FINAL PROJECT – TI 141501

SIMULATION STUDY OF CEMENT DISTRIBUTION CONSIDERING STOCK CRITICALITY AND SHIPMENT DUE-DATE

LALA AYU KANTARI
NRP. 2513100039

Supervisor
Prof. Ir. I Nyoman Pujawan, M.Eng., Ph.D., CSCP
NIP. 196901071994121001

Department of Industrial Engineering
Faculty of Industrial Technology
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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
Faculty of Industrial Technology
Institut Teknologi Sepuluh Nopember
Surabaya

Author:

LALA AYU KANTARI

NRP. 2513 100 039

Approved by,
Final Project Supervisor:

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

NIP. 196901071994121001

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SIMULATION STUDY OF CEMENT DISTRIBUTION CONSIDERING STOCK CRITICALITY AND SHIPMENT DUE-DATE

Name	: Lala Ayu Kantari
Student ID	: 2513100039
Supervisor	: Prof. Ir. I Nyoman Pujawan, M.Eng., Ph.D., CSCP

ABSTRACT

The expansion of Indonesia's infrastructure will effect to the increasing of cement sales. It is very optimistic that cement demand in Indonesia will rise significantly. PT. X is one of the leading cement producer in Indonesia which has two methods of delivery, sea transportation and land transportation using trucks. The utilization of land transportation of PT. X is more dominant than the sea transportation. Thus, the optimization for land transportation in PT. X is highly recommended due to its high frequency.

One of the problem in PT. X is the market of PT.X often run out of stock condition while there are plenty of stock in the plant. The current condition is the distribution order will be directly released after the order is received by the plant and delivered based on the earliest estimated due date of the delivery request. Moreover, there are no visibility of information between the plant and the distributor and the availability of the truck cannot be predicted due to the uncertainty of cycle time. This research aim to optimize the distribution of the cement using Vendor Managed Inventory (VMI) model which consider the visibility of information between plant and distributor. The method in this research is conducting a simulation study which considers the stock criticality of each distributor as the trigger of releasing the order.

By considering the stock criticality, the system will increase the product availability, increase the percentage of on-time delivery, and maintain the utilization of the truck. By using the same dispatching rule with additional number of the truck, the simulation process results in higher fill rate, lower truck utilization, and higher rate of on-time delivery. The suggested scenario is Scenario 7 with fill rate 81.3%, truck utilization 31.6%, and on-time delivery 32.5%. Scenario 7 utilizes 300 trucks and implement stock criticality method.

Keywords: ARENA simulation, cement distribution, shipment due date, stock criticality, Vendor Managed Inventory.

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Surabaya, January 15, 2017

Author

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CHAPTER I
INTRODUCTION

This chapter contains the intro of the whole research which consists of background, problem formulation, purposes of the research, benefit, and the outline of each chapter.

1.1 Background

The push for infrastructure development across Indonesia is expected to cause rising cement sales in Indonesia in 2016. The government started to increase development of government infrastructure such as roads, airports, social welfare, and many more from 2015. Furthermore, several private players are constructing power plants and smelters. The expansion of Indonesia's infrastructure will effect to the increasing of cement sales. It is very optimistic that cement demand in Indonesia will rise significantly. According to ASI (Indonesian Cement Association), domestic cement sales in Indonesia increased by 3.1 percent year-on-year (y/y) to 29.48 million tons in the first half of 2016 and it will continue to increase (Indonesia Investment, 2014).

PT. X is one of the leading cement producer in Indonesia. PT. X has been used to build roads, bridges, skyscrapers, and houses across the country. The types of cement it produces are Portland Composite Cement; Ordinary Portland Cement, including Type I, Type II and Type V; Oil Well Cement; White Cement, and TR-30 White Skim Coat; they are all marketed under the brand, Tiga Roda. Currently, the company is operating 12 plants which are spread across factories in West Java and South Kalimantan. The largest factory is located in Bogor, West Java. The total annual production capacity may reach up to 20.5 million tons of cement.

Distribution process in PT. X is divided into two ways which are land transportation and sea transportation. The distribution using land transportation may handle up to 700 destinations in each day. The delivery order can reach up to 40,000 orders per month. The distribution process is handled by third party logistic. Hence, due to the high contribution of land transportation in the distribution process, it will give a significant contribution to logistics cost (Puspadimiati, 2016). According to data published by the Indonesian Chamber of Commerce and Industry (Kadin Indonesia),around 17 % of a company's total expenditure in Indonesia is absorbed by logistics costs. In particular, transport costs are high both for land and sea. Several causes of the high logistics cost are the lack of adequate infrastructure in Indonesia, the broad destination of the market, the low utilization of the truck, and many more. In this case, the utilization of land transportation of PT. X is more dominant than the sea transportation. Thus, the optimization for land transportation in PT. X is highly recommended due to its high frequency.

Previous research that was conducted by Puspadimiati (2016) shows that the reduction percentage of shipment due date can reduce the probability of late delivery in PT. X. That research did not consider another problem in PT. X which the market of PT.X often run out of stock condition while there are plenty of stock in the plant. This condition shows that the distribution of the cement product does not effective. Several reasons that may cause the low product availability in the market are they does not distinguish the order from the market and the availability of the truck. The current condition of the company is the distribution process will directly release after the order is received by the plant and delivered based on the estimated due date of the delivery request. The trigger to do the delivery process is after receiving the order. The order is generated by the market distributor, it means that they are requesting based on their forecast and the plant does not know the remaining stock that available in the market. In other words, the order is released based on the Earliest Due Date method. It shows that the plant does not consider the criticality of the stock in the market.

Furthermore, there is the fact that the availability of the truck is not as much as the order received by the company. The truck will depart after receiving the order. The availability of the truck cannot be predicted due to the uncertainty of transportation cycle. Several uncertainties of the distribution process starts from the loading process in the cement packer, travel time from plant to distributor, and the unloading process in the distributor. Moreover, each of the distributors will have the specific operational time called time windows. The truck that arrived outside the time windows will stay and wait until the distributor open. In conclusion, the delivery order should be managed in order to fill the demand in the market.

In the light of the previous discussion, the development of a new method is required in order to accommodate several problems in the cement distribution as mentioned above. There are several options that can solve this problem. One of the methods is using the transparency of information between market and plant. In the other hand, the vendor may manage their distribution by processing the information of stocks in the market. This method called by Vendor Managed Inventory (VMI). In this case, it is better to develop a distribution strategy which considers stock criticality of each distributor. Stock criticality shows which distributor that require a supply of cement faster than the other by considering the remaining stock and the demand forecast of each distributor. By determining the optimal distribution strategy, it may improve the stock availability in the market and increase the service level of the company.

Simulation study is the suitable method to be used in this research because it can imitate the real condition and able to deal with complicated system including the uncertainties of the system. There are a lot of uncertainties in the distribution process including uncertain demand, loading time, unloading time, and travel time. The uncertainties is important because it is the main characteristic of distribution process. Moreover, simulation method gives more comprehensive result and able to get through several scenarios in shorter time.

This research aim to optimize the distribution of the cement using the visibility of information between manufacturer and market or applying Vendor Managed Inventory (VMI) model. Vendor Managed Inventory is carried out by determining the stock criticality in each distributor. The method in this research is conducting a simulation study to change the current dispatching rule which does not involve sharing information between manufacturer and distributor with several scenarios which consider the stock information. The improvement model will consider the stock criticality of each market as the trigger of releasing the order.

1.2 Problem Formulation

Stock criticality is not considered while making shipment decisions. Shipment is mostly generated by truck availability and due date. Consequently, shipment priority has neglect stock criticality which leads to frequent stock-out. Based on the aforementioned background, the problem formulation in this research is how to generate the distribution policy that considers the stock criticality and shipment due date of the distributor and how its effect to the product availability, on-time delivery, and the utilization of the truck.

1.3 Research Objectives

The objectives of this research are mentioned in the following list.

1. To develop improvement model which consider the stock criticality of each distributor and its evaluation to product availability, on-time delivery, and the utilization of the truck.
2. To determine the effect of considering stock criticality to product availability, on-time delivery, and the utilization of the truck.
3. To compare product availability, on-time delivery, and the utilization of the truck between scenarios that consider stock criticality and the initial condition.

1.4 Benefits

The benefit obtained from this research are mentioned in the following list.

1. Able to generate the distribution policy that consider the stock criticality of each distributor.
2. Able to generate a solution to accommodate the optimal strategy for cement distribution in PT. X.
3. Able to increase the availability of product in the market, increase the productivity of the truck, and reduce the probability of late delivery.

1.5 Research Scope

The scope that is used to show the boundaries of this research is shown in the limitations and assumptions as follow.

1.5.1 Limitations

The limitation used in the research is determined to be the focus of the research. Those are mentioned in the following list.

1. The observation is conducted in the plant located in West Java.
2. The delivery process is focused in the distributors in West Java only.
3. Working days for the distributor is from Monday to Friday.
4. The product observed in this research is cement in the form of 50 kg bags because currently it becomes the main focus of the company.
5. The research evaluates the land transportation using truck with capacity 10 tons and 30 tons.
6. Smaller truck is used to deliver the product to the short-distance distributor and the larger capacity is for the long-distance distributor.
7. The number of the truck is the total of both capacity types.
8. The expected delivery is limited to 5 days after the order is received, longer than that it is more uncontrollable and result in the more uncertain result.

1.5.2 Assumptions

There are several assumptions that are used in this research. Those are mentioned in the following list.

1. The trucks are always in the good condition which do not require for maintenance and breakdown time.
2. The time windows of the distributor are from 08:00 until 17:00.
3. The inventory data of distributor is recorded accurately by the distributor.
4. Travel time duration for delivery and backhaul is using the same distribution.
5. The break time of the driver is already included in the delivery time so that the truck will able to be assigned directly after return back to the plant.
6. The distributor which located less than 100 km from the plant is classified as short-distance distributor, otherwise it is long-distance distributor.

1.6 Research Outline

This subchapter consists of the brief outline of each chapter. This research consists of several chapters which are explained in the following list.

CHAPTER I INTRODUCTION

This chapter contains the intro of the whole research which consists of background, problem formulation, purposes of the research, benefit, and the summary of each chapter.

CHAPTER II LITERATURE REVIEW

This chapter explains about theories and concepts based on initial literature that have been developed and are used for the research. This literature is aimed to justify the suitable method used in the research.

CHAPTER III RESEARCH METHODOLOGY

This chapter explains about the methodology used in this research. It contains the phases of conducting the research. Generally, the research methodology contains observation and literature study, data collection, data processing, model building, scenario, data analysis and interpretation, conclusion, and recommendation.

CHAPTER IV DATA COLLECTION AND DATA PROCESSING

This chapter includes all processes in order to prepare data to conduct the research. Those processes are data collection, data processing, as well as scenario generation and experiment.

CHAPTER V ANALYSIS AND INTERPRETATION

This chapter consists of analysis and interpretation of the results of all scenarios that conducted in the previous chapter. Several analysis lead to the best scenario that will be put as the recommendation.

CHAPTER VI CONCLUSION AND RECOMMENDATION

This chapter consists of conclusion and the recommendation of the research. It concludes the whole research and contains recommendations for further researches as well as for the company.

CHAPTER II
LITERATURE REVIEW

This chapter explains about theories and concepts based on existing literature that have been developed and are used for the research. This literature is aimed to justify the suitable method used in the research.

2.1 Distribution and Transportation Management

Distribution network is the route of product or service movement from manufacturer to customer using wholesaler, distributor, and retailer. Distribution network transfer the product and its value to the last customer. Distribution and transportation management are the important factors to improve the competitiveness and win the competition in the market. Moreover, by applying the effective transportation system, the company will able to broaden the market area and increase the sales. Distribution management and transportation management have several fundamental functions as mentioned in following numbers (Pujawan & Mahendrawathi, 2010).

1. Do the segmentation and determine the service level target.
2. Determine the suitable transportation modes.
3. Consolidation of information and delivery.
4. Transportation scheduling and determine the route.
5. Give the added value to the product such as packaging, labelling, and others.
6. Managing the inventory.
7. Return policy.

2.1.1 Distribution Management

Distribution refers to the steps taken to move and store a product from the supplier stage to a customer stage in the supply chain. Distribution is a key driver of the overall profitability of a firm because it directly impacts both the supply chain cost and the customer experience. Good distribution can be used to achieve a variety of supply chain objectives ranging from low cost to high responsiveness. As a result, companies in the same industry often select very different distribution networks (Chopra, 2003).

Managing the distribution of the company will have several advantages such as improve the delivery time process, satisfy the after sales service, ensure the quality of the product, and increase the service level of the company itself. There are three distribution strategies to distribute the product from manufacturer to the customer. Below are those three strategies.

1. Direct Shipment

The shipment is done directly from manufacturer to the customer and does not require any support facility such as warehouse. This strategy is suitable for product that have short-life and easy to be damaged. The advantage of using this strategy is the company does not require to invest their money to build a new facility. Furthermore, the number of inventory will be low and the lead time to deliver the product will be short. In contrast, this strategy still have possibility to have higher transportation cost because of the high number of in-transit inventory and higher risk due to the uncertain demand.

2. Warehouse

The distribution process starts from manufacturer to customer and requires one or more support facilities such as warehouse. This strategy is suitable to distribute products that have long-life and have high demand uncertainty. By having a support facility, this strategy requires facility cost and additional operational cost in the facility. Moreover, the lead time for the product will be longer than direct shipment strategy and the possibility of damaged product will be higher due to the loading and unloading process in the warehouse.

3. Cross-Docking

Cross-docking process is the combination strategy to manage the disadvantage of using the previous strategies. Cross-docking takes place in a distribution docking terminal in the warehouse. The facility usually consists of trucks and dock doors on two sides with minimal storage space. This strategy does not requires to store the product in the warehouse, but the product will directly transferred to the outbound transportation after received from inbound transportation. By applying this strategy, the delivery lead time will be shorter and the company may achieve economies of transportation due to the consolidation process. Nevertheless, this strategy requires more advance system in order to have a good information system between company and the 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. Transportation is an important supply chain driver because products are rarely produced and consumed in the same location. Transportation is a significant component of the costs incurred by most supply chains (Chopra & Meindl, 2007). There are two components of transportation which are carrier and shipper. A carrier makes investment decisions regarding the transportation equipment (locomotives, trucks, airplanes, etc.) and in some cases infrastructure (rail), and then makes operating decisions to try to maximize the return from these assets. A shipper, in contrast, uses transportation to minimize the total cost (transportation, inventory, information, sourcing, and facility) while providing an appropriate level of responsiveness to the customer (Chopra & Meindl, 2007).

Supply chains use a combination of the several modes of transportation such as air transport, package carriers, trucks, rail, water, pipeline, and intermodal. Each of transportation mode will have its own advantages and disadvantages. In this research, the using of land transportation becomes the critical aspects. This research will elaborate the using of trucks as the mode of transportation process from plant or manufacturer to distributor. Trucking is more expensive than rail but offers the advantage of door-to-door shipment and a shorter delivery time. It also has the advantage of requiring no transfer between pickup and-delivery (Chopra & Meindl, 2007).

There are two truck load strategies in distribution process using trucks which are full truck load (TL) and less than truck load (LTL). TL operations have relatively low fixed costs, and owning a few trucks is often sufficient to enter the business (Chopra & Meindl, 2007). TL pricing displays economies of scale with respect to the distance traveled. TL shipping is suited for transportation between manufacturing facilities and warehouses or between suppliers and manufacturers. LTL shipments take longer than TL shipments because of other loads that need to be picked up and dropped off. LTL shipping is suited for shipments that are too large to be mailed as small packages but that constitute less than half a TL. Key issues for the LTL industry include location of consolidation centers, assigning of loads to trucks, and scheduling and routing of pickup and delivery. The goal is to minimize costs through consolidation without hurting delivery time and reliability (Chopra & Meindl, 2007).

2.2 Inventory Management

The inventory is important part of the company especially in dynamic condition and serve many destination. Inventory management deals with how to manage the availability of the inventory considering the cost that needed to ensure the availability of product in certain condition. Good inventory management is a careful balancing act between stock availability and the cost of holding inventory (Ballou, 2004). The cement product is classified as functional product. Thus the best strategy is to minimize inventory in order to achieve the lower cost.

The inventory condition often be used as the trigger to make replenishment. One of the parameter to calculate the replenishment time is using reorder point. Reorder point shows the stock criticality of the inventory. Moreover, reorder point can be used to determine when the company should make an order. Besides reorder point, this research will use stock criticality measurement which consider the ratio between inventory, both on hand inventory and in transit inventory, and demand along the lead time.

2.2.1 Vendor Managed Inventory (VMI)

With vendor-managed inventory (VMI), the manufacturer or supplier is responsible for all decisions regarding product inventories at the retailer. As a result, the control of the replenishment decision moves to the manufacturer instead of the retailer. In many instances of VMI, the inventory is owned by the supplier until it is sold by the retailer. VMI requires the retailer to share demand information with the manufacturer to allow it to make inventory replenishment decisions. VMI can allow a manufacturer to increase its profits as well as profits for the entire supply chain if both retailer and manufacturer margins are considered when making inventory decisions. VMI also helps by conveying customer demand data to the manufacturer, which can then plan production accordingly. This helps improve manufacturer forecasts and better match manufacturer production with customer demand (Chopra & Meindl, 2007).

Under VMI, on the other hand, the distributor provides the plant with access to its real-time inventory level as well as its data. In return, the plant takes the responsibility of managing the inventories at the retailer. That is, under VMI, the plant does not only need to take its own inventories into account while making inventory plans, but also the inventories of the distributor (Sari, 2008).

2.2.2 Measuring Product Availability

Product availability reflects a company's ability to fill a customer order out of available inventory (Chopra & Meindl, 2007). A stock out results if a customer order arrives when product is not available. There are several ways to measure product availability. Some of the important measures are as listed as follow.

1. Product fill rate

   Product fill rate is the fraction of product demand that is satisfied from product in inventory. Fill rate should be measured over specified amounts of demand rather than time. Fill rate is equivalent to the probability that product demand is supplied from available inventory.
2. Order fill rate

   Order fill rate is the fraction of orders that are filled from available inventory. In a multiproduct scenario, an order is filled from inventory only if all products in the order can be supplied from the available inventory. Order fill rates tend to be lower than product fill rates because all products must be in stock for an order to be filled.
3. Cycle service level (CSL)

CSL is the fraction of replenishment cycles that end with all the customer demand being met. A replenishment cycle is the interval between two successive replenishment deliveries. The CSL is equal to the probability of not having a stockout in a replenishment cycle. CSL should be measured over a specified number of replenishment cycles.

2.3 Supply Chain Visibility

Information visibility is the important aspect in the supply chain (Cristina, 2014). Information is used to generate the fundamental of decision making and the operational process both in the internal and external of a company. The best decision will lead to the profit of a company. Several actions that need to be done using the information are determining the best lot size for procurement, distribution policy, production process, warehouse, and retailer.

Information visibility helps to manage the information flow from the stakeholder in the supply chain. By managing the information visibility between points, the performance may increase. There are several aspects which can be improved in the performance of the supply chain.

1. Cost: includes distribution cost, inventory holding cost, stock out cost, shortage cost, backorder cost, and total cost. The calculation of cost become more precise and the probability of having loss during operation time will be less by applying the visibility in the information flow.
2. Quality: includes quality of supplier, internal quality, and external quality. The visibility of information will improve the cooperation among all the stakeholder. Thus, the quality of the product can be managed.
3. Service Level: on-time delivery, customer response time, product availability. The higher the service level of a company means the higher satisfaction of its customer.
4. Flexibility: there are five types of supply chain visibility which are product, volume, new product, distribution, and responsiveness.
5. Time: it consists of production lead time, time for developing a new product, cycle time, and responsiveness. The visibility of information will surely

decrease the time required by the process and it will be more effective and efficient.

2.4 Simulation

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

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

2.4.1 Simulation Model

Simulation, like most analysis methods, involves systems and models of them. There are three classification of simulation model according to Kelton, et al (2006).

1. Static vs. Dynamic

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

2. Continuous vs. Discrete

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

3. Deterministic vs. Stochastic

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

Among those three classification, this distribution of cement product is considered as dynamic model because the time will have contribution to the system. It is also classified as continuous model because the system will work continuously. Furthermore, the system have both deterministic and stochastic process.

2.4.2 Simulation using ARENA

ARENA is one of the computer software which can simulate the real system. ARENA simulation have both analytical and graphical model. The simulation using ARENA have several processes which will be mentioned as follow.

1. Collect the data input.
2. Fit the data into distribution.
3. Develop ARENA model.
4. Input the fitted data into the model.
5. Do the simulation.
6. Verification and validation.

ARENA offers a rich and deep hierarchy of several different modeling levels that can handle flexibility as needed to model some peculiar logic. This structure allows you to exploit the easy high-level modeling to the extent possible, yet allows you to drill down lower when you need to. And because all of this modeling power is provided by standard Arena modules, you’ll already be familiar with how to use them; to put them to work, you simply need to become familiar with what they do (Kelton, et al., 2006).

2.5 Previous Researches

There has been several researches with inventory control system issue. Below are the summary of several research that taken into references in this research.

Table 2. 1 Proceeding Research Comparison

	Previous Research			This Research
Title	*Penentuan Keputusan Pengiriman Berbasis Informasi Stock Criticality dan Segmentasi Waktu Kirim*	*Simulasi Sistem Distribusi Pupuk Urea In-bag Bersubsidi (Study Kasus Perusahaan Pupuk di Indonesia)*	*Simulasi Distribusi Produk Semen Dengan Skenario Kepastian Tenggang Waktu Pengiriman*	Simulation Study of Cement Distribution Considering Stock Criticality and Shipment Due Date
Author	Evi Nila Cristina	Stefan Adhie Nugroho	Winda Puspadimiati	Lala Ayu Kantari
Type	Undergraduate Research	Undergraduate Research	Undergraduate Research	Undergraduate Research
Year	2014	2016	2016	2017
Problem Formulation	determine the truck schedule to minimize the cycle time and determine the delivery priority based on stock criticality	determine the effect of dedicated loading line policy and segmentation of delivery time to cycle time and number of truck needed	determine the due-date certainty and its effect to on-time delivery, truck utilization, and packer utilization	how to generate the distribution policy that consider the stock criticality of the distributor and how its effect to the product availability, on-time delivery, and truck utilization
Method	Simulation with Arena	Simulation with Arena	Simulation with Arena	Simulation with Arena
Scenario	Using Stock to Demand Ratio to determine the delivery priority; differentiation of short, middle, and long route; the using of express line for short route.	Using Stock to Demand Ratio to determine the delivery priority; delivery time segmentation based on travel distance; the using of express line for short route.	reducing the probability of same day delivery from 15% to 5%; reducing probability of next day delivery from 45% to 25%; number of truck	Using Stock to Demand Ratio or Inventory Days of Supply to determine the delivery priority, reducing the probability of same day delivery from 15% to 5 %.
Parameter	Cycle Time Calculation; Truck Utilization; Service Level (Fill Rate)	Service Level (Fill Rate); Cycle Time; number of truck	Service Level (On-time delivery); Truck Utilization; Packer Utilization	Service Level (Product Availability); On-time delivery; Truck Utilization

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CHAPTER III
RESEARCH METHODOLOGY

This chapter explains about the methodology used in this research. It contains the phases of conducting the research. Generally, the research methodology contains observation and literature study, data collection, data processing, model building, scenario, data analysis and interpretation, conclusion, and recommendation. The flowchart of this research methodology is given as follow.

