse, the system checks whether the truck arrives when the district warehouse is open. If the warehouse is open, the truck can be proceed to the next process, which are unloading process until the system updates the on hand stock. If it is not, the truck has to wait until the operational hour of the district warehouse starts. At the end, the system checks whether the truck has already delivered the products in amount of the delivery target. If it is not, the truck has to go back to the factory and deliver the products until it finally delivers all the targeted number of products. If the delivery target per month is already reached, the truck can be disposed.

4.4.2 Improvement Scenario Model

This subchapter provides the explanation of every sub-model made in the simulation model of improvement scenario condition, which are classified into two different parts named general sub-model and distribution process sub-model

4.4.2.1 General Sub-model

The general sub-model generated in the existing condition model includes the model of monthly demand updater, district warehouse operational hour updater, total delivered in a day reset, and on hand stock after updated by selling rate. The sub-model of monthly demand updater has the function to update the monthly demand of each product type. The information are obtained from the excel file recalled by the module. Here the entity is set to be the demand, so the time between arrivals is set to be in every month, with maximum arrival of 12 to reflect 12 months. In the file that has been read by the module, there are 12 data of monthly demand, which is automatically updated every month in the system.

There is also a sub-model for updating the operational hours of the district warehouse, which later give the signal to the main distribution process model to indicate whether the district warehouse is open. The district warehouse has the operational hour of 08.00-16.00 on Monday-Friday, 08.00-13.00 on Saturday, and closed on Sunday.

A sub-model for resetting the amount of total delivered in day is also made, since there is a constraint of maximum load delivered in every one shift for every product. So, resetting the number to become 0 at the end of the shift is necessary to keep the number updated.

To update the number of on hand stock after it is reduced by the daily demand in the district warehouse, a sub-model for calculating the number of on hand stock is made. Each product has its own demand rate and also differs between each month. There is also a calculation of amount of stock out whenever the on hand stock is below the demand rate. If there is no on hand stock left to cover the selling needs or the demand, the calculation of the stock out will be automatically updated. But if there is any on hand stock that is able to cover the demand, the on hand stock number will be reduced.

4.4.2.2 Distribution Process Model of Improvement Scenario Model

This part explains about the model of distribution process from the beginning in the factory until it arrives to the district warehouse. In the improvement scenario, the main distribution activity starts with a dispatching rule that is based on the criticality of each product type. The criticality is assessed by calculating Stock to Demand Ratio (SDR) of each product type, and then compare it with the SDR Critical Value owned by the company, which is 14 days, to find the first product type to be shipped. If there is no product type with SDR value lower than SDR Critical Value of the company, the system searches for the product type with the most minimum SDR value. In deciding the second product to be shipped the system searches for the product type that has SDR value lower than the Can-order

Level that has been set before. In this research, it is assumed that the Can-order Level has the value of SDR plus 1 which becomes 15 days. The same method is used for selecting the third product type to be shipped, which is by selecting the product type with the most minimum SDR value.

After assigning the critical products that need to be prioritized to be delivered, then the model calculates the truck load that has to be shipped. If the remaining target delivered is more than the load of truck capacity, which is 30 tons, then the truck load shipped is 30 tons. If the remaining target delivered is less than truck capacity, then the truck load shipped is as the remaining target delivered load. Since there are some product types shipped at once, there has to be a load proportion between each types, which is calculated after the total truck load is determined. After that, the system will proceed to the delivery shift assignment, in which the shift will be only allocated to Shift 1 for delivery process to 5 observed district warehouse in this research, since all of them has the short travel time and distance.

While if the time-windows constraint is neglected, the delivery shift assignment will be based on the current time of the shift and only be transferred to the next shift if the maximum load capacity in that shift has already reached. Then, it begins to the loading process in the existing condition, which is started by having the loading process in the factory warehouse by using forklift and worker to move the fertilizer products from the factory warehouse to the truck. After that, the truck will be checked for the weight and administration needs until it finally departs from the factory to the destination. The travel time differs between each warehouse, since each of them has different distance.

After the truck has arrived in the destination, the model checks whether the warehouse is open. If it is not, the truck has to wait until the warehouse opens. If it is, the truck can be processed to the unloading process. After the unloading process has finished, then the on hand stock can be updated. Then, the model checks whether the remaining target delivered is already fulfilled. If there is still remaining target delivered left, the loop will go back to the load truck proportion calculation to do more delivery until it finally has no more remaining target delivered left.

4.5 Number of Replication Needed

After running the simulation model, then the calculation of number of replication needed has to be done. This process is necessary in order to get a better and more accurate result of simulation, since simulation may generate a probabilistic output with random characteristic of input and output. One of the method to calculate number of replication is by simulating the model with initial replication number, and then calculate the half-width based on that replication sample. The calculation can be done by using Formula (3.3) and Formula (3.4).

The calculation will be done by using the output of number of products delivered in a day, in the unit of product per day. The initial number of replication is set to be 5, in which one replication is running for 1 year. The output of the 5 replications result is shown in Table 4.7.

Table 4.7 Result of Simulation to Calculate Number of Replication Needed

Number of Replication	Output of Simulation (product)
1	455,4087856
2	398,5741667
3	335,7679353
4	274,1589052
5	207,4460898
Average	334,2711765
Standard Deviation	98,11921693

Based on the simulation result, the value of half-width obtained with the error rate assumed to be 5% is

α = 0,05
n = 5
std = 98,11921693

t = 2.776

$$hw = \frac{t_{\left(n-1\,\frac{\alpha}{2}\right)} \text{ x std}}{\sqrt{n}}$$

$$= \frac{2.776\text{x}98.119}{\sqrt{5}} = 121{,}8313$$

$$n' = \left[\frac{z\left(\frac{\alpha}{2}\right) x \text{ std}}{hw}\right]^2$$

$$= \left[\frac{1.96 \text{ x } 98.119}{121{,}8313}\right]^2 = 2.5$$

$$\approx 3$$

Based on the result of number of calculation needed, it can be seen that the number of replication needed is approximately 3. But, since the number of replication needed is below the initial replication value or 5 times, then the number of replication used is the initial replication value. This higher number of replication is chosen in order to obtain more accurate result and reduce the randomness that may occur in the simulation result. This number of replication will be used to run the simulation for both the existing and the proposed scenario.

4.6 Verification & Validation

This subchapter explains about the verification and validation test of the model, to make sure that the model is already representing the real condition.