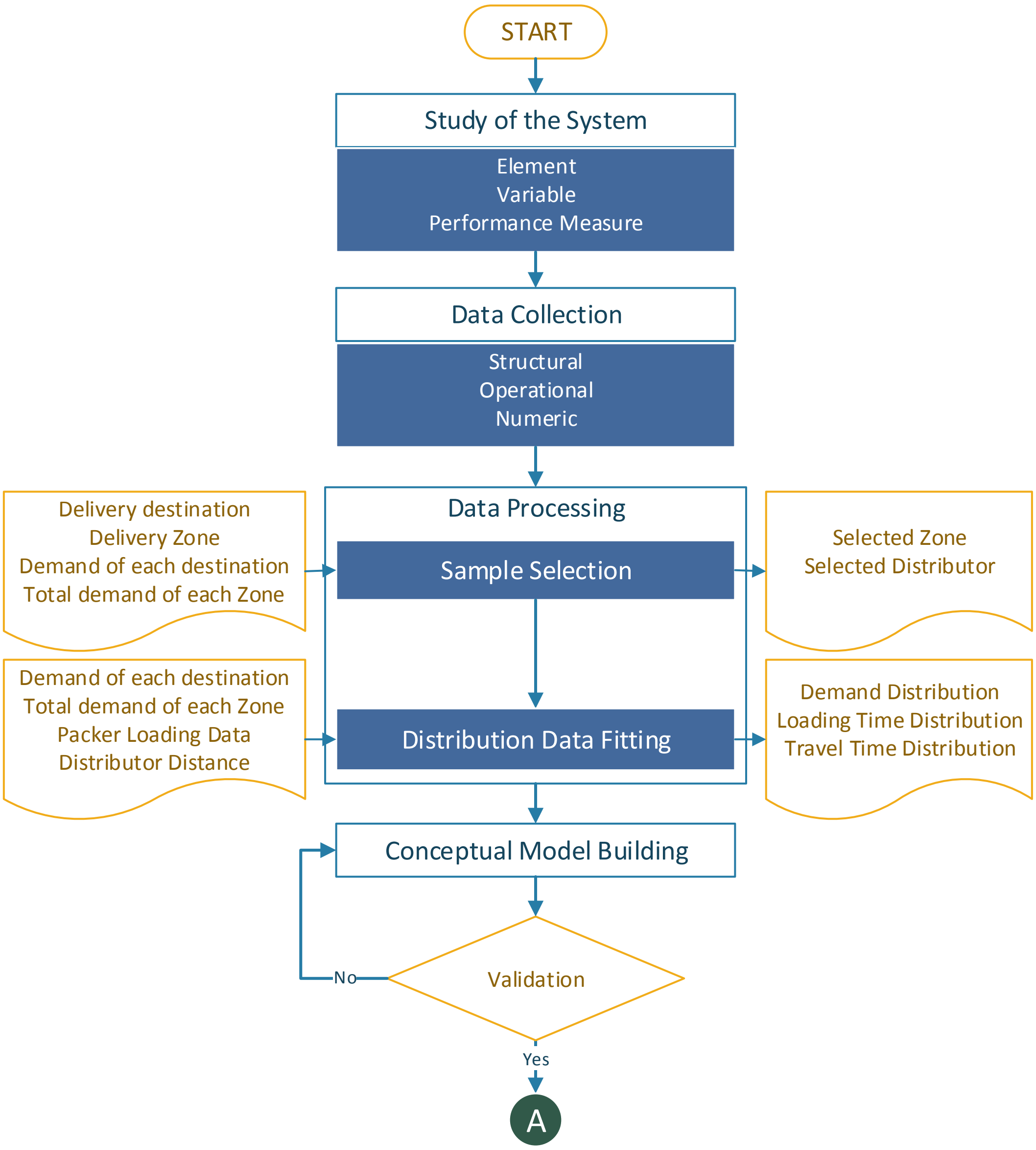

Figure 3. 1 Research Methodology Flowchart

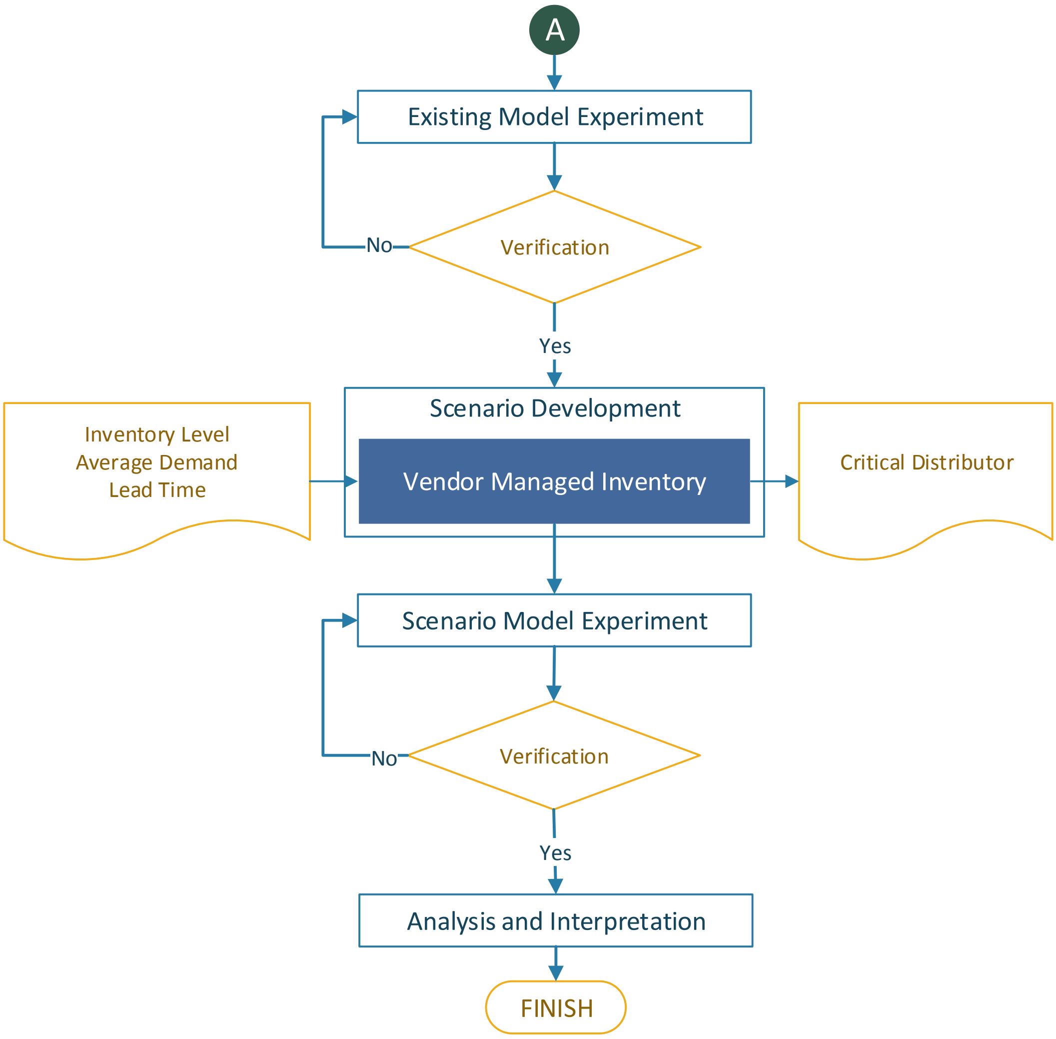

Figure 3. 2 Research Methodology Flowchart (continued)

The explanation of each process in the flowchart above is discussed in the following subchapters.

3.1 Study of the System

The four elements of a problem are (1) the decision maker, (2) the decision maker's objectives, (3) the performance measure for assessing how well the objectives have been achieved, and (4) alternative courses of action or decision variables for achieving the objectives (Daellenbach, 1994). In this research, the identification of the system is done by determining the elements, variables, performance measures, and the scenarios.

3.1.1 Element of the System

The element of the system are entity, resource, process, activity and control. Below are the description of those elements.

a. Entity

The entity is the delivery order. The delivery order is the required number of product. The product is in the form of 50 kg bags of cement. 50 kg bags is chosen because it becomes the current focus to push the marketing of the PT. X. The delivery order will be processed in the system. The required number of delivery order the transformed to the required number of truck.

b. Resource

The resources are truck, packer, and courier. The truck is divided into two type based on its capacity which are 10 tons or 200 bags of cement and 30 tons or 600 bags. Smaller truck is used to deliver the product to the short-distance distributor (less than 100 km) and the larger capacity is for the long-distance distributor. The total number of the truck is the combination number of both capacity types. There are no specific number for each type.

Moreover, the system will utilize 7 packers and each packers will have 5 loading line. The maximum capacity of loading line is 3 queuing number of the trucks. Thus, the loading line that already equal to the capacity will cause the delay or idle time for the truck. Each of the loading process will use 2 workers or couriers. The total available courier is 70 persons.

c. Activity and Process

The activity consists of the cycle of the truck. There are two main activities of the truck which are productive and non-productive. The productive or busy state includes value-added process and travel process. In contrast, the non-productive or idle state is the condition when the truck have to wait before it is used.

d. Control

Control is exercised by imposing something on the system in the form of inputs a set of decisions, or decision rules, or simply an initial state for the system that will affect some activities in the system and therefore the behavior of the system in desired ways (Daellenbach, 1994). The control of the distribution system for cement product are the rule applied to dispatch the truck and the rule applied to travel back to the plant after delivering cement product to the distributor. Furthermore, the number of the truck is also one of the control in this system.

3.1.2 Variable of the System

There are three variables related to the simulation study which are decision variable, response variable, and state variable. Decision variable is the variable that will be adjusted to get desired output. The changes in the decision variable will have a response or effect to the system, it is classified as response variable. The state variable is the state of each resource. Those variables are shown in the following table.

Table 3. 1 Variable of the System

Decision variable	Response variable	State variable
Dispatching rule Number of truck	Fill rate On-time delivery Truck utilization Inventory level Packer utilization Total delivery	State of the truck (busy/idle) State of packer (available/not) State of the courier (busy/idle)

3.1.3 Performance Measure

Besides distribution fitting, some of data that need to be processed in this stage are the calculation of the performance of the system which are product availability, on-time delivery, and the utilization of the truck.

a. Product Availability or Product Fill Rate

Product availability or product fill rate is one indicator of the service level in a company. It shows the ratio between stock out and total of release the order. The product fill rate is important to measure the service level of the manufacturer. The improvement model will success if the product availability or product fill rate is improved. Below is the formula to calculate product availability.

$$Fill\ rate = 1 - \frac{Stockout}{Total\ Release} \times 100\% \tag{3.1}$$

b. On-time Delivery

On-time delivery is the ratio between the deliveries on-time with the total delivery. This parameter will analyze the number of late delivery of the distribution process. The higher the value means the system is good. Below is the equation to calculate the on-time delivery.

$$On\ time\ delivery = \frac{number\ of\ delivery\ on\ time}{total\ delivery} \times 100\% \quad (3.2)$$

c. Truck Utilization

Utilization of the truck is the percentage ratio between productive time and total time of the truck activity from departing until back to the plant. The utilization will have two different point of views. Thus, this parameter will not stay alone, it will be used with additional parameter. The equation to calculate the utilization of the truck is shown in the following notation.

$$Truck\ Utilization = \frac{Productive\ time}{Productive\ time + idle\ time} \times 100\% \quad (3.3)$$

3.2 Data Collection

The first process is collecting the data. Data collection phase is carried out to capture the existing system. The data are divided into three types which are data structural, data operational, and data numeric. Below are the list of the data obtained from the manufacturer and the calculation.

Table 1. 1 List of Data

General	Manufacturer	Distributor
Data Structural		
Types of Product Transportation Mode Number of Truck Distribution Mechanism	Manufacturer Location Number of Loading Packer Number of Loading Line	Distributor Location Number of Distributor
Data Operational		
Dispatching Rule Truck Activity	Dispatching Schedule	Time Window
Data Numeric		
Speed of Truck Distance of Distributor Travel-Backhaul Time	Demand Rate Loading Time Loading Line Capacity	Consumption Rate Unloading Time Inventory Level

The data structural, data operational, and data numeric needed are obtained from the previous research which was conducted by Puspadimiati (2016). Several data need to be adjusted to fit for this research including the number of truck, number of distributor, dispatching rule, and inventory level.

3.3 Data Processing

The next step is processing the data. It consists of several steps which are sample selection, distribution data fitting, and performance measures.

3.3.1 Sample Selection

In the real system, PT.X serves more than 1000 destinations including distributor and other markets. This research will take 75 clusters from distributors that contribute to the demand of PT.X. The selection of the distributor are based on the largest demand and the total demand proportion of long distance and short distance distributor. The proportion in the real condition are 70% of short distance distributor and 30% of the long distance distributor. The flow chart of the sample selection is shown in the **Figure 3.3**.

3.3.2 Distribution Data Fitting

The next step after determining the distributor is conducting the distribution fitting. This process is aimed to get the input for simulation model. The distribution of the data is generated using software Input Analyzer in ARENA. Each of the data that is required to be the input of simulation is translated to a distribution. There are several data that need to be fitted which are the delivery order request from each distributor, the loading time in each packer, the preparation process before departing, the travel time from plan to each destinations, the unloading time in the destinations, and the consumption rate in each market.

3.4 Initial Model Experiment

After all the data is being processed, the model of the initial system can be build. The simulation model is generated using the distribution data of the previous calculation. The conceptual model is necessary to be drawn before it is applied in the ARENA software. It is the simplification of the modules or the processes in the simulation. From the several methods that can be used to present a conceptual model, a method often used the Process Flow Diagrams.

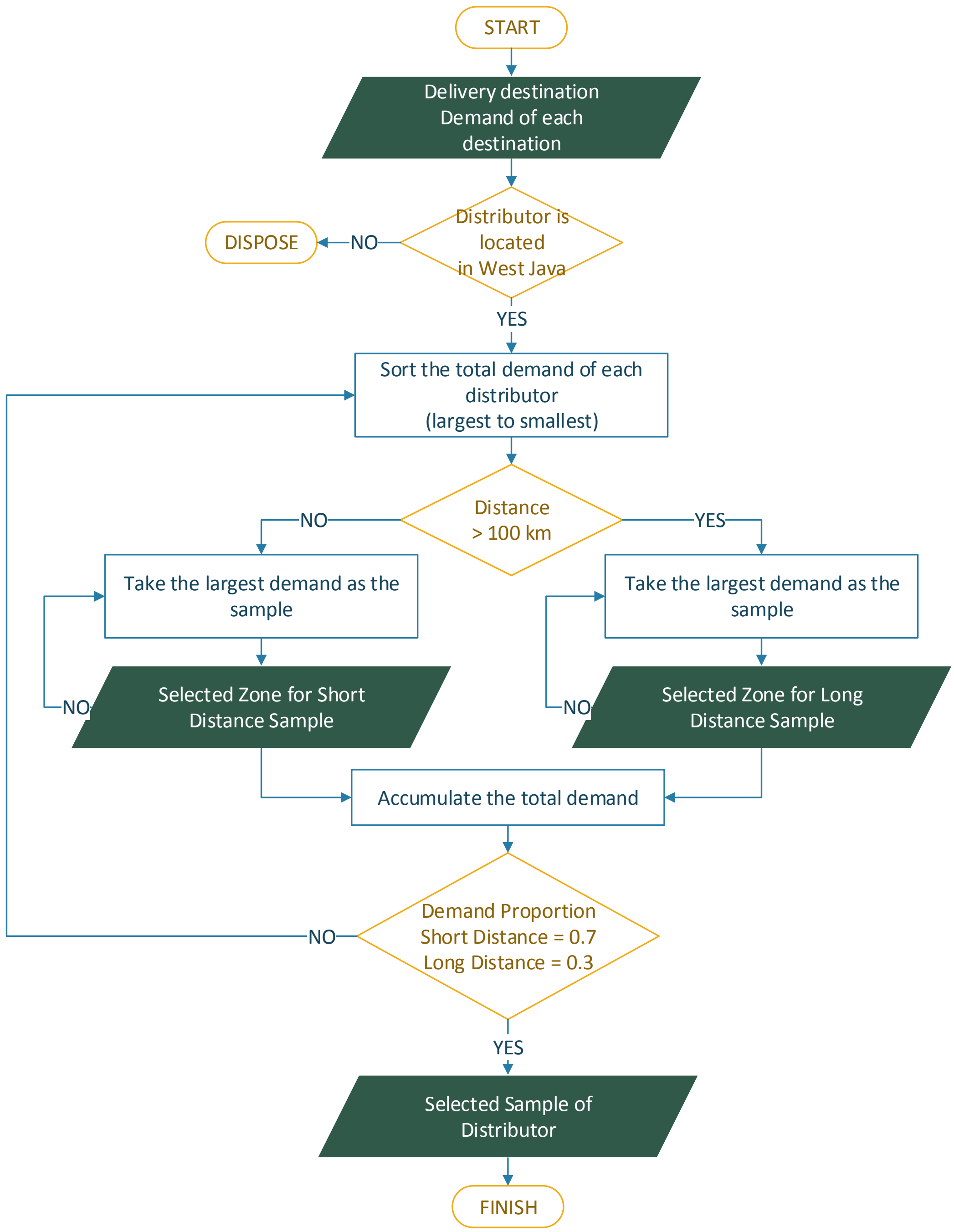

Figure 3. 3 Flowchart of Determining the Sample of Delivery Destinations

3.5 Verification and Validation

The following step after generating the model is ensure the simulation model already valid and verified. Verification is needed to compare the simulation model with the conceptual model. It consists of two processes. The first verification is done to ensure that there are no error in the model by conducting debug check in the software. The second is to check the logic and the mathematical calculation in the model are already correct.

The validation of the model is done by comparing the result of simulation model with the existing data from the real system. In this case, the validation process is done using the demand data from the distributor. The comparison is done using t-test. If the result of the test showing that there are no significant different between the real system and the model, it can be concluded that the simulation is already valid and can be applied in the research.

3.6 Scenario Model Experiment

The development of the scenario become the next step after the model is verified and valid. The scenario is generated in the modules by considering the stock criticality of each distributor. By applying this scenario, the result of the product availability, the on-time delivery, and the truck utilization are predicted to be better than the initial model.

3.6.1 Dispatching Rule

The existing condition uses Earliest Due Date as the trigger of delivery order. This rule does not consider the criticality of the distributor. One of the method to optimize the delivery method is by using Stock to Demand Ratio. Stock to Demand Ratio (SDR) is able to capture the need of each distributor and decide which one is more critical than others. Thus by calculating this ratio, the plant will able to determine the priority of the distributor that should be replenished first.

In this improvement model, there is an additional calculation process which is stock to demand ratio.

1. Stock to Demand Ratio

   Stock to Demand Ratio is the ratio between inventory level in each distributor and the average demand of the distributor in the delivery lead time. In order to calculate SDR, the system need to calculate inventory both on-hand and in-transit inventory and also the lead time of delivery. Below is the formula for SDR.

$$SDR = \frac{onhand\ inventory + intransit\ inventory}{average\ demand \times lead\ time} \tag{3.4}$$

3.7 Data Analysis and Interpretation

This part will give the analysis of the output from ARENA software in the previous phase. The analysis is done for both initial and improvement model. The comparison of both model can be done by determining the parameter of the model which are product availability, on-time delivery, and truck utilization. Each of the parameter will be analyzed separately in different sub chapter. After all, this research will give recommendation based on the output of the simulation.

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CHAPTER IV
DATA COLLECTION AND DATA PROCESSING

This chapter includes all processes in order to prepare data to conduct the research. Those processes are data collection, data processing, as well as scenario generation and experiment.

4.1 Data Collection

As mentioned in the previous chapters, there are several data required in this study. Below are the detail explanation for some data which are distribution process mechanism and truck cycle activity.

4.1.1 Distribution Mechanism

The mechanism of distribution is obtained from the policy and regulation from the manufacturer. It explains the general rules for the distribution system starting from assigning the truck to packer until the truck complete the delivery process then return back to the plant. In the existing condition, the truck will be assigned to the packer after the delivery order received in the system. There are three different time of releasing the order, at 10:00, 14:00, and 16:00. The truck is assigned into the packer based on the availability of the loading line in the packer. The maximum number of queuing in each loading line is three trucks. If the queuing in the loading line already maximum, the truck will be assigned to the next line. This policy is aimed to reduce the unbalance number of queuing in the loading process. The working hours for the packer is 24 hour a day and 7 days in a week.

After being loaded, the truck will be dispatched to the destination. The travel time for each truck will be different, it depends on the distance of the destination. The truck then check the availability of unloading line of the distributor. If the arrival of the truck in the destination exceed the time windows which is 08:00 up to 17:00, the truck need to wait for the next day. This condition makes the truck has longer time than the expected, so then, it may cause the crisis of the truck in the plant.

4.1.2 Truck Activity Data

Truck activity data is the fundamental of the system. It is the main input for developing the model. Truck activity includes assigning the truck after getting the order until the truck travel back to the plant after delivering their load. The activity also includes the duration of each process. The activity is divided into the productive time or busy and non-productive time or idle. By determining the busy and idle state, the utilization of the truck can be calculated.

4.1.3 Delivery Order Data

Delivery order data is the number of product requested by the distributor. Furthermore, it also includes the date and time of releasing the order, expected due-date, destination, and the actual arrival date of the product. The number of product for each distributor will be used as the input for the system and the proportion of delivery due-date will be used for the validation process. Moreover, the due-date is the input to calculate the on-time delivery ratio and it will be adjusted later in the scenario.

4.1.4 Operational Packer Data

Another data that is required as the input for the system is the data from the packer. The data includes the number of packer, the capacity of loading line, and the loading time. These data are used to determine the activity of the truck before dispatching process and the capability of the plant to fulfill the required demand.

4.1.5 Delivery Process Data

The main distribution process is the delivery process. It requires the movement of the product from supplier to customer. The delivery process data are speed of the truck, distance from distributor to the plant, and the travel time rate. The delivery process includes the travel time from plant to the destination and the backhaul process. Both of the process are assumed to have same distribution rate. The uncertainty of the delivery process comes from the road condition, traffic jam, and the speed of the driver. This research use 75 distributor as the sample. Then, the delivery process data will be obtained for all the destinations.

4.2 Data Processing

This subchapter consists of the calculation and the approach to determine the input for the model. It includes sample selection, truck cycle activity, and replenishment of paper bag, delivery order release time, and number of truck calculation approach.

4.2.1 Sample Selection

The simulation model uses the sample of the distributor to approach the real condition. There are 75 distributor selected in this research. Below are the demand data of all distributors.

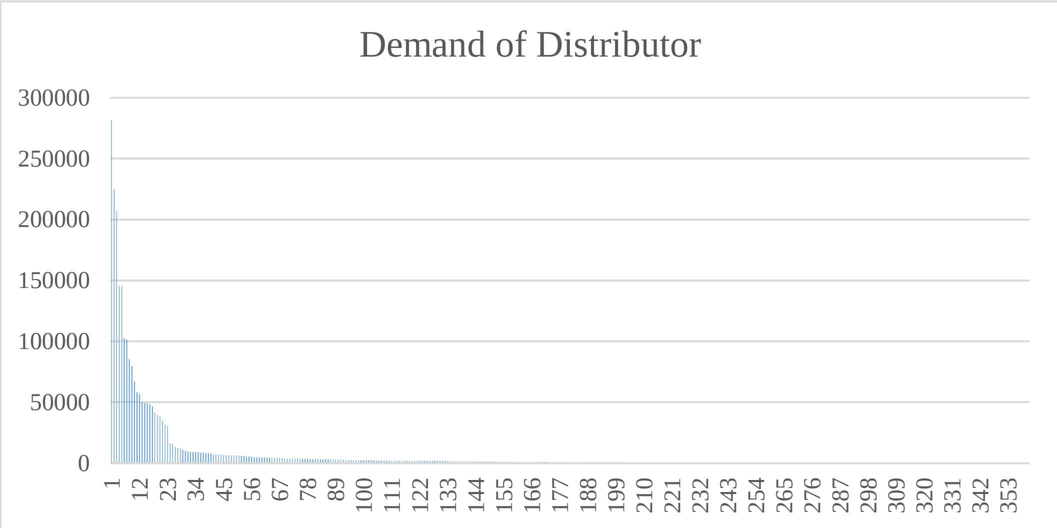

Figure 4. 1 Demand of Distributor Graph

The graph shows the demand of the distributor from the largest to the smallest. This simulation study will not use distributor with the largest nor the lowest total demand to reduce the variation of the input.

4.2.2 Truck Cycle Activity

The activity of the truck and process in the system is shown the following figure. The truck in the existing system will be assigned based on the daily demand rate from the distributor. The black truck shows the unproductive or idle time of the truck and the orange color shows the value added process or productive time of the truck.

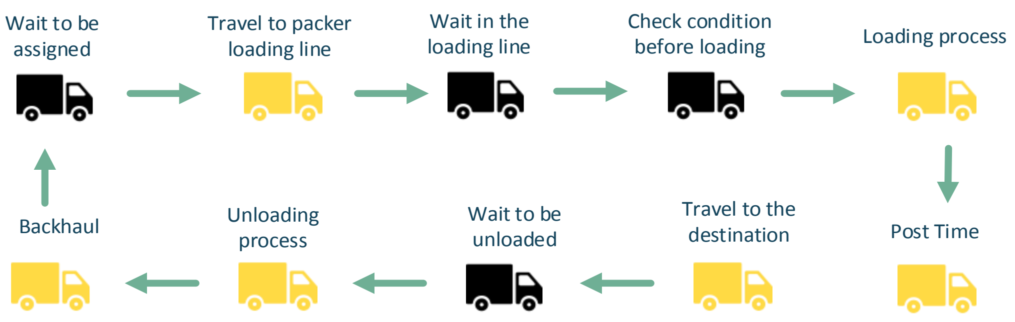

Figure 4. 2 Truck Activity Flow

The activity of the truck is divided into several processes following the flow diagram above. Below are the explanation of each phase.

1. Wait to be assigned

   The truck is ready in the plant and waiting to be assigned to deliver the product. It means that each delivery order will be processed directly while the truck is available in the plant. The delivery order is released 3 times in a day which are at 10:00, 14:00, and 16:00.

2. Travel to packer loading line

   The truck will directly assigned to the packer after receiving an order from the system. There are total 7 packers available for packing 50kg bag of cement. Each packer has 5 loading line. Truck will travel from the gate to the packer using same travel time distribution for all the packers. The distribution is 0.999 + EXPO (116) minutes.

3. Wait in the loading line

   The truck will be assigned to the loading line with smallest number busy resource. The policy of the plant will assign maximum 3 trucks in each loading line. Smallest number busy means the truck will not enter the line if the queuing in the line already 3 trucks. Then the truck will continue to check the other available line.

4. Check condition before loading

   There are several condition need to be checked before the loading process is started. The system need to check the availability of the packer, availability of paper bag, and the availability of loading line. The truck will be load if the current condition of packer is not doing any activities or in the idle state. Furthermore, the availability of the paper bag in the packer should be more than the required load of the truck. The loading process is done by two courier, then the truck need to check the availability of the courier before it is loaded.

5. Loading process

   The loading time are different for each plant. Below are the loading time distribution in each loading packer.

Table 4. 1 Loading Time Distribution of Each Packer

Packer	Loading Time Distribution
P2	4 + LOGN (27.1, 38,6)
P3	0.999 + EXPO (23.6)
P4	0.999 + LOGN (25.8, 23)
P6	0.999 + LOGN (22.4, 18.5)
P7	0.999 + LOGN (20.6, 16.7)
P8	4 + LOGN (21.1, 25.2)
P11	5 + EXPO (18)

6. Post Time

   After being loaded with cement products, the truck will need some preparations before departing. It includes to cover the truck's trunk. Post time follows Normal distribution with average 27.7 minutes and standard deviation 15.7 minutes or NORM (27.7, 15.7) minutes.

7. Travel to destination

   The travel duration from plant to distributor is different based on the distributor distance and the velocity of the truck.

8. Wait to be unloaded

   The arrival of the truck in the distributor have to be inside the range of time windows. In this research it is assumed to have time window from 08:00 to 17:00. The arrival of the truck outside the time window will not be proceed, hence, the truck will stay and wait for the following day. Moreover, the truck also need to wait until the unloading line in each distributor is available or there are no preceding truck in the unloading station.

9. Unloading process

The unloading time in all distributors are assumed to be equal following Triangular distribution with minimum 15 minutes, most likely 17.5 minutes, and maximum 20 minutes or TRIA (15, 17.5, 20) minutes for truck with capacity 10 tons. The truck with capacity 30 tons will follow TRIA (22.5, 25, 27.5)

10. Backhaul

    Backhaul process is the travel duration after the truck being unloaded in the distributor. The backhaul duration is assumed to follow same distribution with travel duration.

4.2.3 Replenishment of Paper bag in Sub-Warehouse

Each packer will have each sub-warehouse that has function to keep the paper bag before it is loaded to the truck. The policy of the plant is to fulfill the required demand for two days. The replenishment of paper bag in the sub-warehouse is done while the availability of the paper bag is less than the required paper bag for two days. Below is the quantity of paper bag for each replenishment.

Table 4. 2 Replenishment Quantity of Each Packer

Packer	Replenishment Quantity Distribution
P2	NORM (2.21e+004,8.16e+003)
P3	NORM (3.11e+004,2.03e+004)
P4	3e+003 + EXPO (1.26e+004)
P6	6e+003 + EXPO (1.82e+004)
P7	NORM (2.49e+004, 7.11e+003)
P8	4e+003 + EXPO (2.1e+004)
P11	4e+003 + EXPO (2.49e+004)

4.2.4 Delivery Order Release Time and Truck Capacity

The delivery order (DO) is released three times a day which is in 10:00, 14:00, and 16:00. In the existing condition, the delivery order is processed based on the earliest due date of the order. Due to the limited number of the truck, the policy of PT.X is focused on the short distance distributor in the morning, so then the truck will arrived back in the plant in the same day to do another delivery. The long distance distributor order will be assigned in the 14:00 and 16:00 along with another short distance distributor order.

Table 4. 3 Delivery Order Release Time

Classification	Truck Capacity	DO Release Time		
		10:00	14:00	16:00
Short distance distributor	10 tons (200 bags)	30%	70%	
Long distance distributor	30 tons (600 bags)	0%	100%	

4.3 Conceptual Model

This subchapter describes the conceptual model of the initial and improvement system. A conceptual model consists of three categories of information about the simulation and the intended application(s), the simulation context, simulation concept, and simulation elements (Liu, et al., 2011). Below is the conceptual model of initial and improvement model.

4.3.1 Conceptual of Initial Model

The conceptual model of this research simulation is shown in the following flow diagram. Further explanation about following figure is explained in the following points.

1. Demand rate

   Each distributor will generate demand for each day, this is become the input of the system. The existing system will release the order based on the request from the distributor.

2. Truck required of each destination calculation

   The system is continued by updating the demand in each distributor. The demand is generated based on the distribution. After that, the system will calculate the required number of truck to deliver all the demand. The calculation will follow equation below.

$$Number\ of\ truck = \left(\frac{Demand}{Load}\right) \qquad (4.2)$$

3. Check availability of the truck

   The assigned delivery order will be assigned if the truck is available in the plant. The order have to wait for the truck to come back to the plant.

4. Assign truck to packer

   The delivery order then received by the truck and being proceed in the packer. The assignment for the packer is calculated based on the capacity of each packer.

5. Check availability of loading line

   The availability of loading line is checked before the truck enter the line. The policy of the plant is to have maximum 3 queuing. Then, the truck is adjusted to fulfill the next line if the queuing is already 3 trucks.

6. Check availability of packer

   The truck need to check the availability of the packer, if the packer is busy then the truck need to wait until the current process is done.

7. Loading process

   The loading process is different for each packer. The loading process is done after all the condition are satisfied.

8. Post time

   The post time process is required after the loading process. It is includes covering the truck and other preparation before departure.

9. Travel time

   The travel process is the in transit process from the plant to the distributor. The time to travel is different for each destination based on the distance and the speed of the truck.

10. Check time windows

    After the truck arrived in the distributor, the truck need to check the time windows. If it still outside the time windows then the truck need to wait until it is open in the next day.

11. Check availability of loading line

    The availability of unloading line also being checked, in this model, the unloading line of each distributor will only accommodate for 1 truck.

12. Unloading process

    The unloading process of the truck is divided into 2 types based on the capacity of the truck. The 30 tons truck will have longer unloading time.

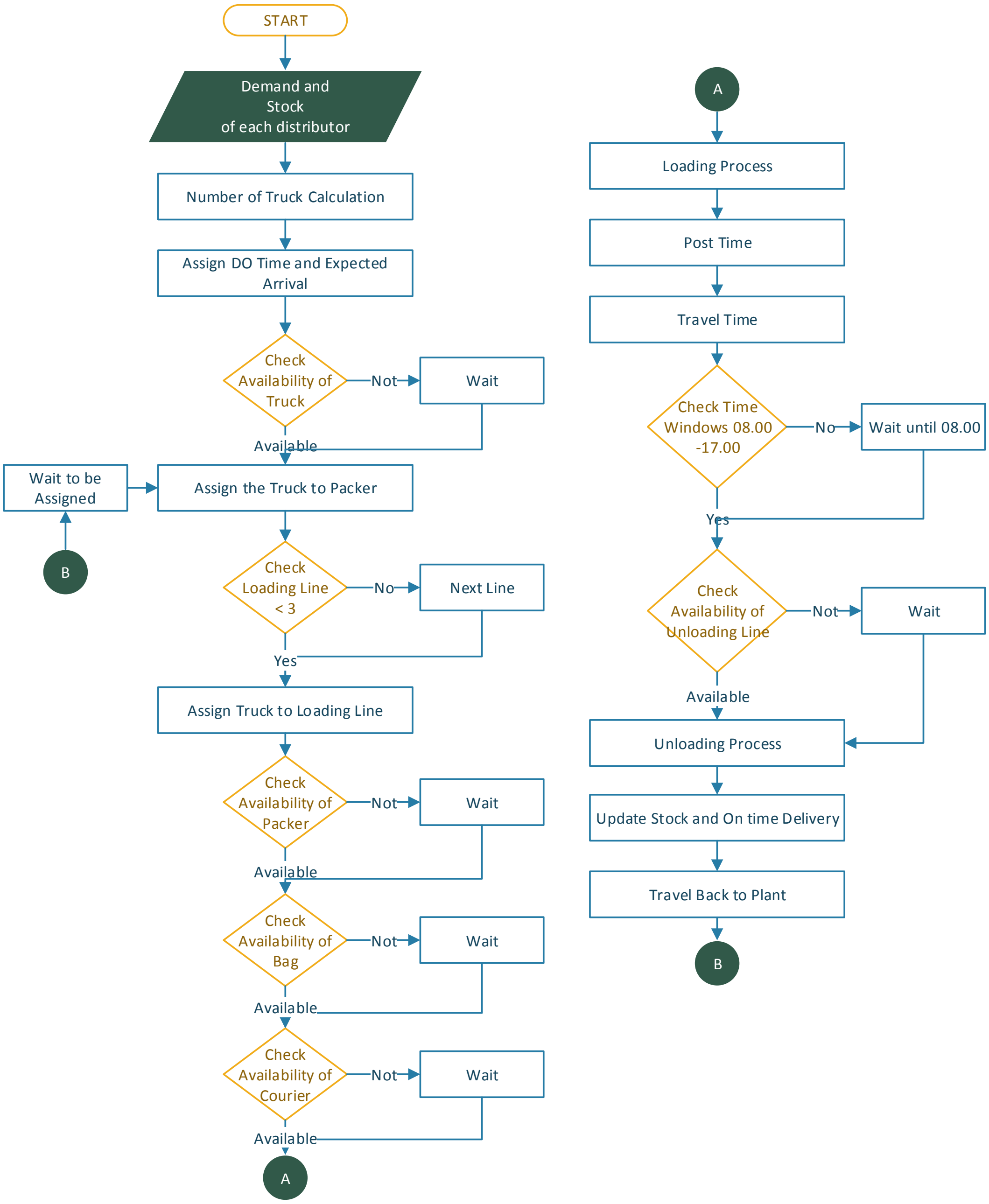

Figure 4. 3 Initial Conceptual Model of Distribution Process

13. Inventory update

    The inventory or the stock of each distributor is updated after the unloading process.

14. Backhaul

    After all process in the distributor are done, the truck is delivered back to the plant and wait to be assigned for the next delivery. It is called backhaul process, the time required is following the same distribution with travel time.

Besides the main simulation process, there are several requirements sub module simulation to update the variables in the specific time. Those updaters will be shown in the following list.

1. Working Hours Updater

   Working hour updater will update the simulation time in each day. This updater aims to get closer to the real system. The hours in the simulation will be reset back to 1 after reaching 24 hours. The conceptual model of this updater is shown in the following figure.

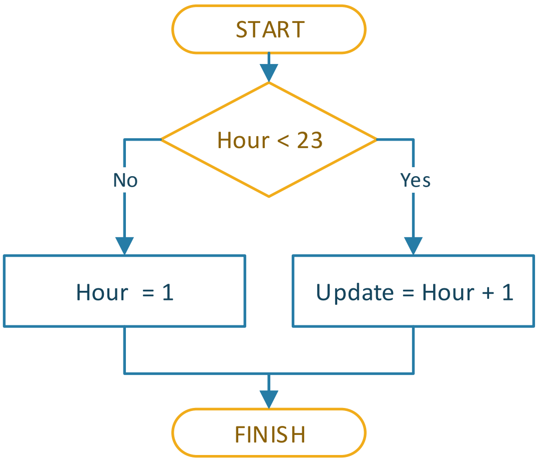

Figure 4. 4 Working Hours Updater

2. Working Day Updater

   Working day ensures the simulation process and other distribution process in the simulation is conducted in the working days only. The working days will restart to value 1 after reaching 5. Thus if the value more than 6 it will be back to 1 again. It shows the working days only from Monday to Friday. The conceptual model of this updater is shown in the following figure.

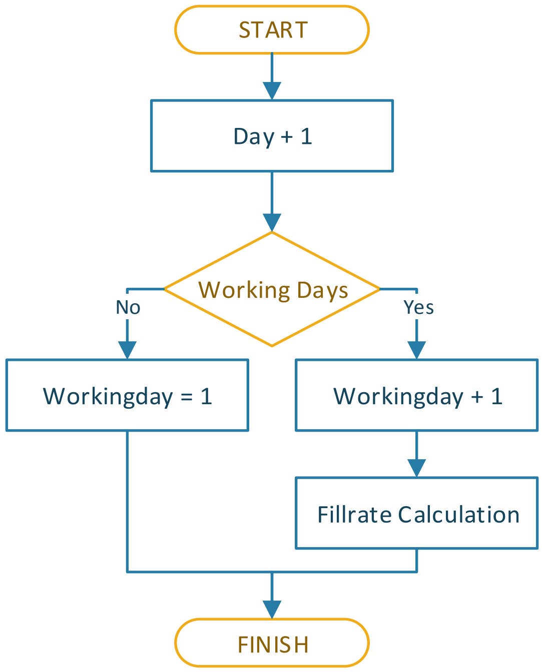

Figure 4. 5 Working Day Updater

3. Distributor Stock Updater

Besides working hours and working days, it is necessary to update the level of inventory in each distributor. The inventory in the distributor will automatically increase after the unloading process is done. Furthermore, the stock will decrease because of consumption rate. This updater aims to show the level of inventory in each distributor. The conceptual model of this updater is shown in the following figure.

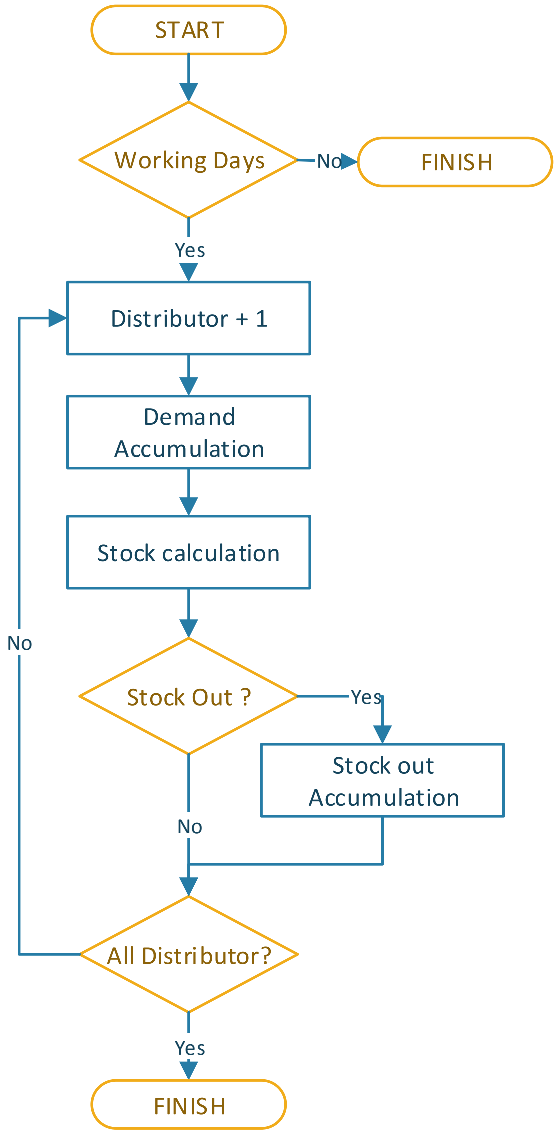

Figure 4. 6 Distributor Inventory Updater

4. Daily Demand Updater

   The demand rate of each distributor is updated daily and it has no demand while not in the working days. Below is the logic to update the demand.

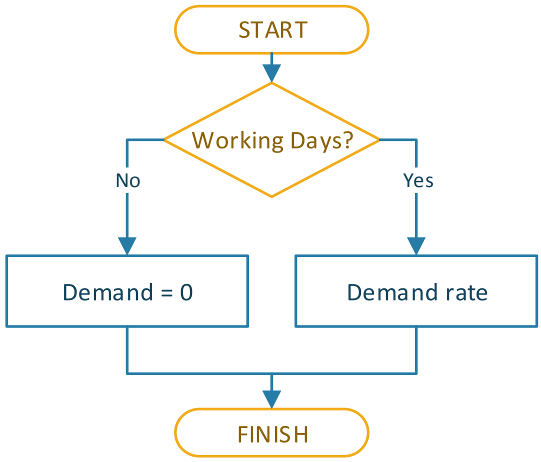

Figure 4. 7 Daily Demand Updater

5. Packer Replenishment

The packer paper bag will be replenished if the remaining stock is less than two days demand. The replenishment of the packer will follow flow chart below.

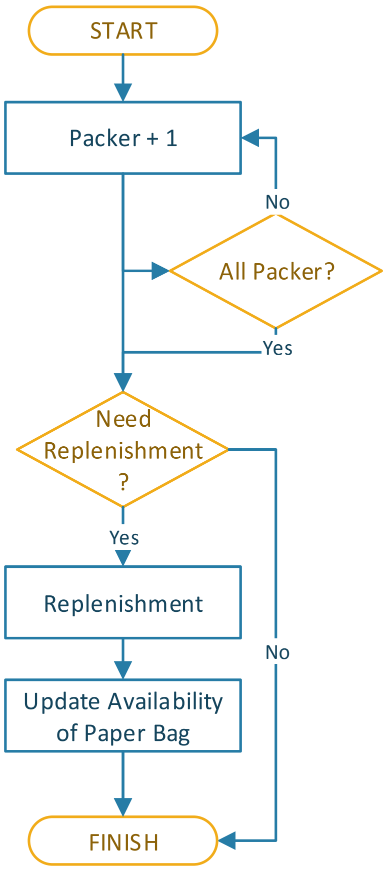

Figure 4. 8 Packer Replenishment Flow Chart

4.3.2 Conceptual of Scenario Model

The scenario model will change the dispatching rule of the system. The current system which applied Earliest Due Date method will be changed into Stock Criticality method. The conceptual model of the improvement method is follow flow chart below.

The different part of the model is in the calculation of the Stock to Demand Ratio before assigning the truck. Below are the explanation of the different part.