4.6.1 Verification

The verification process is done to test whether there is a syntax and semantic error occurred in the simulation model. The syntax error checking can be done by using the debug facilities provided in the ARENA software. It can be seen that no errors or warnings in the model, meaning that the model is verified by the debug facility in the software. The semantic error can be checked by seeing whether the model has the desired logic. The checking can be done by tracking the flow of the simulation run result to see whether the logic of the system has already following the rules, constraint, or consideration that have been inputted to the model before.

1. Verification of Operational Hour of District Warehouse Rule

   The verification is done by checking whether the model has the same logic for the operational hour of the district warehouse. It has been stated before that if the district warehouse is in the operational hour, which is Monday-Friday on 07.00-15.00 and Saturday 07.00-13.00, then the variable named opengate will be valued 1. If it does not the value will remain 0. The result of the verification checking is shown in Figure 4.8.

Based on the result, it can be seen that in the upper figure the opengate status is 0 because the current time is on 01.00, meaning that the operational hour of the warehouse is not started yet. While in the lower figure, the opengate status becomes 1 when the current time is on 10.00, which indicates that the warehouse is open. Thus, it can be concluded that the model is verified.

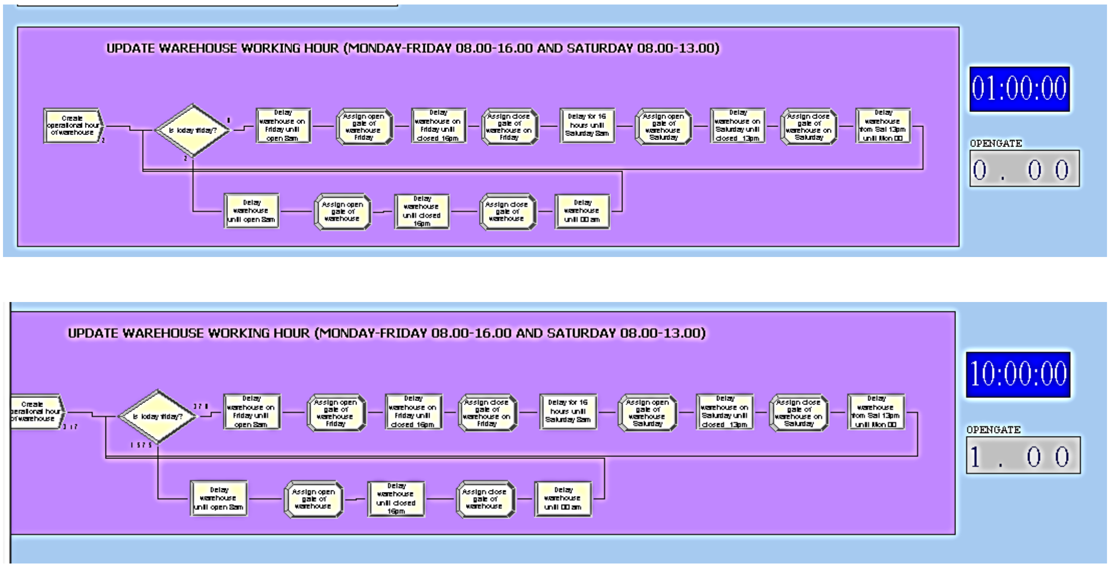

Figure 4.8 Verification of District Warehouse Operational Hour

2. Verification of Inventory Position Calculation

The verification is done by checking whether the inventory position calculation in the model has the same logic and result to the manual calculation result. Here the inventory position is calculated by using the Equation 4.1.

$$Inventory\ Position = On\ Hand\ Inventory + Intransit\ Inventory \qquad (4.1)$$

The checking will be done by using the ReadWrite module in ARENA, to command a ‘write to file’ action to MS. Excel file to get the updated result of on hand inventory, in-transit inventory, and inventory position. The result of the ‘write-to-file’ is shown in Table 4.8.

Table 4.8 Result of WriteToFile from ARENA

On Hand	Intransit	Inventory Position
30	150	180
60	150	210
90	150	240
30	60	90
120	150	270
150	150	300
60	45	105
30	168	198
60	168	228
90	168	258

It can be seen that the result of inventory position is same to the manual calculation using the formula in Equation 4.1. Thus, it can be concluded that the model is verified.

4.6.2 Validation

Validation is a process to check whether the simulation model build is the right model that can reflect the real condition of the system. In this validation test, a statistical test using paired two sample is used to check whether there is a significant difference between the simulation result and the real condition. The data that is going to be tested in this validation process is the lead time to travel to warehouse. The validation test is using two tail test, with the hypothesis as follows

$$H_0: \mu = \mu_0$$
$$H_1: \mu \neq \mu_0$$

By running the simulation with 5 replications as it has been decided in the previous subchapter and setting the alpha to be 0.05, then the lead time data can be obtained and resulting a statistical test shown in Figure 4.10.

t-Test: Two-Sample Assuming Unequal Variances		
	Simulation	*Actual*
Mean	104,56	105,141
Variance	1503,878	2,524
Observations	5	5
Hypothesized Mean Difference	0	
df	4	
t Stat	-0,03320726	
P(T<=t) one-tail	0,487550139	
t Critical one-tail	2,131846786	
P(T<=t) two-tail	0,975100278	
t Critical two-tail	2,776445105	

Figure 4.9 Result of Validation Test

It can be seen that the t-stat (0.03) is between the range of t critical two-tail value, which is between -2.77 and 2.77. Thus, it can be concluded that there is no evidence to prove that there is a significant different between the simulation result and the real condition.