1. Stock update
   Before starting the delivery process, the system will update the stock of each distributor. The current on hand available in the distributor will be updated by the consumption rate.
2. Calculate stock to demand ratio
   Then the stock to demand ratio is calculated based on the current inventory condition of each distributor. The lead time obtained from the average travel time for each distributor.
3. Sequence the ratio
   The ratio is sequenced, the lower ratio will be assigned first. It means that the critical distributor will be replenished first.
4. Assign quantity and number of truck required
   The quantity to be delivered is calculated following the equation below. After the quantity is determined, the number of the truck required to deliver the quantity is determined using equation (4.2).
   $$Quantity = (Demand_i \times Lead\ Time_i) - (In\ Transit_i + On\ Hand_i) \quad (4.3)$$
5. Update in transit inventory
   The in transit inventory is updated after the truck is assigned to the delivery order time.

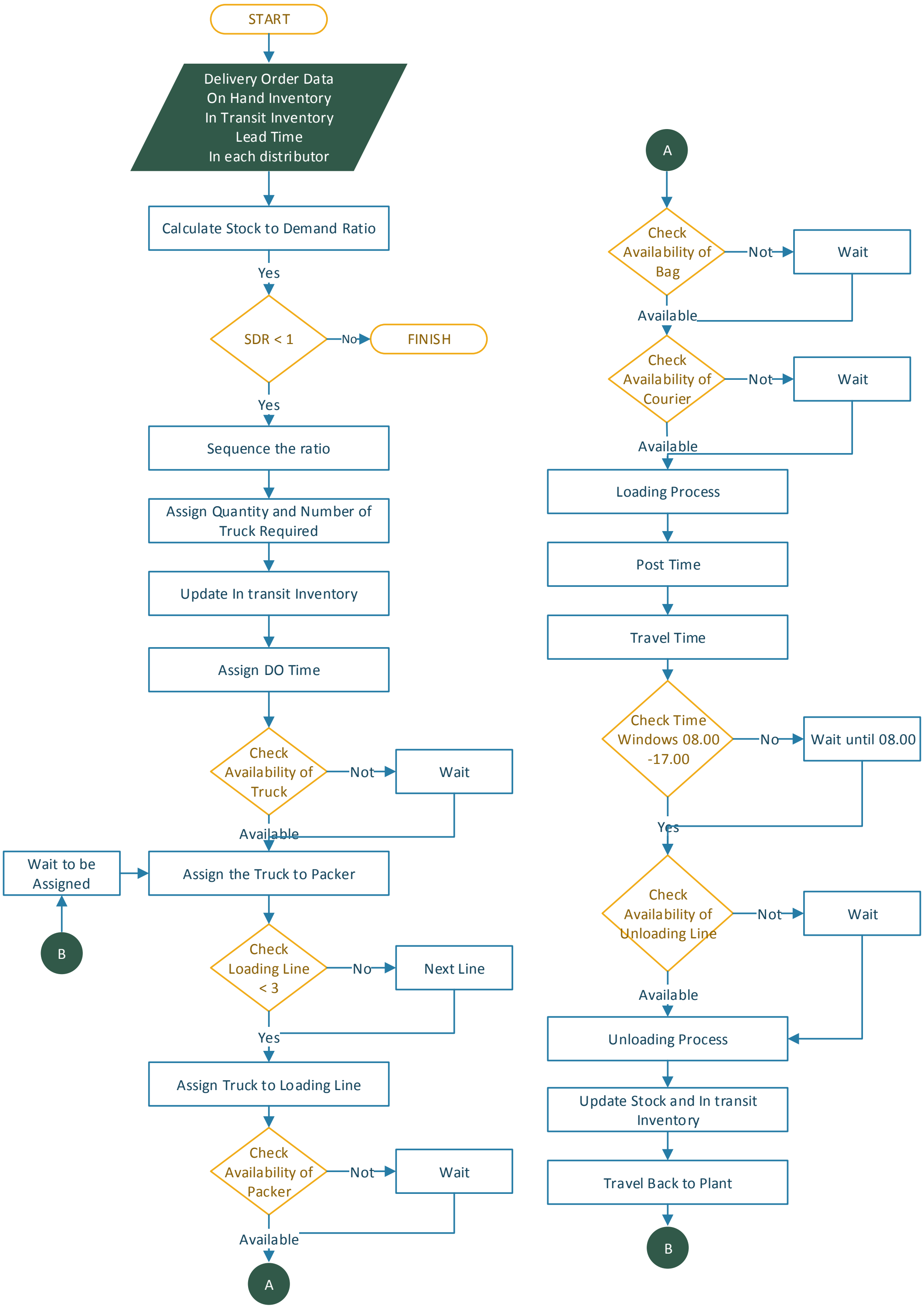

Figure 4. 9 Conceptual Model of Improvement Model

4.4 Model Building

After all the input and parameter are determined. The next step is generating the model of the simulation. The model is developed using ARENA Simulation software. In this research, the entire system in the plant will not fully generated. The scope of the simulation is limited to the main distribution activity, but the regulation and policy will be applied following the real system.

The simulation is generated using ARENA 14 software, the simulation time is for 1 year or equal to 365 days. 1 day in the simulation equal to 24 hours and the working days is from Monday to Friday.

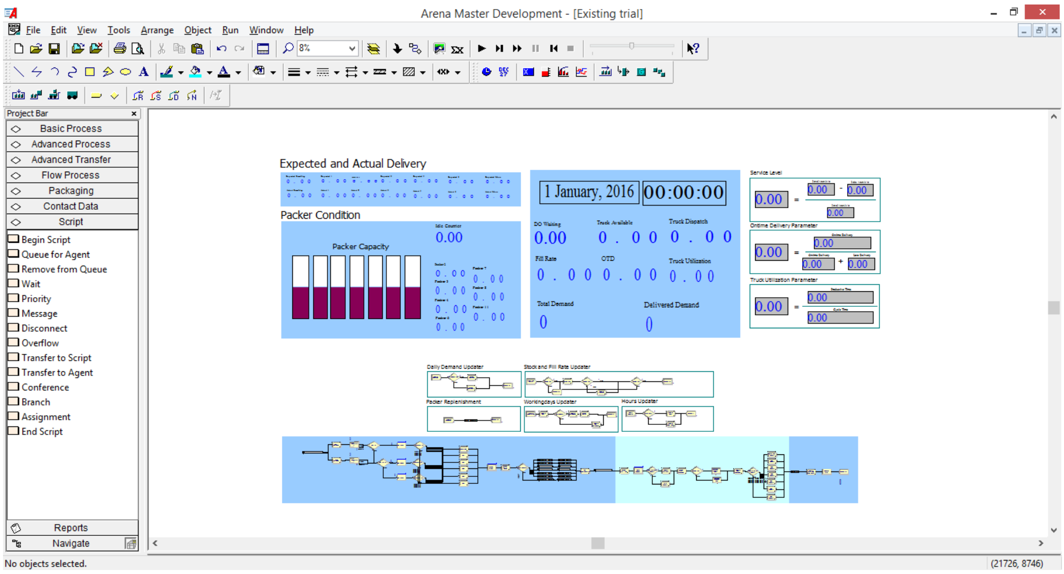

Figure 4. 10 Overall Simulation Interface

4.4.1 Distribution System Model

The model is consists of several parts including the process in the plant and the process unloading the cement product in the distributor. Below are the complete explanation of the model.

4.4.1.1 Dispatching Rule of Initial Model

The dispatching rule of the initial model is based on the earliest due date. The rule is started by the demand of each distributor. Then the plant will classified the demand into two classification of distributor which are short distance or long distance distributor. The short distance distributor will have truck capacity 200 bags, while the long distance distributor will have 600 bags capacity.

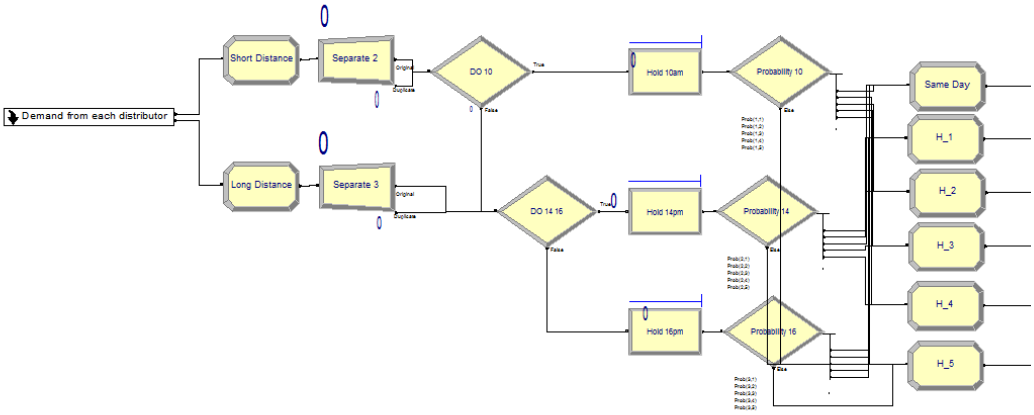

Figure 4. 11 Dispatching Rule Model of Initial System

After the number of truck required is determined, the next step is to assign the order in the delivery order release time. The 30% of the short distance will released at 10:00 and the rest is divided into 14:00 and 16:00. All the long distance distributor will be released at 14:00 and 16:00. Each of the releasing time will have different expected arrival or the due date of the delivery. In this research, the due date is same day until the next 5 days. The rest of the day is assumed to have higher random result.

4.4.1.2 Dispatching Rule of Improvement Model

The dispatching rule of the improvement model is the calculation of stock to demand ratio. The model is shown in the following figure.

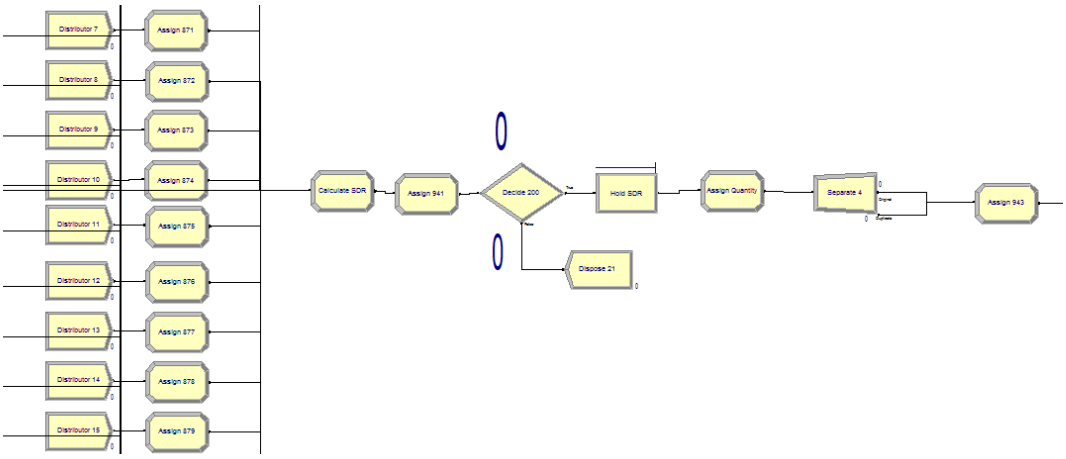

Figure 4. 12 Dispatching Rule Model of Improvement System

The system is started by calculating the stock to demand ratio for all the destination. Then remove the destination which has larger than 1 SDR value. After that, the SDR will be sort from the smallest number to the largest number. The quantity of delivery and the required number of the truck is calculated in the assign module. After the truck is generated, it will divided into three delivery order release time following the same policy for short and long distance distributor.

4.4.1.3 Packer Loading Line Assignment

After the delivery order is released, the truck will be assigned to deliver the request. The delivery order will have to wait for the truck if the current number of the truck is limited. The truck then assigned to the packer. There are 7 packers and each packer will have different characteristics.

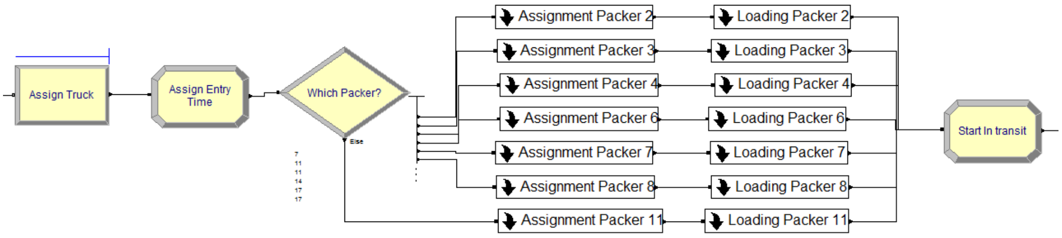

Figure 4. 13 Packer Loading Line Assignment Model

The assignment to the packer is determined by the probability. Then after the truck is arrived in the packer, it will be assigned to the packer line. The truck need to wait for their time to be loaded in the loading line.

4.4.1.4 Loading Process

Before entering the loading process, the truck need to check the availability of the packer, the availability of the paper bag, and the availability of the courier. The loading process will be proceed if all the condition are satisfied.

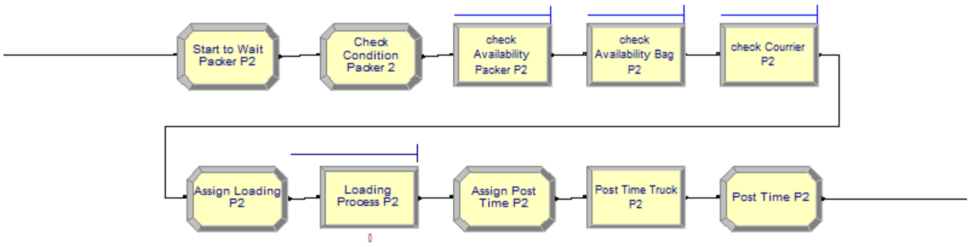

Figure 4. 14 Loading Process Model

The loading process is different for each packer. After the loading process, there is a post time process. It is the finishing process after the truck is loaded with the cement product.

4.4.1.5 Unloading Process

The unloading process in the distributor has to meet several condition which are the time is between the time windows and the unloading line in the distributor is empty.

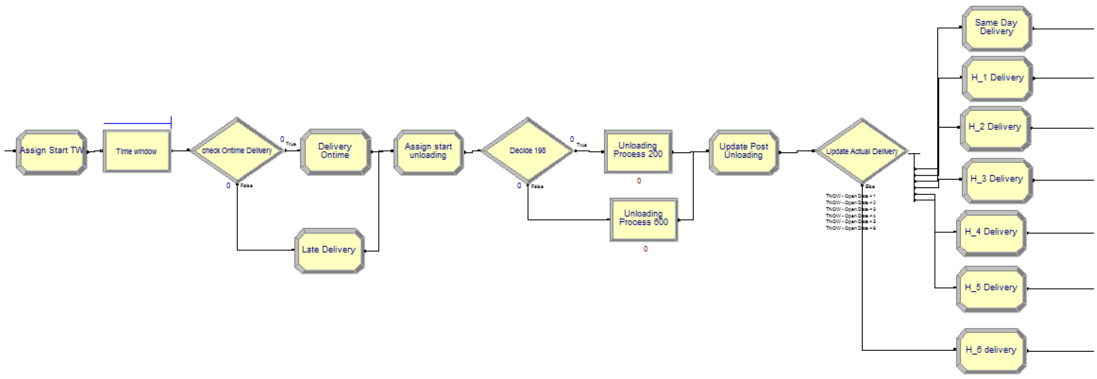

Figure 4. 15 Unloading Process Model

After all the condition are met, the unloading process can be done. The system then update the on-time delivery, the stock of the distributor, and the actual arrival of the truck. The next is the backhaul time of the truck. The truck then arrived at the plant and waiting to be assigned for the next destination.

4.4.2 Warm-Up Period Calculation

The distribution system is a system that runs continuously for the whole year, therefore the system can be categorized as non-terminating condition. It is necessary to set warm-up period of the simulation model. Determination of the warm up period is done to eliminate the random behaviors that does not describe the actual system at the beginning of the simulation.

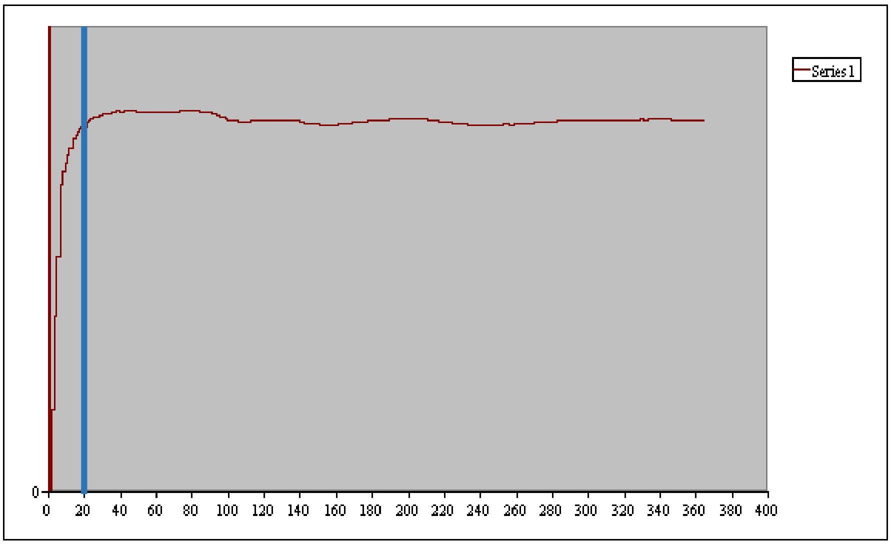

Figure 4. 16 Service Level Plot from Simulation

At the beginning of the simulation all packing plant has no stock. This condition results in the high number of stock out and lower value of service level in the beginning. This condition is shown by the service level plot above. The plot depicts the cumulative value of service level over the time. It shows the high incremental value in the beginning of the simulation. Then it continues to be more constant after 20+ days of simulation. Based on Law & Kelton, 2000 it is necessary to add safety factor about 20%-30% of the warm-up period. Thus, the required warm up period is 30 days.

4.4.2 Number of Replication

The calculation of replication number is performed before the validation process. This process is aimed to prove that the current number of replication is already represent the actual condition. The replication is done to get the closer result with the actual condition because the simulation process will have random output. The current simulation is done with 5 replication. Below is the fill rate result of the simulation.

Table 4. 4 Fill Rate of the Initial System

Replication	Fill Rate
1	0.696
2	0.694
3	0.694
4	0.696
5	0.693
Average	0.69
Std Dev	0.0015
Half Width	0.0018
Replication	4.98

The half width of the system is stated in the report. Based on the half width, the required number of replication is calculated using following equation obtained from (Kelton, et al., 2006).

$$n' = \left(\frac{t_{n-1,1-\frac{\alpha}{2}} \times s}{h}\right)^2 \tag{4.4}$$

n' : Number of replication

$t_{n-1,1-\frac{\alpha}{2}}$: Student t distribution (2.77645)

$n-1$: Degree of freedom

α : Error (5%)

s : Standard deviation

h : Half width

$$n' = \left(\frac{t_{n-1,1-\frac{\alpha}{2}} \times s}{h}\right)^2 = \left(\frac{2.77645 \times 0.0015}{0.0018}\right)^2 = 4.98$$

Using 95% of confidence level or 5% error. The required number of calculation is 4.98 replication. Thus, the current number of replication is enough to approach the real system.

4.5 Verification and Validation

The verification and validation of the model is required to prove that the simulation model is already represent the real system.

4.5.1 Model Validation

The validation process is done to confirm that the result of the current model is already represent the actual process in the real system. The validation is done by doing t-test unequal variance. T-test is used because of the limited information from the company. The actual variance and mean of the data is unknown. Then the random variables obtained from simulation has Student-t distribution with n-1 degrees of freedom. For the two side hypothesis,

$$H_0: \mu = \mu_0$$

$$H_1: \mu \neq \mu_0$$

We reject H_0 at significant level α when the computed statistic exceed $t_{\frac{\alpha}{2},n-1}$ or is less than $-t_{\frac{\alpha}{2},n-1}$ (Walpole, et al., 2012).

In this research, the current simulation model will be simulate up to 30 replication. The replication is made for 1 year simulation or equal to 365 days with 30 days warm up period. The total demand of the simulation will be tested with 95% significant level. The result of the test is shown in the following table.

Table 4. 5 t-Test: Two-Sample Assuming Unequal Variances

	Simulation	*Real*
Mean	3243226	5076420
Variance	224969.8366	1.63099E+12
Observations	30	4
Hypothesized Mean Difference	0	
df	3	
t Stat	-2.870868414	
P(T<=t) one-tail	0.032002419	
t Critical one-tail	2.353363435	
P(T<=t) two-tail	0.064004838	
t Critical two-tail	3.182446305	

The t-crit value is between -3.18 to 3.18 and the t stat value is -2.87. It means that the t stat value is inside the range of the critical value. Hence, there is no evidence suggesting a strong rejection of H_0 based on 5% error, yet it cannot truly conclude that the total demand in a month is unbiased.

4.5.2 Model Verification

The verification is done in two types. The first is to check the error of the model using trace and debug facility and the second is to verify the logic of the system.

4.5.2.1 Verification Using Trace and Debug Facility

The verification is done by pressing button F4 in the ARENA 14 software. This verification is aimed to check whether the current model has an error or not. Below is the screenshot of the trace and debug facility.

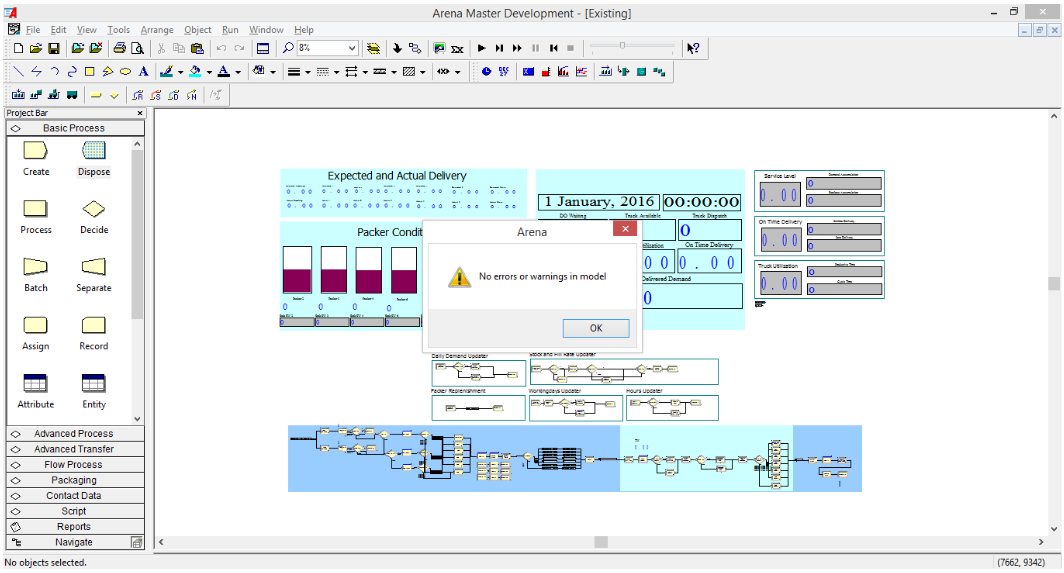

Figure 4. 17 The Screenshot of Trace and Debug Facility

The figure above shows that the current model has no error and it is ready to be used. Then, the next step is to verify the logic in the model. The logic verification is done in the several components.

4.5.2.2 Verification of Parameter Calculation

The calculation of the parameters will be calculated directly by the simulation system. All the calculation need to be check in order to have verified system. Below is the screen capture of all the parameters calculation during simulation process.

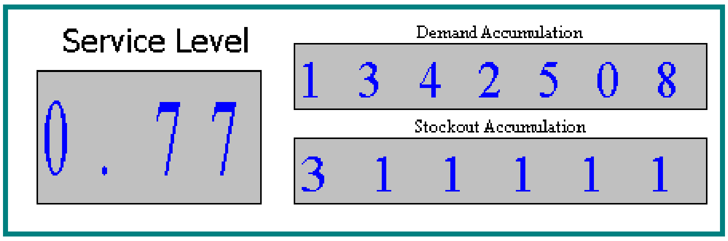

Figure 4. 18 Fill Rate Verification

In the figure above shows the result of the simulation fill rate. The accumulation of total demand is 1,342,508 bags and the stock out accumulation is 311,111 bags. Thus, by manual fill rate calculation using equation (3.1) the result is 0.76826. It is equal to 0.77 in the system. The calculation using manual and the result during simulation have no difference value. Hence, the fill rate calculation in the system is verified.

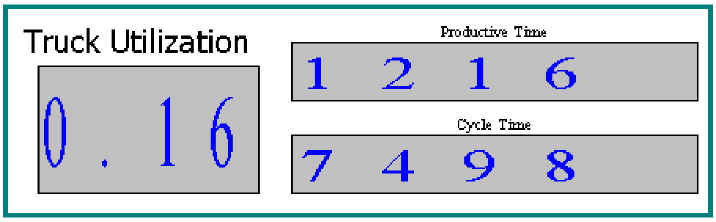

Figure 4. 19 Truck Utilization Verification

The truck utilization parameter in the 7th day of simulation result is shown in the figure above. The utilization is calculated by compare the productive time to the cycle time of each truck. The classification of the productive and not productive time is shown in the Figure 4.1. The result above is showing the accumulation of productive time of all the truck is 1,216 hours and the total cycle time is 7,498 hours. The manual calculation of the utilization is 0.16218 or equal to 0.16. By comparing the manual calculation and the simulation result, it is shown that there are not any difference between them. Thus, the truck utilization is already verified.

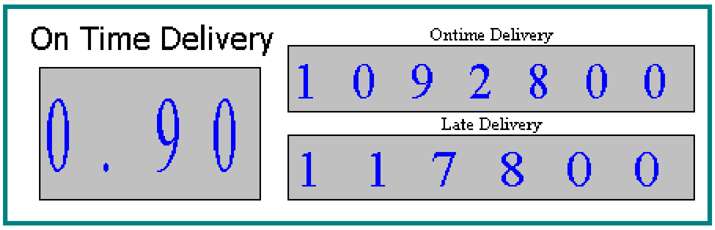

Figure 4. 20 On-time Delivery Verification

In the figure above shows the result of the simulation on-time delivery parameter. The accumulation of total on-time delivery demand 1,092,800 bags and the late delivery is 117,800 bags. By manual calculation using equation (3.2) the result is 0.90269. It is equal to 0.90 in the system. The calculation using manual and the result during simulation have no difference value. Hence, the on-time delivery calculation in the system is verified.

4.5.2.3 Verification of the Logic in the System

The verification process also done in the logic of the simulation. In this research, the verification is done for several element in the system including the unloading process in the distributor and the dispatching rule which is stock to demand ratio.

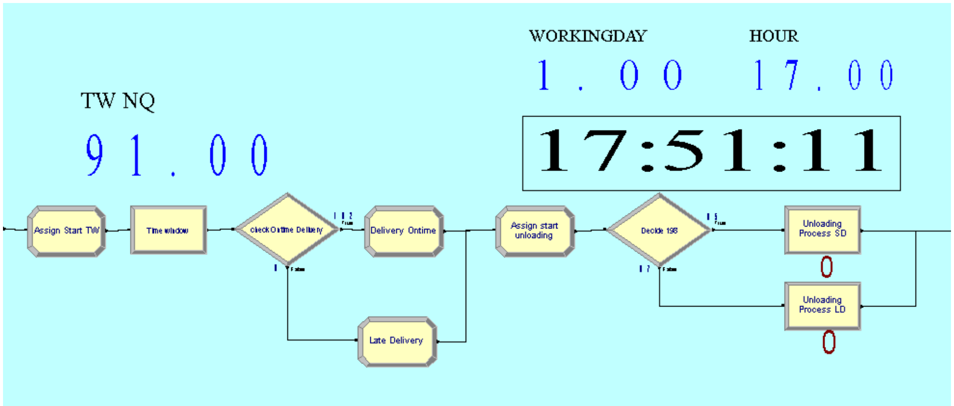

Figure 4. 21 Unloading Process Verification

The unloading process in the distributor will be done if the distributor is open and the unloading line is available. The distributor is open during working days and during its working hours. The working days is from Monday to Friday, it is shown by the value 1 for Monday, 2 for Tuesday and so on. The working hours is from 08:00 to 17:00. The screen capture above is showing the condition when the distributor is out of work time. The unloading process is 0 meaning that there are no unloading process is done during that time. It results to the increasing number of queuing of the truck to wait for the time window shown in the TW NQ value. Thus, the unloading process is already verified.

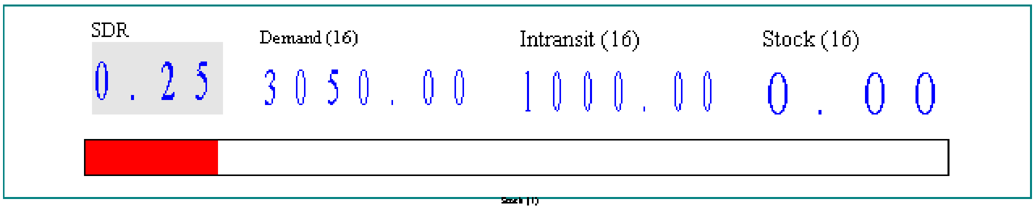

Figure 4. 22 Stock to Demand Ratio Verification

Stock to Demand Ratio Calculation is done in the scenario simulation. The calculation follows equation (3.4). Figure above shows screen capture of the interface during the simulation of one of the scenario. The figure shows that the demand of the Distributor 16 is 3,050 bags, the in transit inventory is 1,000 bags, and the current stock in the distributor is 0. It results in the SDR value is less than 1. Hence, the stock to demand ratio is verified.

4.6 Scenario

The complexity and the uncertainties of the system make the interconnection among variables are bias. The development of the scenario is obtained to determine the changes of the system. The goal of the scenario in this research is to increase the fill rate or the product availability in the distributor up to 80%. One of the method is by doing Vendor Managed Inventory. Vendor managed inventory characteristics are able to know the current condition of the distributor and managed to set the delivery priority to the critical distributor. There are several ways to obtain the goal. In this research the scenarios are the combination of dispatching rule and the number of the truck.

1. Changing the dispatching rule from Earliest Due Date to Stock Criticality. Stock to demand ratio is one of the method to determine the critical distributor. The alternative that can solve the problem is replacing the current dispatching rule which is Earliest Due Date with Stock to Demand Ratio method.
2. Increasing the number of truck. The additional number of the truck aimed to increase the frequency of the delivery so that the flow of the cement product can be faster and increase the availability of the product in the distributor.

Below is the list of the scenarios. The scenarios are the combination of number of the truck and the dispatching rule.

Table 4. 6 Scenario of the Simulation Model

Scenario	Dispatching Rule	No of truck
Scenario 0	EDD	250
Scenario 1	EDD	300
Scenario 2	EDD	350
Scenario 3	EDD	400
Scenario 4	EDD	450
Scenario 5	EDD	500
Scenario 6	SDR	250
Scenario 7	SDR	300
Scenario 8	SDR	350
Scenario 9	SDR	400
Scenario 10	SDR	450
Scenario 11	SDR	500

Scenario 0 represents the initial system. The scenario 1 to 11 are the improvement scenario for the system. EDD stands for Earliest Due Date and SR is Stock to Demand Ratio. The improvement is done to two control variables which are dispatching rule and number of the truck. The dispatching rule in the initial model is using the earliest due date method and it will be changed based on the stock criticality of the distributor. The limitation number of the truck is the one consideration to increase the availability of the product in the distributor. The combination of the scenario with the number of the truck will effect to the parameter of the system. Hence, the number of the truck will be considered in the scenario. In this case, the truck is laid between 250 and 500. All scenarios are run using Process Analyzer in the ARENA 14 software.

4.7 Simulation Result

The initial system and the scenarios are simulated for a year or equal to 365 days with 30 days of warm up period. The simulation is done for 5 replication for each model. The evaluation of the model is divided into three parameter which are product availability or fill rate, truck utilization, and the on-time delivery.

4.7.1 Fill Rate

The product availability is calculated by product fill rate. Fill rate is the comparison between the capability of the plant to fulfill the demand and the total accumulation of the demand. Fill rate parameter shows the capability of the plant to fulfill the required demand in the distributor. The higher value of the fill rate is better because it means that the plant able to meet higher demand in the distributor. Below is the summary of all the scenarios.

Table 4. 7 Fill Rate and Total Delivery Result

Scenario	Fill Rate	Total Delivery
Scenario 0	69.5%	27,142,760
Scenario 1	79.5%	31,064,320
Scenario 2	87.8%	34,324,400
Scenario 3	93.4%	36,563,360
Scenario 4	96.5%	38,040,160
Scenario 5	97.4%	38,525,640
Scenario 6	73.0%	28,266,758
Scenario 7	81.3%	31,561,758
Scenario 8	91.1%	35,388,638
Scenario 9	95.5%	37,134,718
Scenario 10	97.8%	38,085,078
Scenario 11	97.5%	38,003,678

The result shows that the additional number of truck will result in different fill rate. The initial system has 69.5% fill rate and 27,142,760 bags of total delivery in a year. By changing the dispatching rule and number of truck, the total delivery of the system will change. Consequently, the fill rate will also change. The higher number of truck will obtain higher fill rate. Below is the correlation plot between fill rate and total delivery.

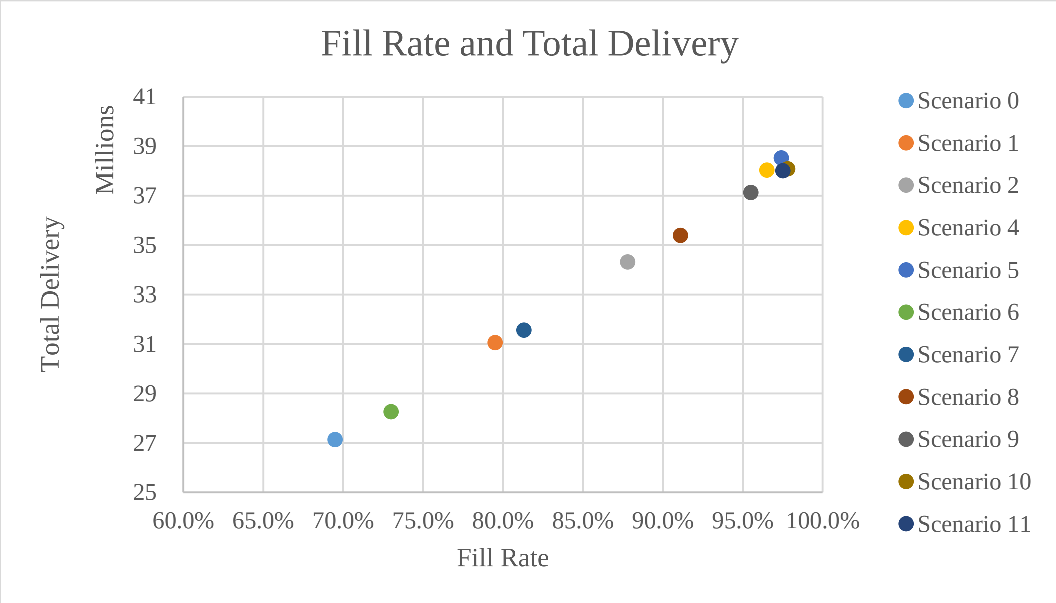

Figure 4. 23 Fill Rate and Total Delivery Plot

The graph above shows the correlation between fill rate and total delivery of each scenario. The initial model has the lowest fill rate value. Certainly, it will also has lowest total delivery for a year. The scenario 4, scenario 5, scenario 9, and scenario 10 are tent to have similar value of fill rate. The higher fill rate will have higher total delivery.

Table 4. 8 Packer Utilization

Scenario	Packer 2	Packer 3	Packer 4	Packer 6	Packer 7	Packer 8	Packer 11
Scenario 0	9.9%	12.2%	13.4%	14.7%	16.5%	19.2%	23.8%
Scenario 1	11.3%	14.0%	15.1%	16.9%	18.9%	22.0%	27.2%
Scenario 2	12.4%	15.4%	16.7%	18.7%	20.8%	24.3%	30.1%
Scenario 3	13.1%	16.4%	17.9%	19.9%	22.2%	25.9%	32.2%
Scenario 4	13.7%	17.1%	18.5%	20.7%	23.1%	26.9%	33.5%
Scenario 5	14.0%	17.4%	18.9%	21.0%	23.4%	27.3%	34.1%
Scenario 6	9.6%	11.9%	12.9%	14.5%	16.1%	18.7%	23.2%
Scenario 7	11.0%	13.5%	14.7%	16.4%	18.5%	21.5%	26.5%
Scenario 8	12.6%	15.6%	17.0%	18.8%	21.1%	24.6%	30.4%
Scenario 9	13.2%	16.5%	17.8%	20.0%	22.2%	25.8%	32.1%
Scenario 10	13.6%	17.0%	18.5%	20.5%	22.9%	26.7%	33.1%
Scenario 11	13.6%	16.9%	18.4%	20.5%	22.9%	26.7%	33.2%

The utilization of packer is different between each scenario. The lowest utilization of packer is obtained in the scenario 6 and the highest is in the scenario 5. The utilization of packer is increase as the increase of the fill rate.

4.7.2 Truck Utilization

The utilization of the truck is calculated in the system. The utilization of the truck is shown in the following table.

Table 4. 9 Truck Utilization

Scenario	Truck Utilization
Scenario 0	32.7%
Scenario 1	31.3%
Scenario 2	29.8%
Scenario 3	27.9%
Scenario 4	25.8%
Scenario 5	23.5%
Scenario 6	33.8%
Scenario 7	31.6%
Scenario 8	30.4%
Scenario 9	27.9%
Scenario 10	25.4%
Scenario 11	22.8%

The changing of the dispatching rule and the number of truck will result in the different truck utilization value. The lowest truck utilization is obtained in the scenario 11 and the highest is in the scenario 6. The value of truck utilization is affected by total productive and total cycle time of each truck. Below is the recapitulation of the productive time and cycle time of all scenarios.

Table 4. 10 Productive Time and Cycle Time

Scenario	Productive Time (day)	Cycle Time (day)
Scenario 0	29789.37	91044.64
Scenario 1	34198.28	109246.98
Scenario 2	37945.03	127448.39
Scenario 3	40569.92	145645.93
Scenario 4	42258.06	163754.87
Scenario 5	42796.16	181959.56
Scenario 6	30782.81	91014.60
Scenario 7	34500.54	109201.52
Scenario 8	38774.25	127362.87
Scenario 9	40537.34	145524.37
Scenario 10	41495.14	163614.71
Scenario 11	41391.11	181759.28

The accumulation of productive time is obtained from all the flow of the trucks in a year. In the initial system has total accumulation of productive time 29,789.37 days and the total accumulation of cycle time is 91,044.64 days. The initial system has the lowest value for both productive time and cycle time. The highest total productive time and cycle time is obtained in the scenario 5.

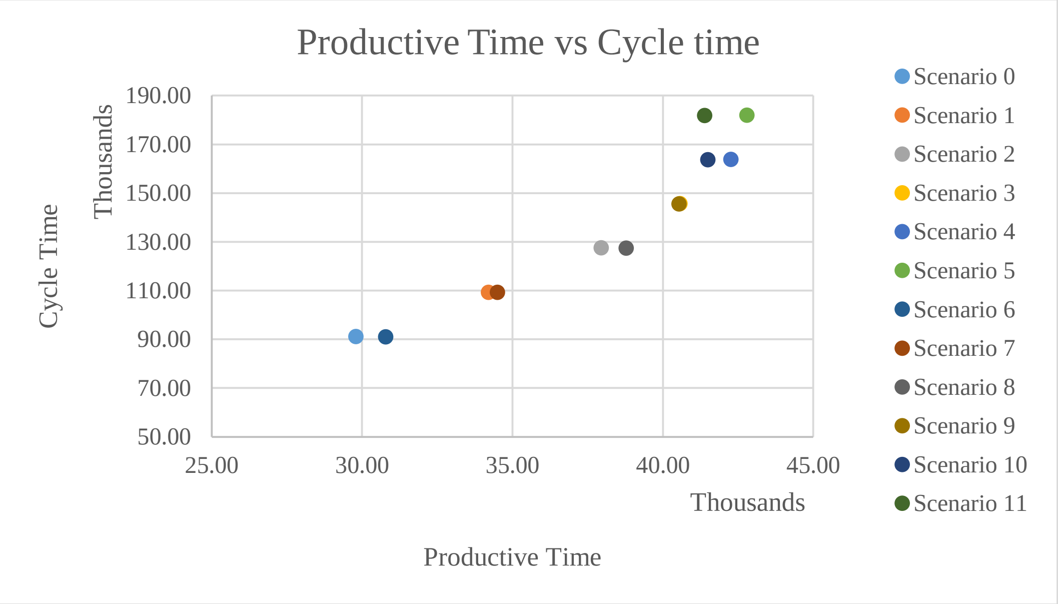

Figure 4. 24 Productive Time and Cycle Time Plot

The productive time accumulation and the cycle time accumulation correlation is shown in the graph above. The higher productive time will also has higher cycle time.

4.7.3 On-time Delivery

On-time delivery shows the capability of the plant to fulfill the product in the right time. The result of the scenarios are shown in the following table.

Table 4. 11 On-time Delivery Result

Scenario	On-time Delivery
Scenario 0	1.6%
Scenario 1	2.2%
Scenario 2	3.2%
Scenario 3	6.4%
Scenario 4	33.4%
Scenario 5	56.2%
Scenario 6	17.7%

Scenario	On-time Delivery
Scenario 7	32.5%
Scenario 8	51.9%
Scenario 9	66.0%
Scenario 10	78.8%
Scenario 11	79.4%

The lowest on-time delivery is obtained in the scenario 0 which is 1.6%. The highest on-time delivery is in the scenario 11 that is 79.4%. On-time delivery parameter is calculated using two components which are the actual arrival and the expected arrival of the product. Below are the result of the simulation.

Table 4. 12 Expected and Actual Arrival of Delivery

Scenario		Same Day	D1	D2	D3	D4	D5	More
0	E	9,385,000	18,971,880	4,685,200	1,554,600	2,666,320	1,646,200	-
	A	320,440	139,480	134,920	173,800	174,240	256,960	25,942,920
1	E	9,430,280	18,906,800	4,711,120	1,573,440	2,623,680	1,653,600	-
	A	255,560	344,960	301,520	339,920	337,640	405,040	29,079,680
2	E	9,409,600	18,931,760	4,697,680	1,558,440	2,649,760	1,651,240	-
	A	321,920	542,240	582,680	635,760	782,320	1,048,360	30,411,120
3	E	9,418,240	18,940,360	4,708,320	1,564,800	2,618,960	1,653,560	-
	A	549,160	1,264,320	1,568,520	1,135,480	1,958,880	1,595,760	28,491,240
4	E	9,398,280	18,939,560	4,712,160	1,558,600	2,636,040	1,652,800	-
	A	6,441,760	5,614,040	4,002,320	3,228,880	3,718,600	1,422,360	13,612,200
5	E	9,399,520	18,947,400	4,730,120	1,553,240	2,619,600	1,651,280	-
	A	16,151,880	4,450,640	4,861,080	2,857,280	2,842,840	1,753,520	5,608,400
6	E	6,259,360	14,161,240	3,549,360	1,182,080	1,971,760	1,219,120	-
	A	238,480	221,440	11,037,120	1,148,040	12,850,160	2,537,400	10,440
7	E	7,184,960	15,674,000	3,894,720	1,288,640	2,194,000	1,369,200	-
	A	344,000	6,883,320	9,702,800	4,097,240	9,767,840	433,680	109,200
8	E	8,319,760	17,382,440	4,351,640	1,443,840	2,390,440	1,515,760	-
	A	654,360	20,918,920	1,390,280	9,881,160	2,092,640	171,720	55,880
9	E	8,853,360	18,124,960	4,543,240	1,490,000	2,530,720	1,573,240	-
	A	11,405,040	14,499,160	2,730,720	6,668,000	1,150,840	311,560	145,720
10	E	9,124,600	18,554,520	4,635,360	1,519,800	2,570,360	1,610,960	-
	A	23,643,200	5,816,400	4,047,600	3,318,400	658,200	231,800	145,800

Scenario		Same Day	D1	D2	D3	D4	D5	More
11	E	9,095,520	18,502,920	4,586,440	1,522,760	2,582,040	1,613,520	-
	A	24,656,320	4,716,320	4,246,040	2,832,320	815,520	261,960	251,520

Notes:
E : Expected
A : Actual

The expected proportion is obtained from the behavior of the real system. In this research the expected arrival of the product is limited to Day + 5 after the order is received. The actual arrival of the product can be exceed 5 days.

Table 4. 13 Average Queuing Number and Queuing Time of Delivery Order

Scenario	DO Queuing Number	DO Queuing Time
Scenario 0	27682.5	59.59
Scenario 1	18466.6	39.79
Scenario 2	10679.9	23.00
Scenario 3	5269.1	11.32
Scenario 4	2339.0	5.09
Scenario 5	868.6	1.86
Scenario 6	960.7	3.02
Scenario 7	819.1	2.27
Scenario 8	616.1	1.49
Scenario 9	396.6	0.91
Scenario 10	171.7	0.38
Scenario 11	125.0	0.28

The table above shows the average number of delivery order that waiting for the truck and the average queuing time of the delivery order. The delivery order is in the form of truck assignment. It means that one delivery order is assigned to one truck. In the initial system, the delivery order was waiting to be assigned for average 59.59 days and the average delivery order waiting is 27,682.5 trucks. The value of both average number and average time is decreasing as the increasing number of trucks.