4.7 Scenario Model Building

This subchapter explains about the scenario model that is going to be proposed to make a development in the existing distribution process in PT. X. The purpose of the scenario is to balance the service level between one types of product to another, so that the stock in the district warehouse will be available for all the types of the product instead of only available for one type only. Thus, an improvement scenario is made in order to reach that purpose, which is explained as follows

1. Prioritize the delivery of a type of product by calculating the Stock to Demand Ratio (SDR), and comparing it with the Critical SDR value, as the Reorder Point, and also comparing it with the Can-order Level. This regulation makes it able to deliver more than one product types in one truck and find the right combination based on the stock criticality, so that the availability of each different type of product will increase. After the stock to demand ratio of each product has been calculated, then this value is compared to the SDR critical standard owned by the company, which

becomes the reorder point set by the company. The company has been stated that a stock is considered critical if the current stock is only able to cover 14 days of demand. Thus, the first type of product selected to be delivered is the one with SDR value closest to the criticality standard. If there is no critical stock, then the product type chosen is the one with the lowest value of SDR, meaning that this product type is the closest to the criticality. And then, select the second product type delivered by prioritizing the most critical destination according to Can-order Policy. In this research, the value of Can-order Level is obtained from value of Stock to Demand Ratio (SDR) plus 1. The second product type chosen is the one with the SDR value below can-order Level, or the one with the lowest value of SDR if there is no stock lies below the Can-order Level. In the second scenario, the dispatching rule is set to have three different types of product shipped at once in one truck. The third product type selected is the product type that is also has SDR value lower than the Can-order Level. If there is no product type that has SDR value lower than Can-order Level, the product type selected is the one with the lowest value of SDR.

2. Allocating all of the truck that deliver the product to the district warehouse which has short distance and travel time to the earliest shift, in this research it is in the range of 07.00-15.00. By having this rule, it is expected that the truck will arrive in the destination when the district warehouse is still open, and also the truck will be faster to come back to the factory to do another delivery.

4.8 Simulation Result

The existing and scenario simulation model are simulated for 365 days, with 5 replications on each of the model. Each of the scenario will be evaluated by considering the service level and the distribution cost. For additional evaluation, a calculation of waiting time to enter the district warehouse is also shown.

4.8.1 Service Level

The service level is calculated by calculating the ratio between the days when there is no stock out in the product, with the total planning horizon. In this research, the calculation will be done in the period of a year to see the achievement of the company to fulfill the accumulation of monthly needs. Table 4.9 shows the service level of each product in each district warehouse with an accumulation in a year

Table 4.9 Simulation Output in terms of Service Level of Existing Condition

	Magetan	Lamongan1	Lamongan2	Tuban1	Tuban2
Urea	84.1%	67.6%	46.1%	29.1%	17.3%
ZA	34.2%	51.3%	49.8%	51.73%	26.8%
SP36	94.5%	61.17%	88.13%	91.57%	83.56%
Phonska	45.7%	45.2%	93.34%	91.72%	81.58%

In this research, it is targeted that the desired service level is at least 50%, meaning that 50% of the planning horizon day has followed the minimum amount of stock in a day requirement. Based on the percentage of service level result shown in the table above, it can be seen that the service level between each product in one warehouse has a huge difference between each other. The deviation between them is high, which indicates that there are some period of time in which one type of product is critical in the stock, while other type of products has the stock is much higher. And there are some of the product types in a warehouse that has the service level lower than 50%, which is below the minimum target. For example, as it is seen in Lamongan2 Warehouse, which has Urea service level of 46.1, while Phonska has service level of 93.34% in which the deviation between each product type in one warehouse is too high.

In the first improvement scenario, the truck is set to carry two different product types which are the most critical among the rest of the product types. The first product chosen is the one that is below the SDR Criticality standard set by the company, which is in the value of 14 days. Then, the second product chosen is the one with the SDR value lower than the can-order level. Here the can-order level is assumed to be obtained from the SDR value plus 1, which makes the value becomes 15 days. All of the delivery activities observed are allocated to Shift 1 (07.00-15.00) since all of the district warehouses observed in this research have short travel time and distance. After running the first scenario simulation, it results a distribution schedule which includes the information about the prioritized product type shipped and also the load of each type. The example of the output is attached in the

Attachment 1. After summarizing the result, then the service level of this first improvement scenario is as shown in the Table 4.10.

Table 4.10 Simulation Output in terms of Service Level of Scenario 1

	Magetan	Lamongan1	Lamongan2	Tuban1	Tuban2
Urea	77.2 %	85.47%	75.8%	79.4%	74.2%
ZA	78.8%	77.5%	92.8%	84.38%	78.6%
SP36	63.01%	72.6%	86.3%	74.5%	78.35%
Phonska	74.2%	73%	64.93%	73.4%	82.4%

The service level of scenario 1 model shown in the table above is obtained from comparing the average daily on hand stock with the daily minimum stock that has to be available in the warehouse. If the stock amount is below that value, so the condition is considered as stock out. Based on the calculation, then it obtained the service level value shown in the table above. It can be seen that service level between product types in one warehouse does not have a high deviation between them, meaning that the service level is more balanced between each other. All of the service level results are also higher than 50%, meaning that more than 50% days of the planning horizon has already achieved the minimum daily stock per product type in a warehouse.

Here it has to be noted that the inability of the company to reach particular service level is not because the company is unable to reach the monthly delivery target, but the company failed to balance the delivery amount between each day for every product type, which becomes the problem observed in this research. This issue becomes a new concern for the company, since in agricultural commodity as the main market of PT. X, it usually needs more than one variety of fertilizer types rather than demanding a very high number of fertilizers in a day. So, a stable and balance availability between each product type in every warehouse has to be maintained very well.

The second improvement scenario sets the dispatching rule to have three different product types can be shipped at once in the same truck, in which the selection is based on the criticality. And all of the delivery activities are assigned to Shift 1 due to the short travel time and distance. Table 4.11 shows the result of the service level after running the simulation with 5 replications with duration in one year.

Table 4. 11 Simulation Output in terms of Service Level of Scenario 2

	Magetan	Lamongan1	Lamongan2	Tuban1	Tuban2
Urea	85%	85.47%	60.6%	67.67%	74.3%
ZA	48.2%	50%	92.8%	84.38%	42.8%
SP36	63.01%	78.5%	47.8%	58%	69.3%
Phonska	76.3%	66%	79.5%	54.52%	70.68%

4.8.2 Cost

The cost in the existing condition which is calculated by Equation (3.1) and using the data provided in Subchapter 4.1.2 are shown in the Table 4.12. The holding cost is obtained from multiplying 25% with the total price of average inventory per day. After finding the average inventory per day of every product at each district warehouse, then it has to be multiplied with the known unit price per ton. The cost occurred in improvement scenario 1 is provided in Table 4.13. While for the cost occurred in improvement scenario 2 is provided in the Table 4.14.