4.7.4 Correlation between Fill Rate, Truck Utilization, and On-time Delivery

The correlation between the parameters is checked using correlation test in the Microsoft Excel. Below are the scatter plot result of the correlation and the correlation test.

Table 4. 14 Correlation Test Result

	Fill Rate	*Truck Utilization*	*On-time Delivery*
Fill Rate	1		
Truck Utilization	-0.892711	1	
On-time Delivery	0.70191	-0.698956	1

The table above shows the correlation value between two parameters. The graph of the correlation is shown in the following figures.

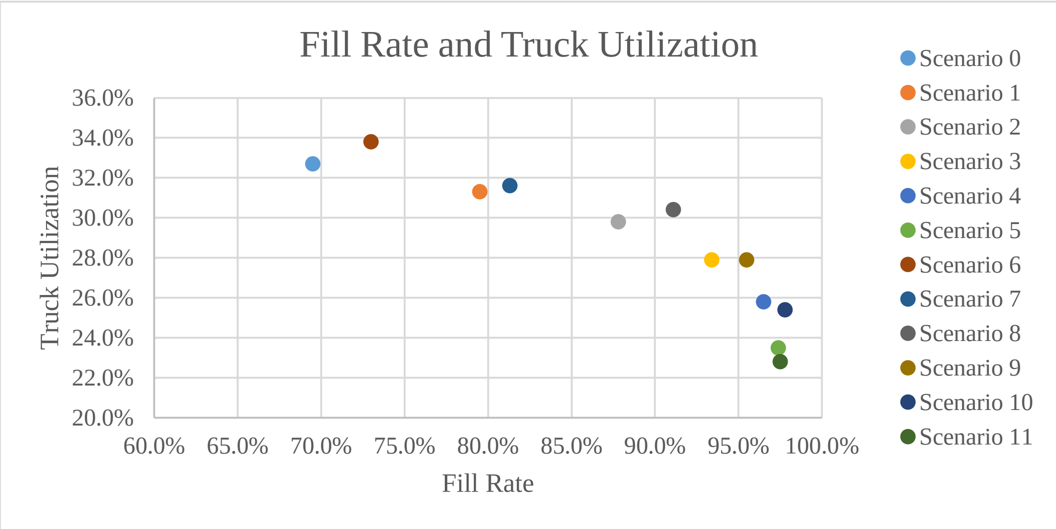

Figure 4. 25 Fill Rate and Truck Utilization

The correlation between fill rate and truck utilization is -0.893. it is shown in the graph above that the increasing number of fill rate will equal to the decreasing value of truck utilization.

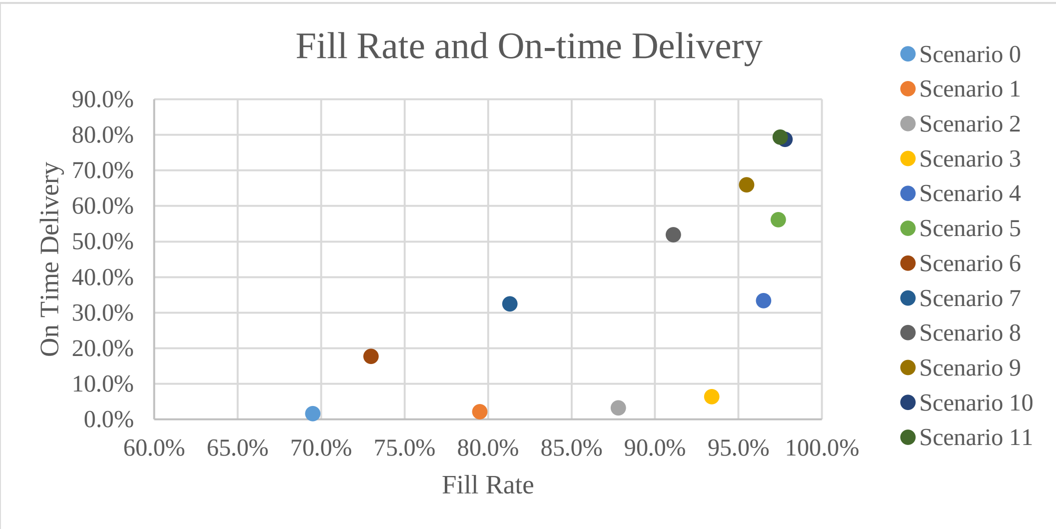

Figure 4. 26 Fill Rate and On-time Delivery

The correlation between fill rate and on-time delivery is 0.702. It means that the increasing value of fill rate will has increasing value of on-time delivery.

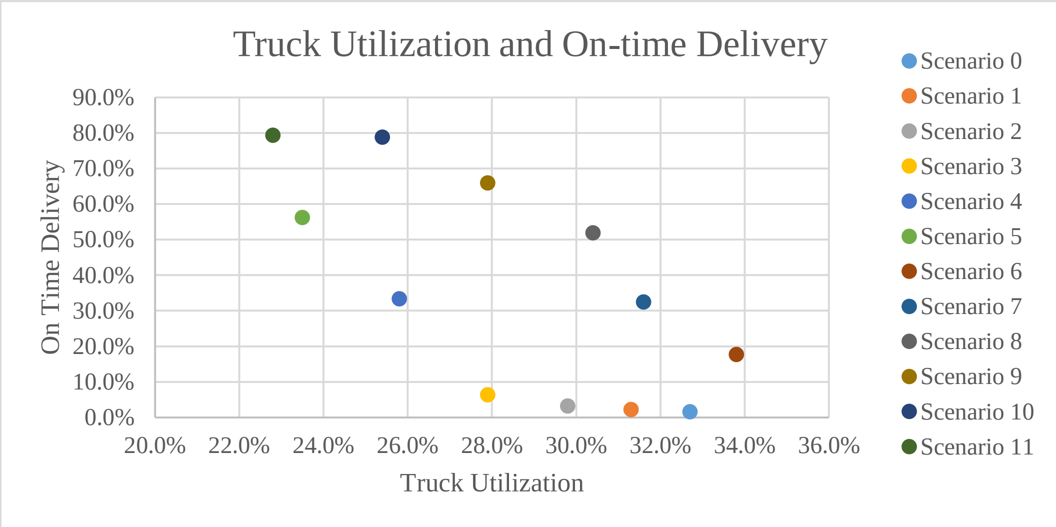

Figure 4. 27 Truck Utilization and On-time Delivery

The truck utilization and the on-time delivery has correlation about – 0.699. It means downhill linear pattern between both parameters. The increasing of truck utilization value results in the decreasing of on-time delivery rate.

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CHAPTER V
ANALYSIS AND INTERPRETATION

This chapter consists of analysis and interpretation of the results of all scenarios that conducted in the previous chapter. Several analysis lead to the best scenario that will be put as the recommendation.

5.1 Fill Rate Comparison

Fill rate is calculated using Equation (3.1). Product fill rate calculates the product availability in the distributor. The higher fill rate value means the higher capability of the plant to satisfy the demand in the distributor. In this research, the fill rate shows the service level of the plant. Fill rate result for all scenarios are shown in **Table 4.7**. The initial condition of the system has Earliest Due Date method to dispatch the truck with the available resource is 250 trucks. By having this combination, the simulation results in 69.5% fill rate. It means that the plant only able to fulfill 69.5% of the total demand in the distributor. Conversely, the distributor has 30.5% of stock out. The current value of fill rate is obtained by delivering 27,142,760 bags of cement in a year. The low value of fill rate means that some of the distributors cannot fulfill the required demand for the customer. The capability of the plant actually able to supply the customer demand but the uncertain delivery process and the limited number of the truck become the limitation for the plant to supply the required demand. Thus, the optimization of the delivery process needs to be done to achieve better service level.

The scenarios are developed to achieve at least 80% of fill rate. The scenario 1 to 5 have the same dispatching rule with the initial model which is Earliest Due Date. The scenario 6 to 11 have a different method to dispatch the truck which is using Stock to Demand Ratio calculation. Below is the plot of the fill rate result for all scenarios.

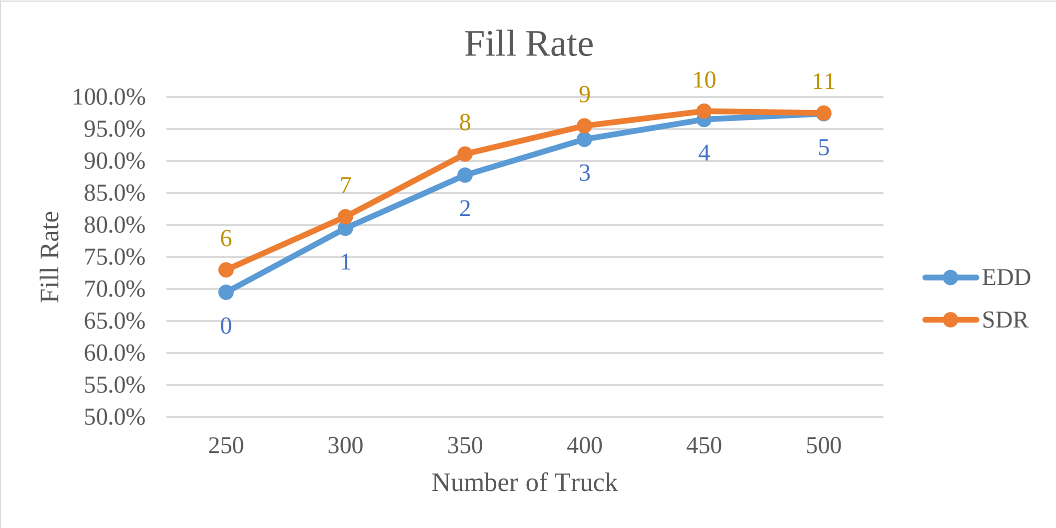

Figure 5. 1 Fill Rate Comparison

By using the same dispatching rule with an additional number of the truck, the simulation process results in higher fill rate. The scenario 1 increases the truck number by adding 50 trucks from the initial model. It results in increasing 14,4% of fill rate. Then, the higher additional number of the truck results in the higher value of fill rate. The similar behavior happened in the stock criticality method. The increasing number of the truck will also increase the value of fill rate by determining the stock criticality of each distributor before dispatching the truck.

As the increasing number of the truck, the frequency of the delivery is increasing. The delivery process is done in three different delivery order release time which are 10:00, 14:00, and 16:00. In the first delivery order release time that is 10:00, the system will generate an order for 30% of the short-distance distributor and the truck will directly come back to the plant to deliver the remaining order. By having more number of the truck, the second and the third of delivery release time will proceed a higher number of delivery order. It means that the product flow will be higher and the frequency of delivery is increasing. The increasing of the frequency will increase the stock available in the plant faster. Thus, the availability of the product in the distributor will increase and number of stock out will decrease. It results in the higher fill rate.

The different dispatching rule affects the fill rate value. It can be seen in the graph above, the fill rate of the scenarios considering the stock criticality tend to have higher fill rate. By using the same number of the truck with the initial system which is 250, the fill rate increases by 5% from the initial condition from 69.5% to 73.0%. The value of all the fill rate using stock to demand ratio calculation dispatching rule has higher value than using earliest due date method. Even when the number of the truck is 500 shown by scenario 5 and scenario 11. It is not clearly seen in the graph above that the fill rate when using 500 trucks is higher because the difference is only about 0.1%. The earliest due date method (Scenario 5) has fill rate 97.4% and scenario 10 which use stock criticality method has 97.5% rate.

The fill rate while considering the stock criticality method is higher than using earliest due date method. The stock criticality method will set the delivery priority to the most critical distributor. The critical distributor means that the current stock in the distributor and the stock in transit is limited to fulfill the predicted demand in the distributor. The system will fulfill the demand of the critical distributor first then continue to satisfy the other distributor. The stock criticality also determines the quantity that the distributor should have to fulfill the demand from the market. By having the calculation the remaining delivery order will not be high so then the flow of the product and the frequency of delivery is more controllable. Thus, the distributor will have enough stock, nor too much neither too little.

The stock criticality method will not effective while utilizing a larger number of trucks. The fill rate while using the stock criticality method will not always generate larger rate than the using of earliest due date method. It is shown in the graph while the systems are utilizing 500 trucks which are Scenario 5 and Scenario 11. The value of the fill rate is almost the same even the total delivery of the scenario 11 is larger than the scenario 5. While using stock criticality method in the scenario 6 to 11 the incremental value of fill rate is not linear with the incremental number of the truck. From scenario 6 to 7, the fill rate increases 8.3%. The fill rate still increase until scenario 9 to 10. In contrast, the fill rate for scenario

10 to 11 decrease by 0.3%. It shows that the more trucks utilized by the system no longer give effective product availability in the distributor.

5.2 Truck Utilization Comparison

The truck utilization is calculated by classifying the productive time and not productive time. In the delivery process of cement, the productive time includes the travel time, loading, and unloading process. Almost all of the activity have the uncertain factors. In this research, the productive time consists of traveling to packer loading line, loading process in the packer line, post time after loading, traveling to the destination, unloading process in the distributor, and the backhauling process. Other than those activities are classified in not productive time. The not productive time includes waiting to be assigned, waiting in the loading line before the loading process, checking the condition before loading process, waiting for the time windows, and waiting to be unloaded in the distributor. The total of productive time and not productive time is cycle time of the truck. The truck utilization is calculated by dividing the productive time accumulation to cycle time accumulation for all trucks flow in the whole year.

The truck utilization is highly affected by the total number of the truck. The summary result of the scenarios is shown in the following graph.

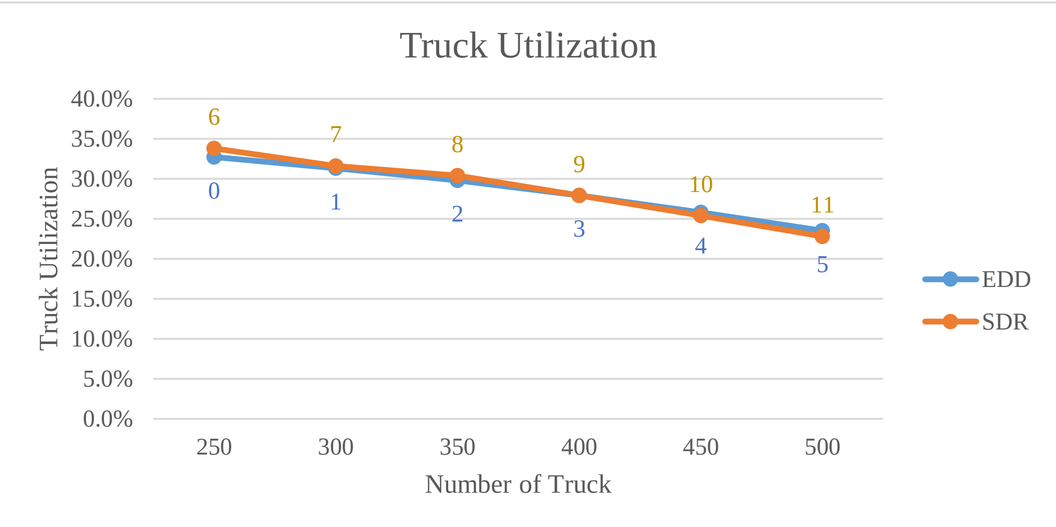

Figure 5. 2 Truck Utilization Comparison

The graph above shows the truck utilization rate for each different number of truck scenarios. The summary value of truck utilization is shown in **Table 4.9**. The initial system using earliest due date method with total 250 trucks has 32.7% of utilization. It means that the productive time of the truck is 32.7% of the total cycle time of all the trucks in a year. The higher truck utilization is obtained in scenario 6 which is 33.8% with the combination of stock criticality method and 250 trucks. The lowest utilization is shown by scenario 11 which is 22.8%. Scenario 11 is using stock criticality method with 500 trucks.

The increasing number of the truck results in decreasing value of truck utilization. The higher number of truck affects the total idle time of the truck. the truck that is assigned in the first delivery order assignment time which is at 10:00 will arrived back in the plant after doing the delivery process. The truck will wait to be assigned for the next delivery order. The waiting process will increase if the current number of available resource is high. The waiting time before the assignment is classified as the not productive time and it becomes one of the reasons of the low utilization of the truck. The same behavior also happens in the queuing process before loading and unloading process. The more truck assigned in the loading line will increase the time to wait before the loading process. Moreover, the truck that is already assigned to the distributor will wait longer before unloaded because of the higher number of truck assigned.

Different dispatching rule does not result in significant difference in the truck utilization. It is clearly seen in the graph above that the gap between methods are not significant. The value of both dispatching rule method are similar to each number of the truck. The truck utilization itself has a correlation with the total delivery of each scenario. The total delivery result is shown in **Table 4.7**. While using 200 trucks, the stock criticality method will deliver higher product than the earliest due date method. In the other hand, the stock criticality method delivers lower number of products while using 500 trucks. Furthermore, the distribution process has uncertainties in each process. The simulation uses random input that also creates random output.

The good system will have high utilization. It means that the available resources are able to give their best performance to deliver the delivery order. Thus, by evaluating the truck utilization, the best scenario is the scenario 6 which consider stock criticality and 250 trucks in the system. Nevertheless, the company is using third party logistics to deliver their cement products. Thus the truck utilization is not the main parameter to decide the best scenario, but it is one of the good parameters to evaluate the system.

5.3 On-time Delivery Comparison

On-time delivery is calculated using Equation (3.2). It is obtained by comparing the expected arrival of the delivery and its actual arrival. The expected arrival of the delivery proportion is already decided by the current system. The expected arrival is considered up to 5 days after the delivery order is received. This limitation is obtained because the longer the arrival expectation, the harder to be monitored in the real condition and the more bias the result is. In the other hand, the actual delivery that arrived more than five days is still recorded. Below are the on-time delivery result of all scenarios.

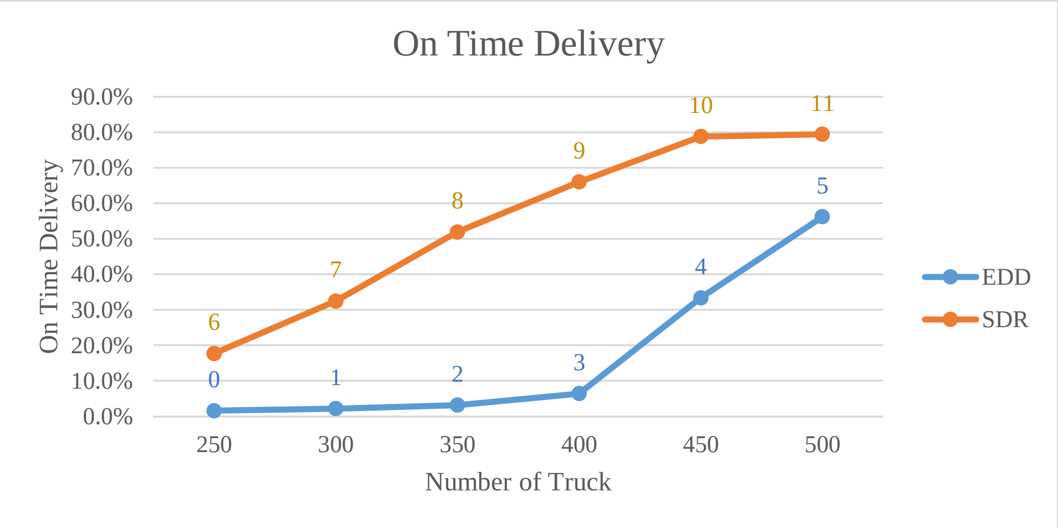

Figure 5. 3 On-time Delivery Comparison

The graph above shows the comparison of on-time delivery for two dispatching rule methods. The values of all the scenarios are shown in the plot above. The lowest value is obtained by the initial system which is 1.6%. It means that the plant only capable of delivering 1.6% of the products in the right time as expected by the distributor. Other than that 1.6% products are delivered longer than the expected arrival. The scenario 11, moreover, has the highest on-time delivery rate. The plant capable of delivering 79.4% of the product exactly in the same due-date or even faster than the due-date.

The increasing number of the truck results in the increasing rate of on-time delivery. The graph above shows clearly the rising value of on-time delivery rate. The increasing value of truck increases the availability of truck. It means that the delivery order is assigned faster so then the delivery order does not have to wait. The average queuing number of the delivery order is shown in the **Table 4.13**. The average queuing number of delivery order is decreasing by the increasing number of the truck. It is proved that the delivery order is delivered faster and it increases the on-time delivery of the demand.

The consideration of stock criticality increases the on-time delivery rate. The earliest due date method will fulfill the demand quantity as requested by the distributor. The plant does not know the actual remaining stock in the distributor, then the due-date is determined after receiving the order. By doing this method, there is the probability that the distributor with very low demand will be assigned later or the distributor with enough demand will be served first. The quantity requested by each distributor may be higher than the demand or may be lower than the demand.

5.4 Relationship between Fill Rate, Truck Utilization, and On-time Delivery

The relationship among three parameters are described in this sub chapter. The parameters that become the evaluation of the model are fill rate, truck utilization, and on-time delivery. The analysis are divided into three combination which are correlation between fill rate and truck utilization, fill rate and on-time delivery, and the last is the comparison between truck utilization and the on-time delivery.

The relationship between fill rate and truck utilization tend to have downhill linear pattern. The **Figure 4.25** shows that the rising fill rate has a tendency to have lower truck utilization. The test shows that fill rate and truck utilization of the system has a very strong correlation with value -0.893. The closer the correlation value to -1 for the downhill tendency indicates the stronger correlation between both variables. In the simulation result, the higher fill rate is obtained by the highest number of truck combination which is 500 trucks. Moreover, the lowest utilization value is obtained while using 500 trucks. In conclusion, there is a tradeoff between fill rate and truck utilization. The good system is obtained by good combination of those parameters. In this research, the utilization of the truck is not the main consideration because the actual delivery process is done by the third party.

The correlation value between fill rate and on-time delivery is 0.702. It means both parameter combination results in a moderate uphill relationship. The trend is positive and the plot is rising from lower value to higher value for both parameters. The scatter plot in the **Figure 4.26** shows the correlation. The distribution of the result not clearly in the linear form. Thus, the value of the correlation is not close enough to 1. The higher on-time delivery means that the order is delivered in the right time to the distributor. By having the right time delivery, the stock in the distributor become more predictable. It increases the product availability in the distributor and results to the lower value of stock out. Furthermore, the flow of the truck will become more predictable, so then the delivery order can be more controllable. The controllable delivery order and the increase of product availability in the distributor generate higher fill rate. The higher fill rate represents the better service level of the plant.

The correlation between truck utilization and on-time delivery is classified as a moderate downhill relationship with correlation value -0.699. The negative value shows that the increasing rate of a variable will result in the decreasing rate of another variable. The lowest on-time delivery is shown by the initial system or scenario 0. In the scenario 0, the average queuing number of delivery order before it is assigned is very large. There are several reasons that contribute to the low on-time delivery rate. The initial system only utilizes 250 trucks which mean the frequency of delivery is also limited. Then by using the limited resource, the system no longer able to deliver the product as the expectation. Moreover, the average queuing number of delivery will continue to increase because there will be no demand reduction from the distributor. In conclusion, the lower on-time delivery is obtained while using a limited number of resource and the limited number of the truck will have higher truck utilization.

5.5 Comparison of Earliest Due Date and Stock Criticality Method

The initial system has earliest due date method. The distributor requests for their own delivery quantity then the plant will record and give the shipment due-date based on both agreements. By using this method, the truck is assigned based on the due-date, the earliest the due date will be delivered first. By using this method, the plant does not know the actual condition of the distributor. Some of the distributors may request for larger quantity but they are currently having enough stock. Some other distributor may request for larger quantity but they already in the critical stock. The earliest due date does not provide information visibility between the plant and the distributor. So then the plant will accept both conditions as an equal condition. Furthermore, the limitation number of the truck to deliver the product makes the delivery do not arrived as the expectation. It results in the lower on-time delivery.

This research aims to implement the vendor managed inventory which is stock criticality method. Stock criticality is one of the methods that considers the information visibility between two supply chain entities. In this case, the entities are the plant and the distributor. The plant will deliver the cement products based on the current stock of the distributor. The distributor will inform their current stock and the plant will deliver the products in the sufficient quantity to meet the predicted demand. The plant will determine the critical distributor using stock to demand ratio calculation. The stock to demand ratio considers the current inventory on hand in the distributor, the in-transit inventory, the lead time from plant to distributor, and the predicted demand of the product. The quantity assigned to the distributor will be determined by the plant based on the stock to demand ratio value.

All the stock criticality method result in higher fill rate compared to the earliest due date method. The determination of the critical distributor will affect the delivery process. The system will set the delivery order in a sufficient quantity and a sufficient number of the truck for all the distributor. Moreover, the delivery process is done to the critical distributor first. It will reduce the probability of having stock out. So then, the fill rate increases. The increasing fill rate is also proved by the higher number of total delivery in a year. It means that the system able to fulfill higher demand than the earliest due date method.

The truck utilization has no significant different value while using stock criticality method. Both methods are having similar truck utilization. The truck utilization involves all the productive and not productive time of each truck. The changing of the dispatching rule does not create a significant transformation of the truck utilization because the process involves in the delivery system is not change. In conclusion, the truck utilization is not affected by the dispatching rule but it still influenced by the number of the truck.

The on-time delivery while using stock criticality method is significantly higher than using earliest due date method. The changing of the method is clearly shown by the on-time delivery rate result. The gap between both methods while using an equal number of trucks are high. The stock criticality tends to have sufficient quantity to be assigned. Then the order will be more controllable and it will be delivered as the prediction. Stock criticality itself does not consider the due-date of the delivery. Nevertheless, the arrival expectation of the order is considered to distinguish the changes obtained by performing different dispatching rule.

The using of stock criticality will be the best method to be used with a limited number of the truck. It is shown in the incremental value of fill rate and on-time delivery. The incremental value of both parameters tends to decrease due to the additional number of trucks while using stock criticality method. It means that the method is no longer effective to be implemented. The stock criticality will be the best solution while having the limited resource in the delivery process.

5.6 Suggested Scenario

Below is the recapitulation table for the scenarios. It consists of the control variables and its responses to the parameters.

Table 5. 1 Comparison of the Result

Scenario	Control		Response		
	Dispatching Rule	No of Truck	Fill Rate	Truck Utilization	On Time Delivery
Scenario 0	EDD	250	69.5%	32.7%	1.6%
Scenario 1	EDD	300	79.5%	31.3%	2.2%
Scenario 2	EDD	350	87.8%	29.8%	3.2%
Scenario 3	EDD	400	93.4%	27.9%	6.4%
Scenario 4	EDD	450	96.5%	25.8%	33.4%
Scenario 5	EDD	500	97.4%	23.5%	56.2%
Scenario 6	SDR	250	73.0%	33.8%	17.7%
Scenario 7	**SDR**	**300**	**81.3%**	**31.6%**	**32.5%**
Scenario 8	SDR	350	91.1%	30.4%	51.9%
Scenario 9	SDR	400	95.5%	27.9%	66.0%
Scenario 10	SDR	450	97.8%	25.4%	78.8%
Scenario 11	SDR	500	97.5%	22.8%	79.4%

In the light of the previous discussion, the suggested scenario is scenario 7 with fill rate 81.3%, truck utilization 31.6%, and on-time delivery 32.5%. Scenario 7 will utilize 300 trucks and implement stock criticality method. The plant needs to add 50 trucks to get at least 80% of service level.

The higher number is not chosen even it has better fill rate value because it will have bigger cost and lower utilization. The stock criticality method is chosen because it is more effective to be implemented in the limited number of the truck. The combination of both method and number of the truck will create an optimal delivery system. It is stated in the result that to achieve the goal of the improvement which is 80% of Fill Rate, the fit scenarios are Scenario 2, Scenario 3, Scenario 4, Scenario 5, and Scenario 7 up to Scenario 11. The higher fill rate is achieved while using the larger number of trucks. In contrast, the higher number of the truck will result in the lower utilization and the probability of higher investment cost. Thus, instead of choosing the larger number of the truck, the suggested scenario is based on the minimum value of the required fill rate with the higher number of truck utilization, and the higher value of on-time delivery.

Moreover, the chosen scenario will be based on the company's preference. The company will obtain 73% fill rate or increase about 3.5% from the initial system while using the current number of resource which is 250 trucks and applied stock criticality method. Meanwhile, to obtain at least 80% of service level, the company need to apply scenario 7 or scenario 2 with the combination of earliest due date method and 350 trucks.

CHAPTER VI
CONCLUSION AND SUGGESTION

This chapter consists of conclusion and the recommendation of the research. It concludes the whole research and contains recommendations for further researches as well as for the company.

6.1 Conclusion

The highlight of the research will be summed in the following points.

1. The application of new dispatching rule which considers stock criticality of the distributor affects the distribution of cement product in PT.X. The new rule gives significant difference for fill rate and on-time delivery but not significant difference in the utilization of the truck. All the stock criticality method result in higher fill rate compared to the earliest due date method. The on-time delivery while using stock criticality method is significantly higher than using earliest due date method. The truck utilization has no significant different value while using stock criticality method.
2. The increasing number of the trucks affect all the parameters. By using the same dispatching rule with additional number of the truck, the simulation process results in higher fill rate. The increasing number of the truck will decrease the truck utilization. Furthermore, the increasing number of the truck results in the increasing rate of on-time delivery.
3. The suggested scenario is Scenario 7 with fill rate 81.3%, truck utilization 31.6%, and on-time delivery 32.5%. Scenario 7 utilizes 300 trucks and implement stock criticality method. It is already achieve the goal to obtain at least 80% of service level. Moreover, the chosen scenario will be based on the company’s preference. The company will obtain 73% fill rate or increase about 3.5% from the initial system while using the current number of resource which is 250 trucks and applied stock criticality method.

6.2 Suggestion

The suggestion for the following research are put in the following points.

1. The further analysis needs to consider the benefit-cost analysis to determine the feasibility of the method.
2. Conduct the evaluation which considers the capacity of each distributor.

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ATTACHMENTS

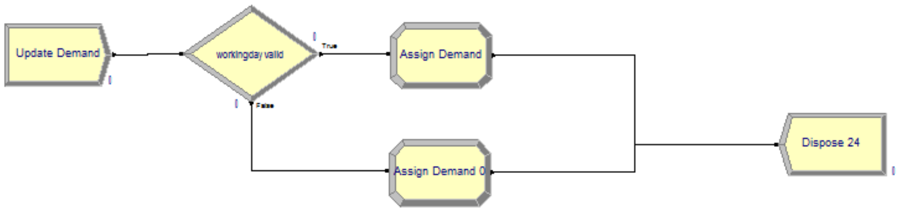
Attachment 1 List of Distributor

No	Zone	Distributor
1	Purwakarta	Purwakarta
2	Jakarta Selatan	Jatinegara
3	Kuningan	Sindang Agung
4	Indramayu	Haurgeulis
5	Jakarta Selatan	Cilandak
6	Indramayu	Karangampel
7	Jakarta Selatan	Setiabudi
8	Bekasi Kota	Jatisampurna
9	Bogor	Jasinga
10	Bekasi Kota	Bekasi Selatan
11	Indramayu	Indramayu WAD
12	Jakarta Selatan	Pesanggrahan
13	Cirebon	Ciledug
14	Tangerang Kabupaten	Curug
15	Jakarta Selatan	Mampang Prapatan
16	Jakarta Selatan	Tebet
17	Majalengka	Baturajeg
18	Bekasi Kota	Medan Satria
19	Bogor	Parung
20	Bogor	Parungpanjang
21	Bogor Kota	Bogor Barat
22	Jakarta Pusat	Cempaka Putih
23	Bekasi	Tarunajaya
24	Bekasi	Babelan
25	Tangerang Kabupaten	Pamulang
26	Bogor	Ciampea
27	Bogor	Cileungsi
28	Bogor	Cibinong
29	Jakarta Selatan	Pulogadung
30	Tangerang Kota	Ciledug
31	Bogor	Cibungbulan
32	Majalengka	Talaga
33	Tangerang Kabupaten	Cisauk
34	Jakarta Selatan	Pasar Rebo
35	Jakarta Utara	Cilincing
36	Jakarta Selatan	Makasar
37	Jakarta Utara	Koja
38	Jakarta Selatan	Kebayoran Baru

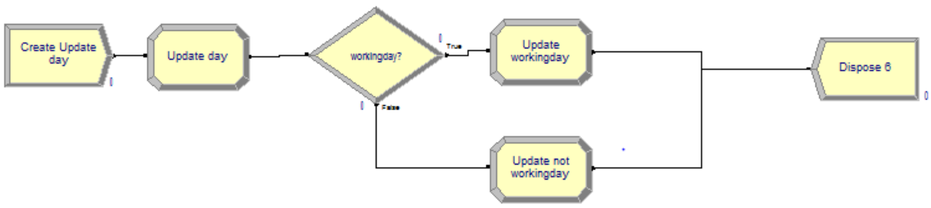
No	Zone	Distributor
39	Depok Kota	Limo
40	Tangerang Kabupaten	Legok
41	Indramayu	Anjatan
42	Tangerang Kabupaten	Serpong
43	Tangerang Kota	Cipondoh
44	Indramayu	Lohbener
45	Kuningan	Luragung
46	Depok Kota	Sawangan
47	Majalengka	Maja
48	Jakarta Pusat	Tanah Abang
49	Jakarta Selatan	Matraman
50	Jakarta Selatan	Pancoran
51	Bogor	Cigudeg
52	Bogor	Tenjo
53	Majalengka	Majalengka
54	Bogor	Rumpin
55	Bogor	Nanggung
56	Garut	Bungbulan
57	Indramayu	Loserang
58	Jakarta Pusat	Senen
59	Tangerang Kabupaten	Cikupa
60	Jakarta Pusat	Sawah Besar
61	Indramayu	Kandang Haur
62	Bogor	Gunung Sindur
63	Bogor	Kemang
64	Bekasi Kota	Bekasi Timur
65	Indramayu	Jatibarang (Jabar)
66	Bogor	Pamijahan
67	Indramayu	Juntinyuat
68	Bekasi	Setu
69	Indramayu	Terisi
70	Tangerang Kota	Larangan
71	Jakarta Barat	Tambora
72	Bogor Kota	Tanah Sereal
73	Cirebon	Losari
74	Indramayu	Widasari
75	Jakarta Pusat	Joharbaru

Attachment 2 Simulation Model

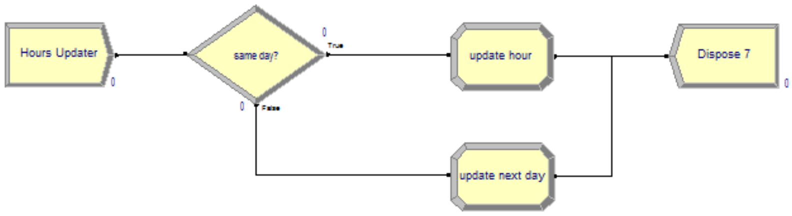
a. Daily Demand Updater



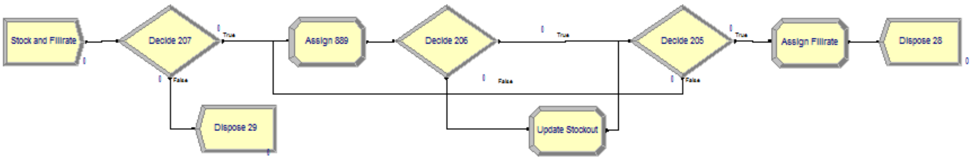
b. Working Day Updater



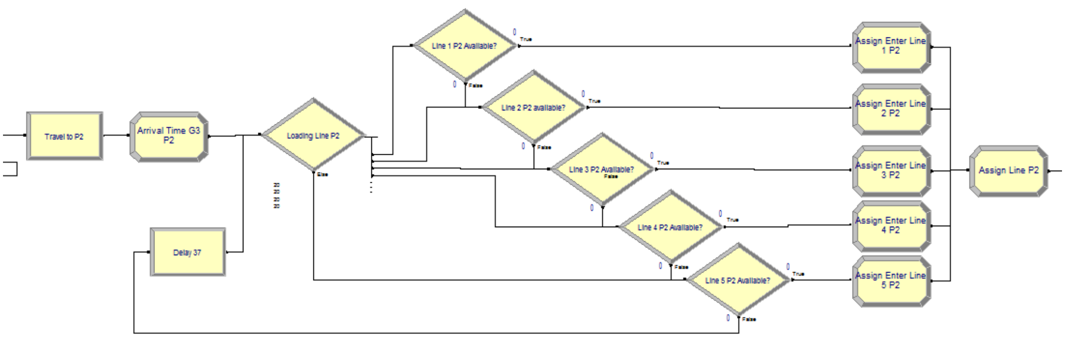
c. Hours Updater



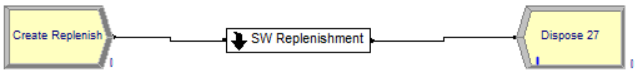
d. Stock and Fill Rate Updater



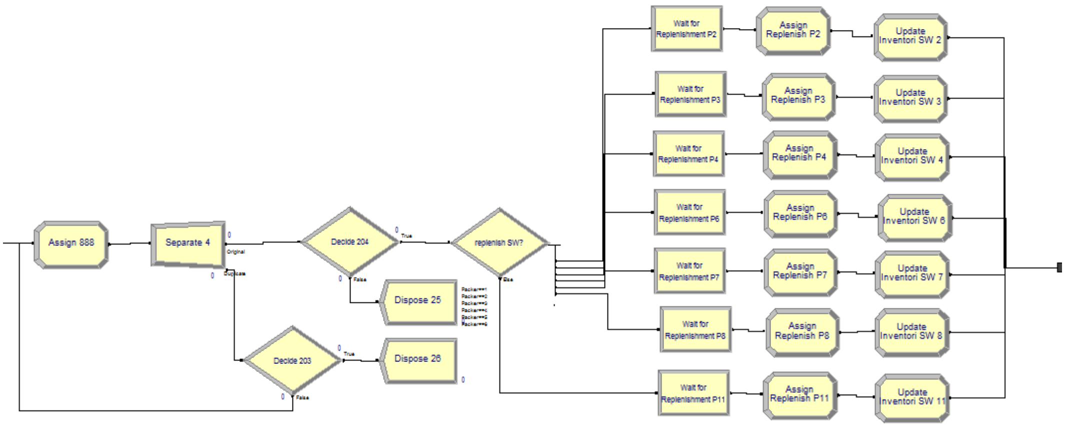
e. Assign to Packer Sub Model



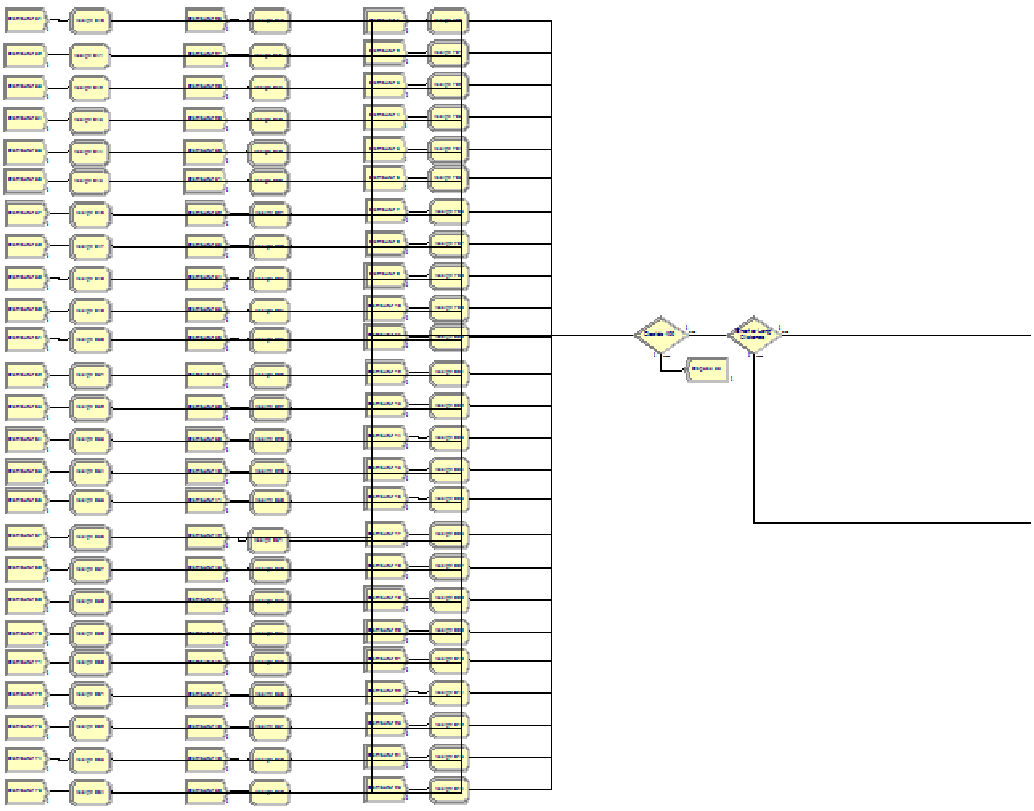
f. Packer Replenishment Model



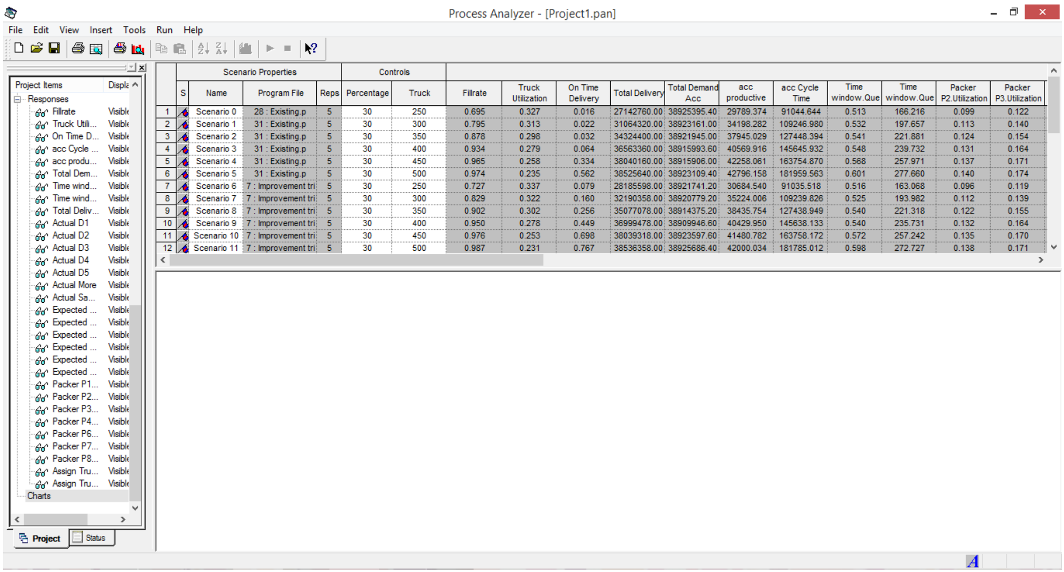
g. SW Replenishment Sub Model



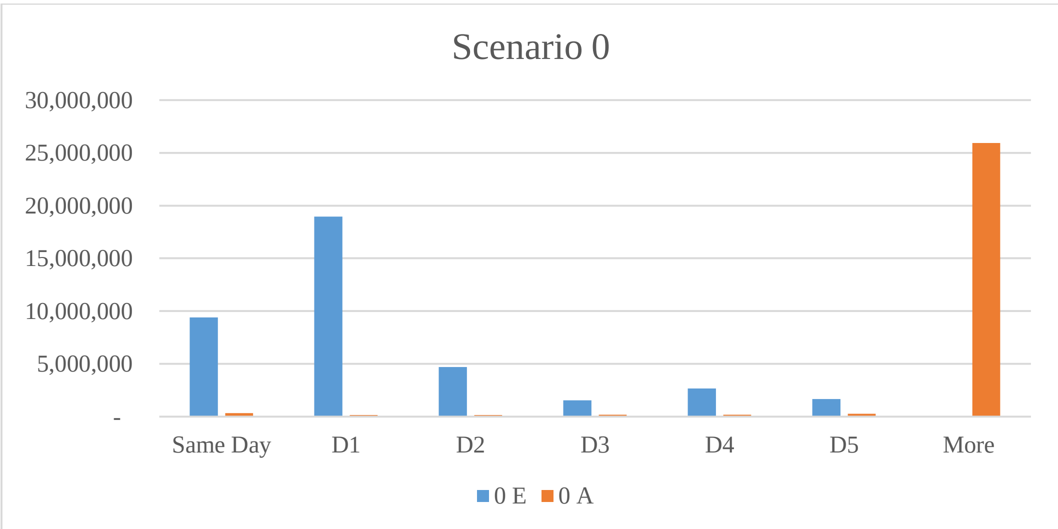
h. Assign Delivery Order

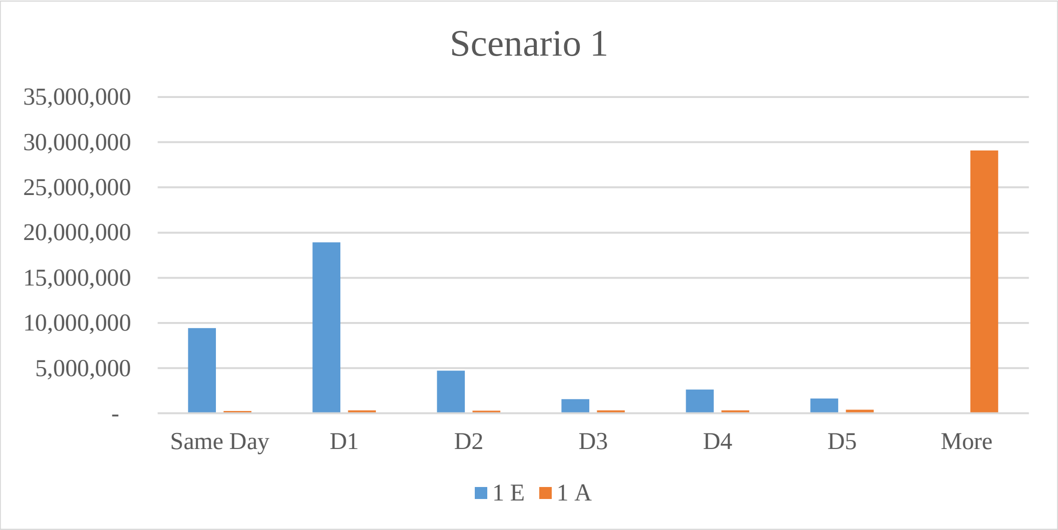


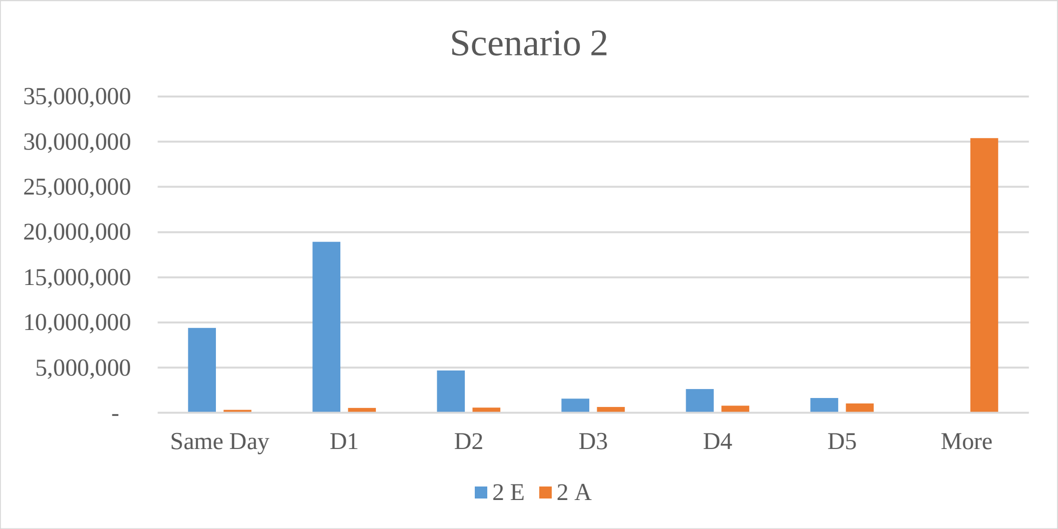
Attachment 3 Screenshot of Process Analyzer