Table 4.12 Cost of Distribution in Existing Condition

No	District Warehouse Name	Transportation Cost	Loading Cost	Unloading Cost	Holding Cost	Total Distribution Cost
1	Magetan1	Rp 3.769.335.383	Rp 269.142.119	Rp 336.427.649	Rp 987.346.515	Rp8.137.953.525
2	Lamongan1	Rp 2.621.984.192	Rp 396.909.505	Rp 496.136.882	Rp 370.855.014	Rp5.708.482.983
3	Lamongan2	Rp 1.808.981.328	Rp 234.486.000	Rp 293.107.500	Rp 304.143.433	Rp4.241.203.388
4	Tuban1	Rp 2.590.152.515	Rp 280.446.000	Rp 350.557.500	Rp 1.068.155.701	Rp6.863.838.286
5	Tuban2	Rp 1.593.015.005	Rp 172.482.000	Rp 215.602.500	Rp 419.084.959	Rp8.063.416.819
TOTAL						Rp33.014.895.000

Table 4.13 Cost of Distribution in Improvement Scenario 1 Condition

No	District Warehouse Name	Transportation Cost	Loading Cost	Unloading Cost	Holding Cost	Total Distribution Cost
1	Magetan1	Rp 3.769.335.383	Rp 269.142.119	Rp 336.427.649	Rp 279.688.438	Rp7.430.295.448
2	Lamongan1	Rp 2.621.984.192	Rp 396.909.505	Rp 496.136.882	Rp 228.324.137	Rp5.565.952.106
3	Lamongan2	Rp 1.808.981.328	Rp 234.486.000	Rp 293.107.500	Rp 129.344.390	Rp4.066.404.345
4	Tuban1	Rp 2.590.152.515	Rp 280.446.000	Rp 350.557.500	Rp 172.301.968	Rp5.967.984.553
5	Tuban2	Rp 1.593.015.005	Rp 172.482.000	Rp 215.602.500	Rp 261.169.967	Rp7.905.501.827
TOTAL						Rp30.936.138.279

Table 4.14 Cost of Distribution in Improvement Scenario 2 Condition

No	District Warehouse Name	Transportation Cost	Loading Cost	Unloading Cost	Holding Cost	Total Distribution Cost
1	Magetan1	Rp 3.769.335.383	Rp 269.142.119	Rp 336.427.649	Rp 136.520.060	Rp7.287.127.070
2	Lamongan1	Rp 2.621.984.192	Rp 396.909.505	Rp 496.136.882	Rp 114.056.353	Rp5.451.684.322
3	Lamongan2	Rp 1.808.981.328	Rp 234.486.000	Rp 293.107.500	Rp 1.399.485.089	Rp5.336.545.045
4	Tuban1	Rp 2.590.152.515	Rp 280.446.000	Rp 350.557.500	Rp 123.436.132	Rp5.919.118.717
5	Tuban2	Rp 1.593.015.005	Rp 172.482.000	Rp 215.602.500	Rp 200.720.830	Rp7.845.052.690
TOTAL						Rp31.839.527.843

Based on the calculation that has been done, it can be summarized that the total cost of each scenario is shown in Table 4.15. Here it can be seen that the lowest cost is obtained in Scenario 1, and the highest cost is obtained in existing condition.

Table 4.15 Summary of Total Cost in Each Scenario

Scenario	Total Cost
Existing Condition	Rp33.014.895.000
Scenario 1	Rp30.936.138.279
Scenario 2	Rp31.839.527.843

4.8.3 Waiting Time to Enter District Warehouse

This part provides the explanation of the result of waiting time to enter the district warehouse shown in existing condition, improvement scenario 1, and improvement scenario 2. Actually, this parameter is not the main consideration used in deciding the improvement distribution rule. But, the result of the waiting time also can be one of the indicator that the improved condition gives the desired result. In this case, it expected that in the improvement scenario 1 and 2, which has all the delivery assignment set to be in Shift 1, will have lower waiting time to enter the district warehouse compared to the existing condition.

The existing condition, with the delivery shift assignment is based on the current time of the truck arrived to the factory, has the result of average waiting time in the unit of hours shown in Figure 4.10. The graph below shows the average waiting time by taking 200 first samples of each of the assigned shift. The x axis indicates the n^{th} delivery shift assignment, in which the $0\text{-}200^{th}$ data are the average waiting time data of trucks assigned in Shift 1, the $201^{st}\text{-}400^{th}$ data are the average waiting time data of trucks assigned in Shift 2, and the rests are the data of trucks assigned in Shift 3. The y axis indicates the number of waiting time in the unit of hours.

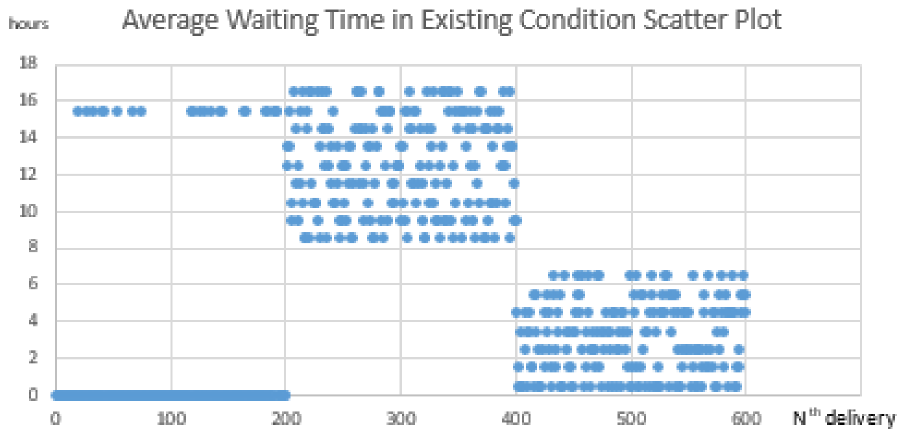

Figure 4.10 Average Waiting Time in Existing Condition (hours)

The improved scenario 1 also being assessed for the average waiting time of the truck to enter the district ware house in the unit of hours, which is shown in Figure 4.11.The x axis indicates the n^{th} delivery shift assignment, while the y axis indicates the number of waiting time in the unit of hours.