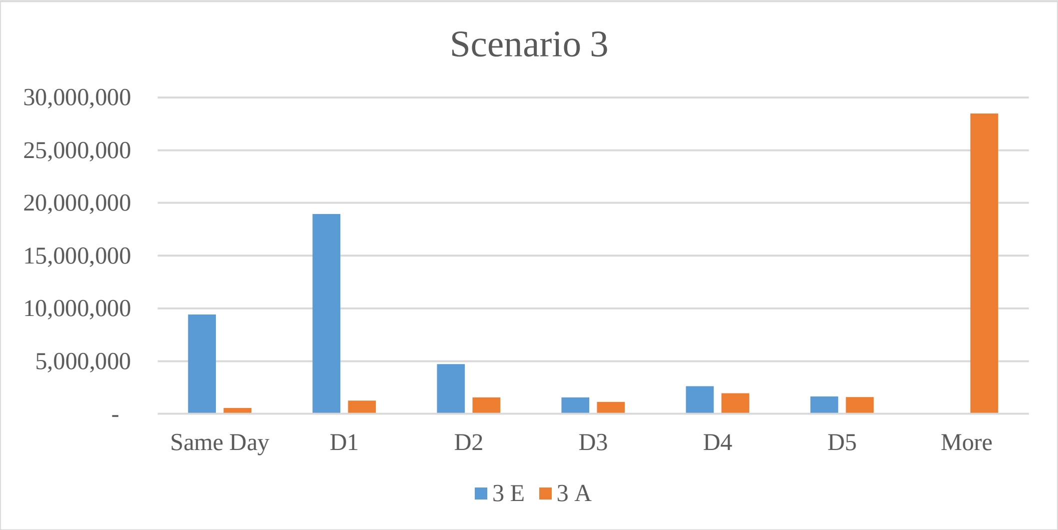


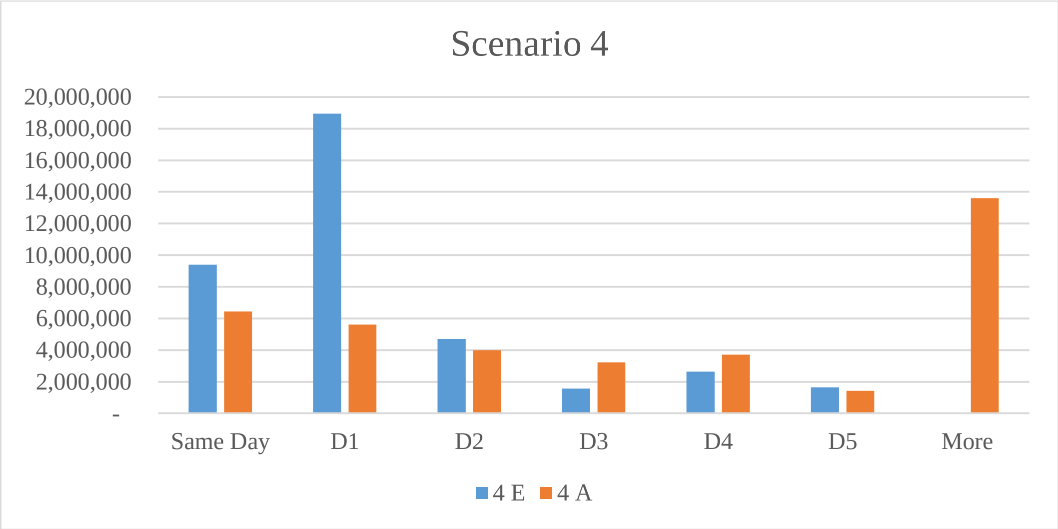
Attachment 4 Expected and Actual Arrival of Delivery Order

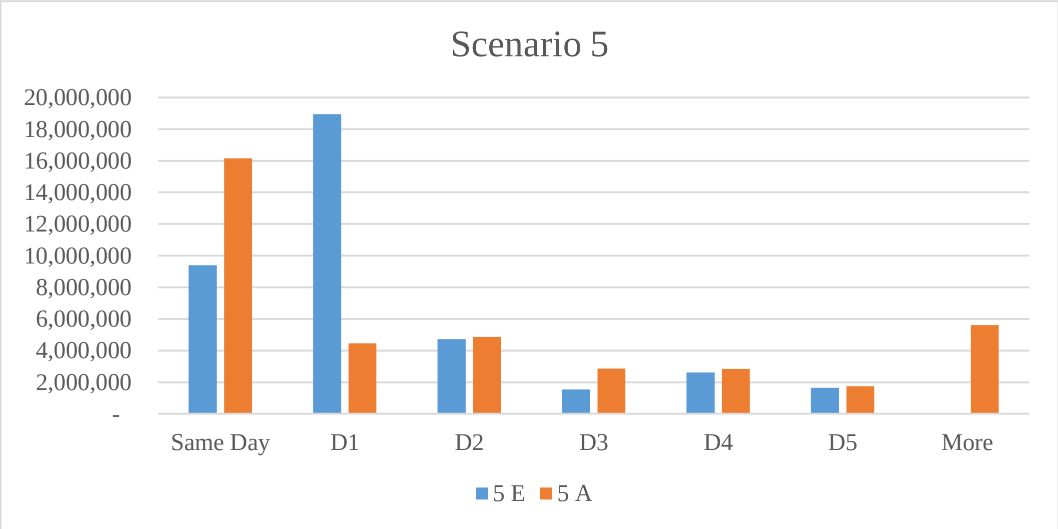


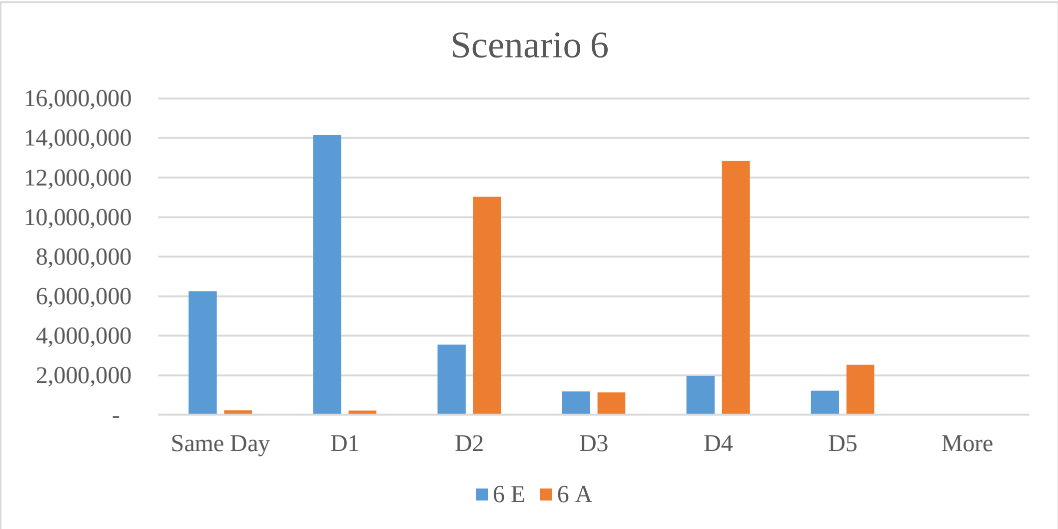

Scenario 1
35,000,000
30,000,000
25,000,000
20,000,000
15,000,000
10,000,000
5,000,000
-
Same Day
D1
D2
D3
D4
D5
More
1 E
1 A

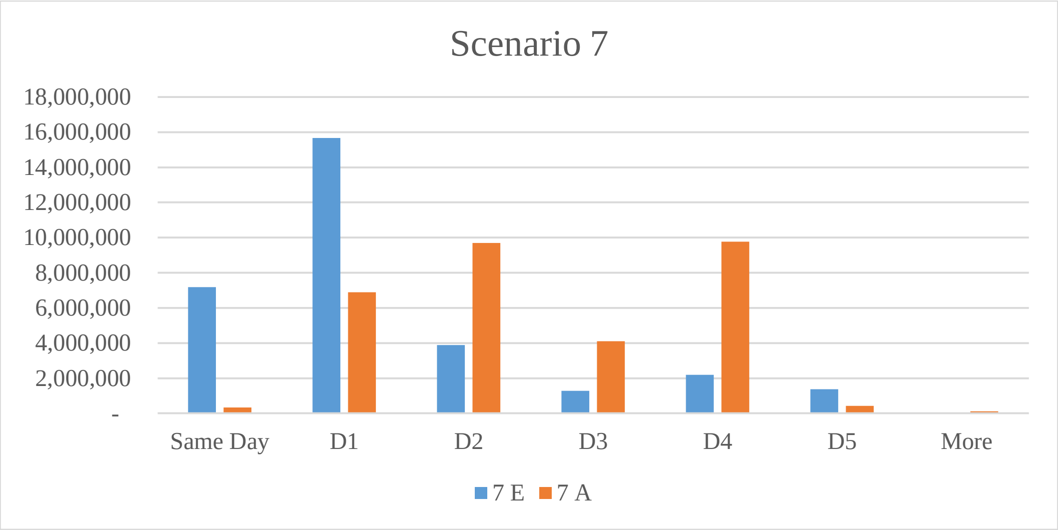

Scenario 2
35,000,000
30,000,000
25,000,000
20,000,000
15,000,000
10,000,000
5,000,000
-
Same Day
D1
D2
D3
D4
D5
More
2 E
2 A

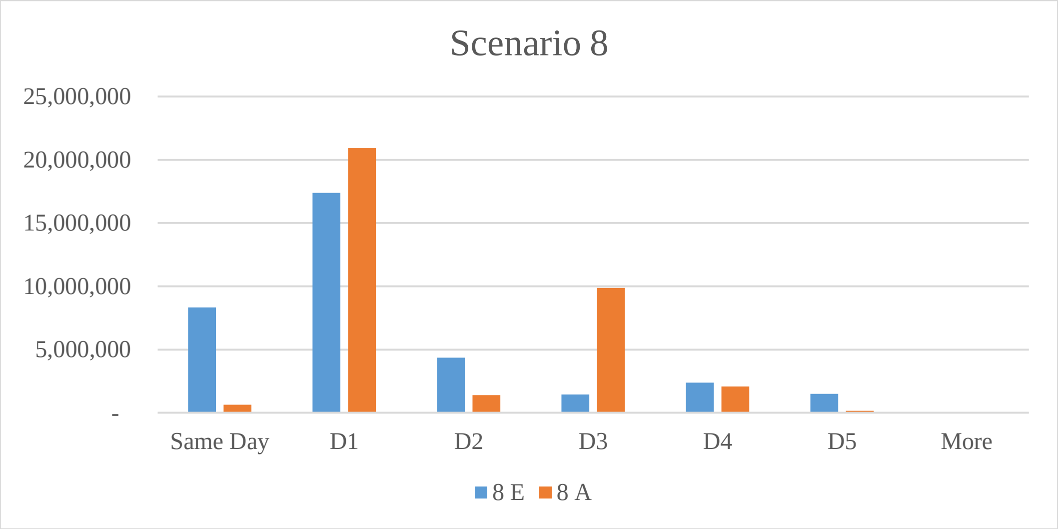

Scenario 3
30,000,000
25,000,000
20,000,000
15,000,000
10,000,000
5,000,000
-
Same Day
D1
D2
D3
D4
D5
More
3 E
3 A

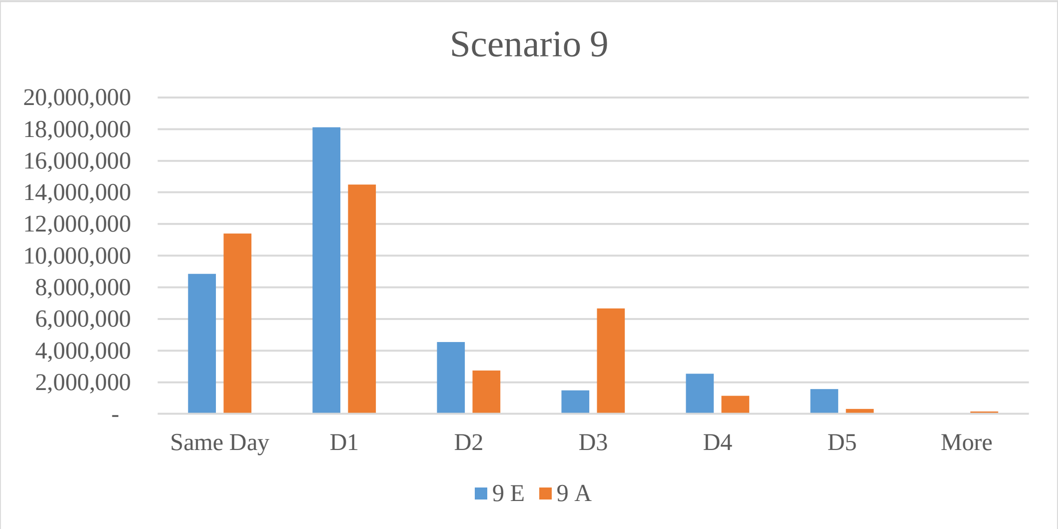

Scenario 4
20,000,000
18,000,000
16,000,000
14,000,000
12,000,000
10,000,000
8,000,000
6,000,000
4,000,000
2,000,000
-
Same Day
D1
D2
D3
D4
D5
More
4 E
4 A

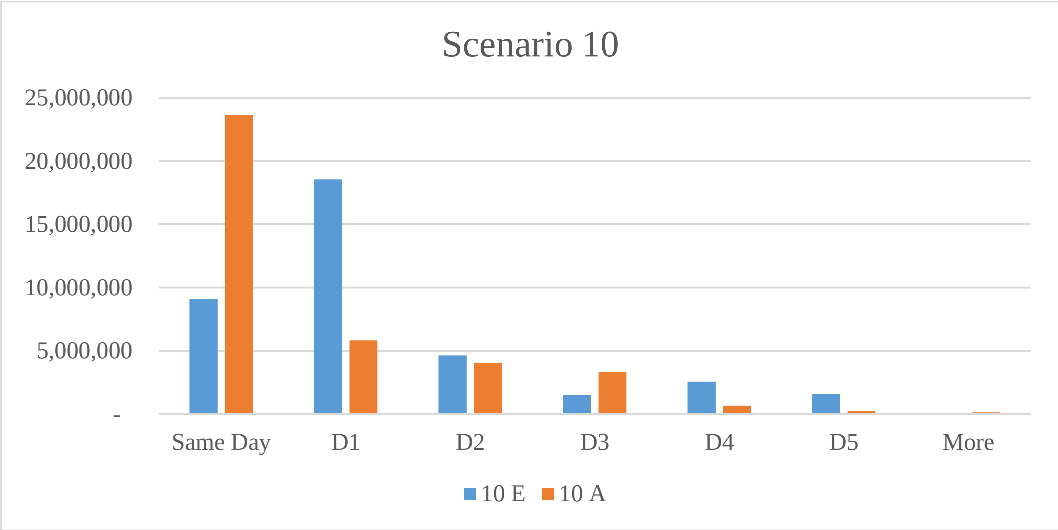

Scenario 5
20,000,000
18,000,000
16,000,000
14,000,000
12,000,000
10,000,000
8,000,000
6,000,000
4,000,000
2,000,000
-
Same Day
D1
D2
D3
D4
D5
More
5 E
5 A

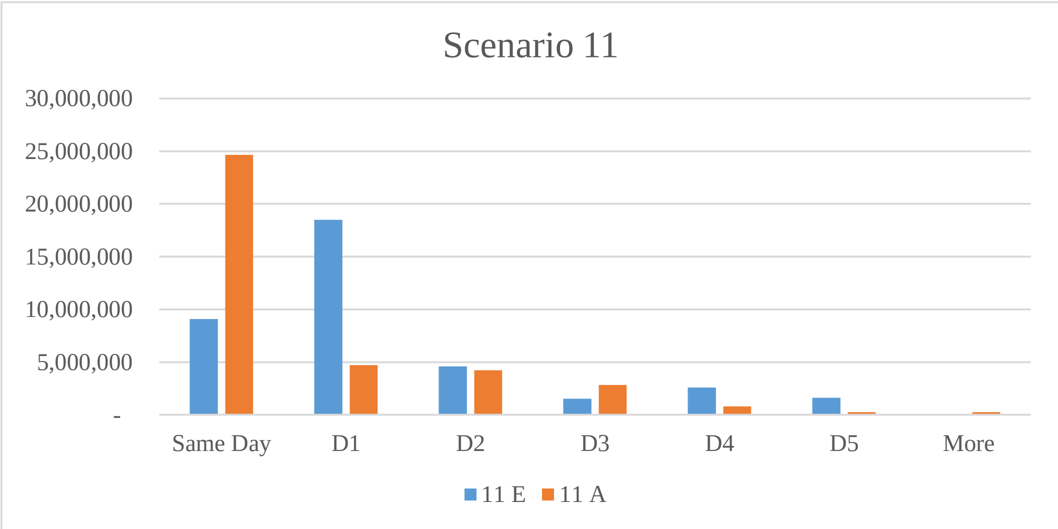

Scenario 6
16,000,000
14,000,000
12,000,000
10,000,000
8,000,000
6,000,000
4,000,000
2,000,000
-
Same Day
D1
D2
D3
D4
D5
More
6 E
6 A


Scenario 7
18,000,000
16,000,000
14,000,000
12,000,000
10,000,000
8,000,000
6,000,000
4,000,000
2,000,000
-
Same Day
D1
D2
D3
D4
D5
More
7 E
7 A


Scenario 8
25,000,000
20,000,000
15,000,000
10,000,000
5,000,000
-
Same Day
D1
D2
D3
D4
D5
More
8 E
8 A


Scenario 9
20,000,000
18,000,000
16,000,000
14,000,000
12,000,000
10,000,000
8,000,000
6,000,000
4,000,000
2,000,000
-
Same Day
D1
D2
D3
D4
D5
More
9 E
9 A


Scenario 10
25,000,000
20,000,000
15,000,000
10,000,000
5,000,000
-
Same Day
D1
D2
D3
D4
D5
More
10 E
10 A


Scenario 11
30,000,000
25,000,000
20,000,000
15,000,000
10,000,000
5,000,000
-
Same Day
D1
D2
D3
D4
D5
More
11 E
11 A

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BIOGRAPHY

The author, Lala Ayu Kantari, is the oldest daughter in her family. She was born in Blitar on July 12, 1996. The formal study was achieved in SDN Purwantoro VI Malang (2002-2008) for elementary school, SMPN 5 Malang (2008-2011) for junior high school, SMAN 1 Malang (2011-2013) for senior high school. In 2013, the author started to begin the college year in Industrial Engineering Department. Institut Teknologi Sepuluh Nopember, Surabaya, Indonesia.

During the college time, the author had actively engaged in several communities and interests. The author worked as a staff in IGCDP Department of AIESEC Surabaya (2015-2016) and as a member of AKATARA HMTI (2013-2015). The author was also a laboratory assistant in Logistics & Supply Chain Management (LSCM) Laboratory of Industrial Engineering Department where she helped the faculty members in laboratory engagement activities for students and practitioners (2015-2017). In the third semester, the author got an opportunity to join Student Exchange program in Universiti Teknikal Malaysia Melaka for one semester. Moreover, she also active to join some programs and events for both national and international such as ITS EXPO 2014 and INCHALL 2016. To get the practical experience, the author has join internship program in PT GMF Aeroasia in the Business Development field in 2016. For further discussion, the author can be reached through email *lalakantari@gmail.com*.