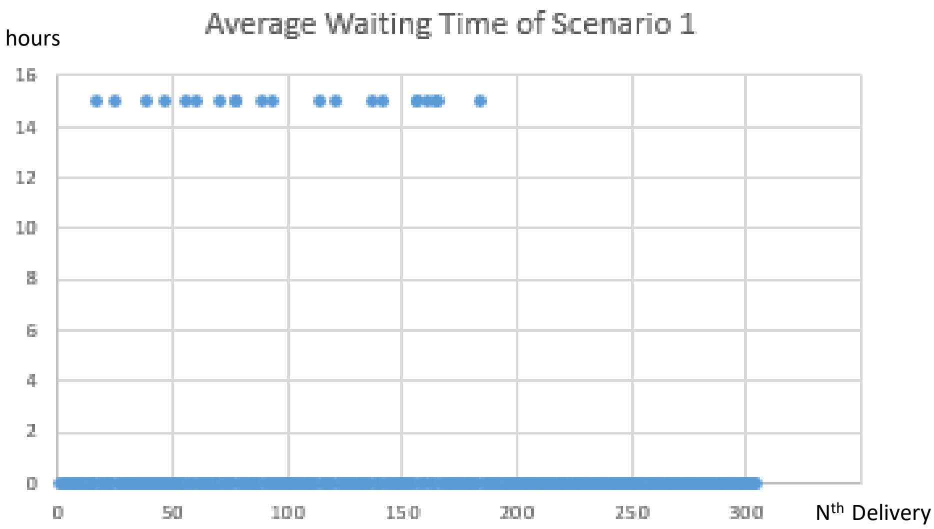

Figure 4.11 Average Waiting Time in Scenario 1 (hours)

The improved scenario 2 also being assessed for the average waiting time of the truck to enter the district warehouse in the unit of hours, which is shown in Figure 4.12. The x axis indicates the n^{th} delivery shift assignment, while the y axis indicates the number of waiting time in the unit of hours.

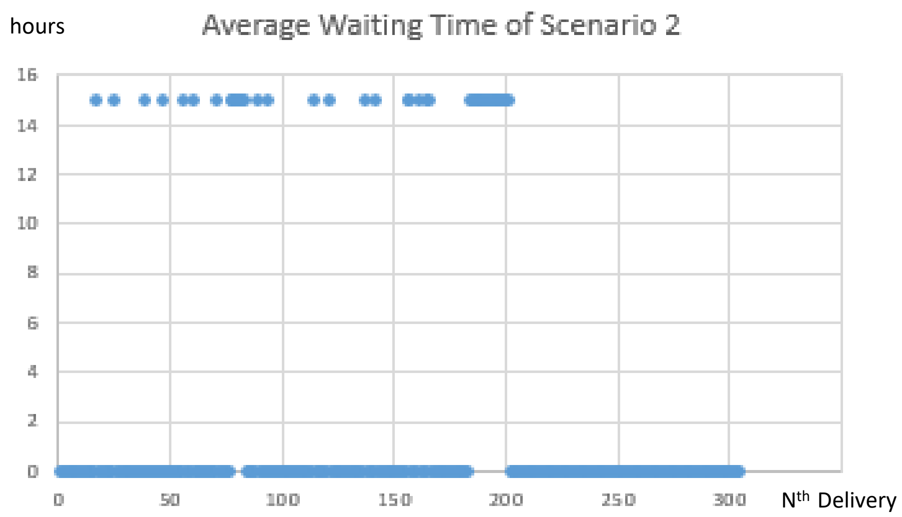

Figure 4.12 Average Waiting Time in Scenario 2 (hours)

CHAPTER V
ANALYSIS AND INTERPRETATION

This chapter explains about the analysis and interpretation of the simulation model results provided before. The analysis and interpretation discussed in this chapter will later become the basis for the conclusion and recommendation in the next chapter.

5.1 Service Level Comparison

Based on the calculation that has been done in the previous chapter, it can be concluded that the result of the service level can be expressed in the form of graph shown in the Figure 5.1 for the existing condition, Figure 5.2 for the scenario 1, and Figure 5.3 for the scenario 2.

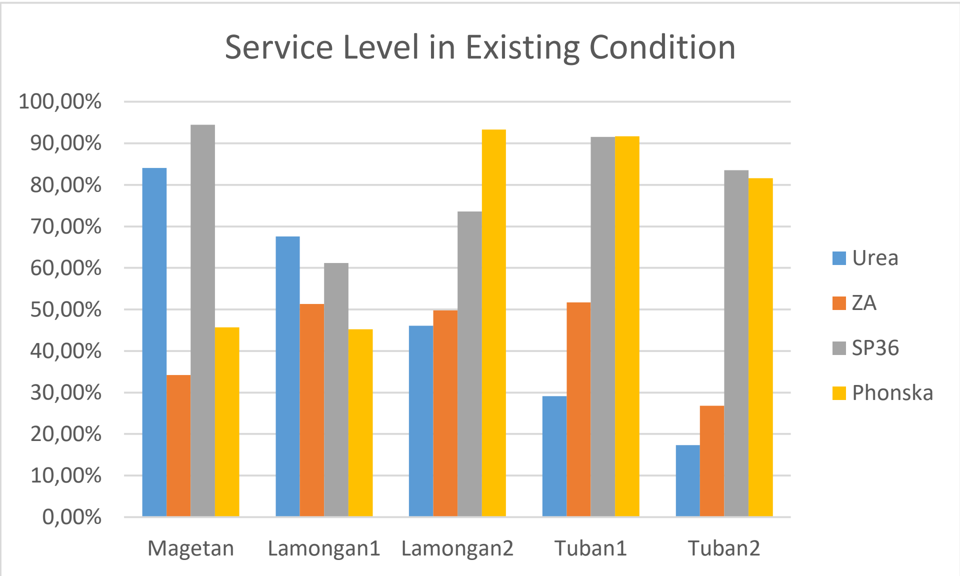

Figure 5.1 Service Level in Existing Condition

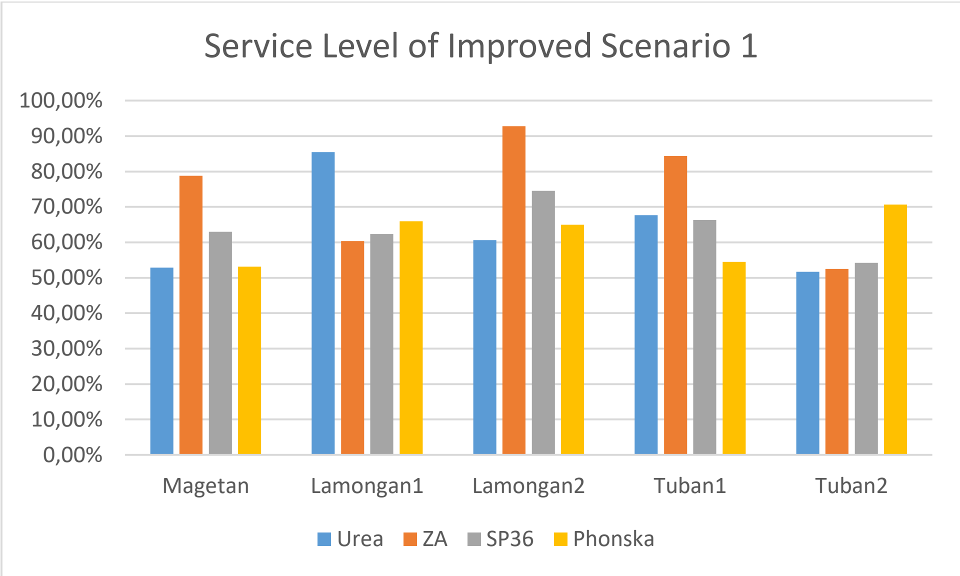

Figure 5.2 Service Level in Improved Scenario 1

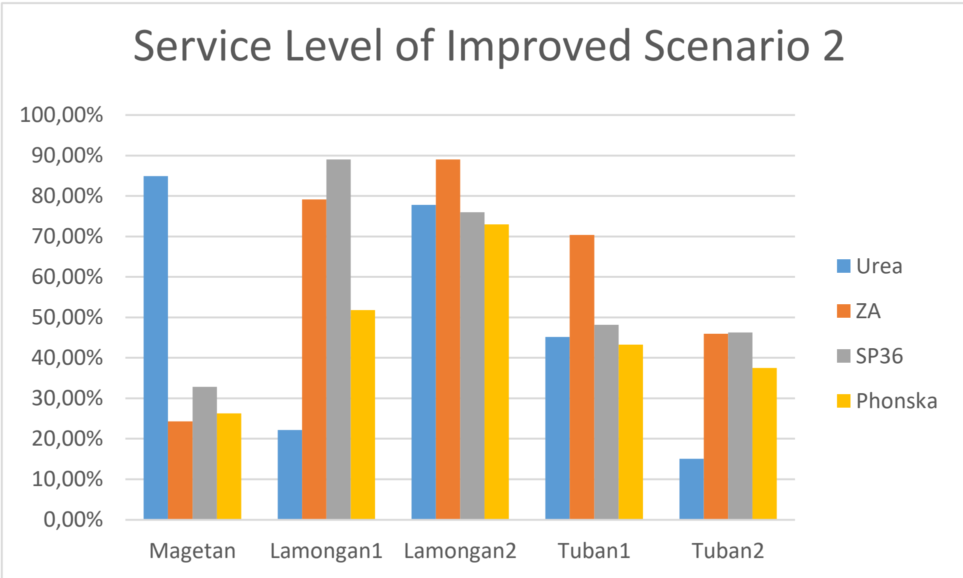

Figure 5.3 Service Level in Improved Scenario 2

According to these service levels resulted from different scenario, a comparison of maximum difference between each product types in the same district warehouse can done to determine whether the scenario is resulting a balanced service level between each of different product. The summary of this service level difference can be seen in Table 5.1.

Table 5.1 Comparison between Service Levels in each District Warehouse

District Warehouse	Maximum service level difference between product type in Existing	Maximum service level difference between product type in Scenario 1	Maximum service level difference between product type in Scenario 2
Magetan	60,30%	15,79%	36,80%
Lamongan1	22,40%	12,87%	35,47%
Lamongan2	47,24%	27,87%	45,00%
Tuban1	62,62%	10,98%	29,86%
Tuban2	66,26%	8,20%	31,50%

Based on the result of existing condition model, it can be seen that the service level of each product in the same district warehouse in the existing condition varies quite significantly. The highest difference of service level between different product types in one warehouse occurs at District Warehouse Tuban2, which has difference of 66.26%. This can be happened due to the limited number of truck available, which makes the delivery order has to wait to be served until there is an idle truck to do the delivery process. The value of service level here represents the ratio of the days when the stock on hand is in the number desired, or on the other word it can be said that there is no stock-out in the period of planning horizon. The higher the service level, the higher the performance of the company in fulfilling the demand of the customer.

In this research, it is targeted that the desired service level is at least 50%, meaning that 50% of the planning horizon day has followed the minimum amount of stock in a day requirement. Based on the result of the simulation in existing condition, it can be seen that the service level between each product in one warehouse has a huge difference between each other. The deviation between them is high, which indicates that there are some periods of time in which one type of product has critical amount of stock, while other type of products has abundance of stock. And there are some of the product types in a warehouse that has the service level lower than 50%, which is below the minimum target. For example, as it is seen in Lamongan2 Warehouse, which has Urea service level of 46.1%, while

Phonska has service level of 93.34% in which the deviation between each product type in one warehouse is high.

By using the existing distribution rule, the variance of service level between each type of product in one warehouse becomes very high. When one truck is only dedicated to one type of product, it makes the availability of each product type is not balanced between each other. This is indicated by the service level of each product that has high difference between each other. Also, since the dispatching rule is only consider the earliest delivery order requested, it does not represent the stock criticality that may happen in the district warehouse. There may be some moments when the transportation provider assigned themselves to deliver the product type that is actually not critical in terms of stock, and leaving the product type with the critical stock not delivered yet. This condition may be happened because in the existing distribution system, the company opens the delivery quota to all of the transportation and let them freely choose which destination of warehouse that they want to deliver. The allocation of the delivery shift time is also depends on the transportation provider, since in the existing rule they can choose the destination and the shift time freely. This condition makes sometimes there are trucks that depart not in the right time that is following the time-windows constraint, which makes the truck arrived when the district warehouse is already closed. If the truck has to wait for the district warehouse to open, it means that there are some idle time the truck have spent, which is actually can be used for the truck to do another delivery in another destination which is more suitable in terms of the time-windows.

If this condition keeps happening, it can give a disadvantageous impact to the company due to the unstable service level of the company. Even though the company does not always have a low service level, for example like the achievement of service of SP-36 product in Magetan Warehouse that has the value of 94.5% , but other product in the same warehouse has a very low service level which is ZA product with a service level value of 34.2%. In the real condition, the agriculture commodity as the main target market of PT. X of their fertilizer products, usually needs more than one type of fertilizers in one time. One of the example is in rice commodity that needs Urea and Phonska fertilizer products at the same time. If the variability and stability of the service level of each product in every warehouse is not maintained well, or having a high difference of service level between each product, it can make the customers unable to get what they actually need to plant their agriculture product. Also, in this existing process, the delivery shift assignment of each truck does not consider the time-windows of the district warehouse. This makes sometimes there are some trucks that have to wait for the next day until the warehouse opens, because the truck arrives when the warehouse is already closed.

According to this analysis, it can be seen that what causing the company to be unable to reach a stable service level between each type of product is not because of the failure in the production system, but it is in the distribution process to deliver the product from the factory to the market. Thus, an analysis and improvement in the distribution decision applied by the company has to be made in order to increase the performance of the company, especially in terms of service level of all variances of fertilizer products.

Based on those considerations, then an improvement scenario is made by having a dispatching rule that consider the criticality and allowing multiple product types shipped in one truck. The first scenario is made by setting two most critical products shipped in one truck, and assigning all the delivery schedule shift to Shift 1. After running scenario 1 in the simulation model, it can be seen that service level of all the product types in all the district warehouse are all improving and reaching the minimum service level that has been set before, which is 50%. The service level of overall product types also become more stabilized and have lower deviation between each type of product compared to the result in existing condition. In the result of scenario 1, the maximum difference between the highest service level and the lowest service level for each warehouse is all lower than the result in existing condition. The highest difference is occurred on Magetan District Warehouse with maximum service level value difference of 15.79%, while for the lowest difference is occurred on Tuban2 District Warehouse with maximum service level value difference of 8.2%. This result can be obtained because the dispatching rule is changed from based on earliest delivery order registered to be based on stock criticality. The new distribution decision that allows two different types of product shipped in one truck of delivery is also contributing to this better result compared to the existing condition. Both of these new distribution rules are able to increase the service level of each product type, since it allows two most critical product to be delivered first. By using this distribution decision, it allows the daily stock amount of all product types becomes at least in the quantity of minimum stock per day that is able to fulfill the daily demand. Even though during the day, the on hand quantity of each of the product is not as high as the existing condition, but that quantity is still able to fulfill the daily customer demand. This condition is more preferable for the company, since in agriculture sector as the main customer of PT.X usually needs more than one type of products rather than demanding a high quantity of one product type only. Furthermore, this lower yet more balanced on hand stock compared to the existing condition also gives more benefit to the company, since it results a lower holding cost.

While for the improvement scenario 2 is basically using the similar method with the improvement scenario 1 that is using the approach of Can-order Policy to prioritize the critical product type to be delivered. What makes it differ from the first improvement scenario is in this second scenario is the truck is now set to carry three different type of products which are the most critical. In the scenario 2, it can be seen that the service level of some product types are increasing compared to the existing condition. There are also some product types that have higher increase from the existing condition, compared to the increase occurred in scenario 1. One of the example is the service level of SP-36 product in Lamongan1 District Warehouse that has increased for 11.43% in Scenario 1, and increased for 17.33% in Scenario 2. But, there are also some others that have the service level much lower than the existing condition. One of the example is the service level of SP-36 product in Lamongan2 District Warehouse, which has decreased until it reaches the service level of 47.8%. As it is stated before, the service level value below 50% is not desirable for the company, since it is below the minimum service level that has been set before. This means that even though in some product types the result of the service level is good, but there are some of the product types that have the service level value lower than the target.

In the overall result, the scenario 2 mostly gives lower difference of service level between types of product in the same warehouse compared to the existing condition. But, the difference between service levels of each product in the same warehouse t is still higher than the result obtained in Scenario 1. This condition can be happened because the delivery will prioritize three from four of the product types, which makes the delivery is prioritized for three critical product type and left the other one product type not delivered until the delivery for the three critical product type are achieved. In this scenario 2, the delivery also takes longer time because the load has to be divided for three different product type, which makes the truck has to go back and forth to fulfill the target delivery. So, it can be said that in terms of criticality, the scenario 2 is unable to give balanced service level between one product types to another as good as scenario 1.

5.2 Cost Comparison

Based on the cost calculation that has been done in the previous chapter, it can be concluded that the cost of each scenario is shown in Table 5.2.

Table 5.2 Comparison of Cost between Scenarios

Scenario	Total Cost
Existing	Rp33.014.895.000
Scenario 1	Rp 30.936.138.279
Scenario 2	Rp31.839.527.843

In this research, the cost component that makes the overall cost differs between each scenario condition is the holding cost. The transportation cost of all the scenarios remain the same, since the basis of calculating the transportation is the tonnage shipped by the truck. Since in this research the company is given the same delivery target in all condition, it makes the transportation cost remains the same for all the conditions.

According to the cost calculation result of the existing condition, scenario 1, and scenario 2, it can be seen that the existing condition has the highest overall cost compared to all the conditions. Meanwhile, the lowest overall cost is obtained from the result of improvement scenario 1. Scenario 1 can have the most minimum cost because it has the lowest holding cost compared to the others. Since scenario 1 has the best configuration to balance the service level between product types by adjusting the amount of daily on hand stock to become sufficient to fulfill the daily demand, it makes the holding cost that considers the average amount of on hand inventory per day becomes lower. While for the overall cost in scenario 2 is also lower than the existing condition, but it is still higher compared to the result in scenario 1. The overall cost of scenario 2 can be higher than scenario 1 because the service level of each product type in scenario 2 is not as balanced as the result in scenario 2. According to the analysis in the previous subchapter, it is seen that the scenario 2 only give a high service level, which can be indicated by the daily on hand inventory, in some product types while leaving the rest of the product types having a low service level.

5.3 Waiting Time in District Warehouse Comparison

Based on the simulation result, it can be seen that the existing condition gives frequent occurrence of waiting time to enter the district warehouse. Since the delivery shift assignment in the existing condition is based on the current time of the system, it makes the trucks sometimes arrive in the district warehouse when it is already closed. The most frequent waiting time occurs in the delivery shift assignment of Shift 2 (15.00-23.00) and Shift 3 (23.00-07.00). This result can be obtained because all of the observed district warehouses in this research have short travel time and distance, which makes it not suitable if the truck is departed in Shift 2 and Shift 3. If the truck departs in that period of time, it makes the truck will arrive in the district warehouse when it is already closed.

While the result of both improvement scenario 1 and scenario 2, in which the delivery shift assignments are all set to be in Shift 1, has much lower frequency of waiting time to enter the district warehouse. This result can be obtained because Shift 1, which is in the time period of 07.00-15.00, is suitable for delivery assignment in short travel time and distance.

5.4 Suggested Scenario

Based on the discussion that has been done in the previous subchapter, it is suggested that the scenario of improvement taken is the first scenario, which provides the delivery of two different types of product at one truck and considering time-windows. This scenario is able to make the service level in the warehouse is balanced between one product type to another, which becomes the concern in this research. Even though in terms of quantity the amount of daily on-hand inventory of each product type does not seem high, but this daily on-hand is still able to fulfill the daily demand requested by the market. And in terms of cost, since it implements the joint replenishment policy, it has been proven that the overall cost of scenario 1 is the most minimum among the other conditions due to the low holding cost results in scenario 1. Moreover, since scenario 1 considers time-windows on its delivery shift assignment, it can reduce the frequency of waiting to enter the district warehouse due to its time-windows.

By implementing this scenario, it is expected that the daily on-hand inventory of all products in each district warehouse is at least near the minimum daily stock required, so that the service level of all product types in each warehouse are balanced between each other. This condition indicates that the product availability of all product types in each warehouse are balanced between each product type.

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CHAPTER VI
CONCLUSION AND SUGGESTION

This chapter explains about the conclusion and suggestion of this research, which are made for the whole research, the next research, and the company as the research object

6.1 Conclusion

The conclusions that can be obtained from this research are explained as follows.

1. The implementation of new distribution decision as the rule for the company to do its distribution process can increase the performance of the company, since it can increase the service level of the products, and product availability of all product types in the district warehouse. The new distribution decision includes the rule to prioritize the type of product delivered based on the stock criticality, which can use can-order policy method as the approach. The adjustment of delivery shift assignment to become considering time-windows is also needed so that the truck will arrive right in the time when the warehouse is still on its operational hour. Here the most suitable improvement is the Scenario 1, which provides distribution with carrying two most critical product in the same truck by using the Can-order Policy method, and also setting the delivery shift considering time windows.

   This scenario is able to increase the service level in the range of 0.82% to 56.9%.

2. The implementation of this new distribution rule, especially Scenario 1, will give the impact of reducing the overall cost incurred. The cost, which includes the transportation and holding cost, in the existing condition is Rp 33,014,895,0000. While for the overall cost of Scenario 1 is Rp 30,936,138,279. This indicates that there is a saving of Rp 2,078,756,721 or 6% from the existing condition cost. The

implementation of Scenario 1 also gives impact to the service level. In the existing condition, the service level is highly vary from 17.3% to 94.5%, with the overall average service level of 61.73% and average difference between each product service level in the same warehouse is 51.76%. While in Scenario 1, the service level lies between 63.01% and 92.8% meaning that all of the service levels are above the minimum target (50%), with the overall average service level of 77.34% and average difference between each product service level in the same warehouse is 15.14%. This indicates that improvement Scenario 1 has better cost and service level compared to the existing condition.

6.2 Suggestion

1. A further analysis is needed to consider the facility owned by the company, and whether the company is fully ready to implement the whole distribution system by using this method
2. The company should analyze further when implementing this new distribution decision in the distribution system, since probably an adjustment in terms of cost related to the distribution activity can be occurred.

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ATTACHMENT

Attachment 1. Example of New Distribution Decision Output in Scenario 1

Date	Month	Critical Product 1	Load Product 1 (tons)	Critical Product 2	Load Product 2 (tons)
1	1	2	21	3	9
1	1	2	21	3	9
1	1	2	21	3	9
1	1	2	21	3	9
2	1	2	21	3	9
2	1	2	21	3	9
2	1	2	21	3	9
2	1	2	21	3	9
2	1	2	21	3	9
4	1	2	21	3	9
4	1	2	21	3	9
5	1	2	21	3	9
5	1	2	21	3	9
6	1	2	21	3	9
6	1	2	21	3	9
6	1	2	21	3	9
6	1	2	21	3	9
7	1	2	21	3	9
7	1	2	21	3	9
7	1	2	21	3	9
7	1	2	9	3	3
7	1	1	22	4	8
8	1	4	8	1	22
8	1	4	8	1	22
8	1	4	8	1	22
8	1	4	8	1	22
…	…	…	…	…	…
…	…	…	…	…	…
25	12	1	7	2	23
25	12	1	7	2	23
25	12	1	7	2	23
26	12	1	7	2	23
26	12	1	7	2	23
26	12	1	7	2	23
26	12	1	7	2	23
27	12	1	7	2	23

Attachment 2. Example of New Distribution Decision Output in Scenario 1 (continued)

Date	Month	Critical Product 1	Load Product 1 (tons)	Critical Product 2	Load Product 2 (tons)
27	12	1	7	2	23
27	12	1	7	2	23
28	12	1	7	2	23
28	12	1	7	2	23
28	12	1	7	2	23
29	12	1	7	2	23
29	12	1	7	2	23
29	12	1	7	2	23
30	12	1	7	2	23
30	12	1	7	2	23
30	12	1	7	2	23
31	12	1	7	2	23
31	12	1	7	2	23
31	12	1	7	2	23
31	12	1	7	2	23

BIOGRAPHY

The author, Azaria Zada Noordika, was born on 28 June 1998 in Malang, Indonesia. The author had completed her formal studies at SD Al-Hikmah Surabaya (2004-2009) and SDN Ketabang 5 Surabaya (2009-2010) for the elementary school, SMPN 1 Surabaya (2010-2012) for the junior high school, and SMAN 5 Surabaya (2012-2014) for the senior high school. In 2014, the author started to continue her study in Industrial Engineering Department of Institut Teknologi Sepuluh Nopember (ITS).

During the study, the author had actively involved in student organization (Himpunan Mahasiswa Teknik Industri ITS) as a staff of big event division (IE FAIR) and given a role as secretary & treasurer of Industrial Engineering Challenge (INCHALL) 2016 in her second year, and as a Steering Committee of Industrial Engineering Challenge (INCHALL) 2017 in the third year. Beside university activities, the author also got an opportunity to be an XL Future Leaders Batch 5 Awardee, a self-development scholarship provided by PT. XL Axiata Tbk. In the final year of the study, the author participated in the internship program of PT. Petrokimia Gresik in Purchasing Department. For further discussion and suggestion regarding to this research, the author can be reached through email at azariazadaa@gmail.com.