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PERENCANAAN PENGIRIMAN DAN KAPASITAS PENYIMPANAN TERINTEGRASI: SEBUAH STUDI SIMULASI

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AN INTEGRATED SHIPMENT PLANNING AND STORAGE CAPACITY: A SIMULATION STUDY

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AN INTEGRATED SHIPMENT PLANNING AND STORAGE CAPACITY: A SIMULATION STUDY

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AN INTEGRATED SHIPMENT PLANNING AND STORAGE CAPACITY DECISION: A SIMULATION STUDY

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ABSTRACT

In a transportation and distribution system, the shipment decisions, fleet capacity, and storage capacity are interrelated in a complex way, especially when uncertainty of the demand rate and shipment lead time are taken into account. In this paper the effect of various factors on total costs and service level of a distribution system are investigated. The objective is to obtain a better policy related to a number of issues in transportation and distribution under uncertain situation and to obtain insights on which factor affect the performance significantly. This research develops a simulation model that mimics transportation and distribution of bulk cement by the use of ships in a large cement company in Indonesia. The system consists of a storage at the depot and storage at two port of destinations, which then referred to as packing plants. Several numbers of scenario related to storage capacity at port of origins as well as port of destinations, number of ships employed, operating hours of ports, and rules for ship dispatching are then developed. Each scenario is evaluated in terms of shipment costs and service level. A factorial experiment has been conducted and ANOVA has been used to analyze the results. The results suggest that all factors have significant effects on both total costs and service level. However, the use of different number of ships appear to have the most substantial impacts on those two performance measures. It is also observed that a strong correlation exists between total costs and service level and an efficient frontier of cost and service level has been presented. This paper brings an important recommendation to the company as well as insight for maritime logistics in general. Cost is a very important competitive factor for bulk items like cement, and thus the proposed scenarios could be implemented by the company for substantial transportation and distribution cost reduction. In addition, the efficient frontier graph resulted from this study can be used as an internal target or performance benchmark.

Keywords: Bulk Product, Efficient Frontier, Maritime Distribution, Maritime Transportation, Supply Chain Uncertainty

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PREFACE

Alhamdulillah, all praises are belonging to Allah SWT, by whose grace, guidance, and blessing the author can finish this final research entitled "An Integrated Shipment Planning And Storage Capacity Decision: A Simulation Study" by the end of fourth year of study in Department of Industrial Engineering of Institut Teknologi Sepuluh Nopember (ITS) Surabaya.

This final research is conducted as a requisite to finish Industrial Engineering major and to achieve Bachelor degree from Institut Teknologi Sepuluh Nopember (ITS). During the completion of this research, the author receives countless support, motivation, inspiration, and help from various people and communities. Therefore, in this opportunity, the author would like to express his biggest appreciation and gratitude to those who contribute the most and play important part during the study and especially completion of this final research, namely:

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Last, the author realizes that this research is far from perfect. Therefore, the author welcomes positive suggestion and constructive critics from anyone. May this research contribute to academic world and provide improvement for better future.

Surabaya, 11 July 2014

Author

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CHAPTER I
INTRODUCTION

This chapter describes the background, problem identification, objectives, benefits, scope of this research. In the last part of this chapter, the report outline will be described.

1.1 Research Background

Distribution and storage are two important parts in logistics activities. This importance has become more significant in cement industry because cements are low margin and high volume products and will most likely be distributed in bulk using huge transporters whose chartered cost is very high. However, regardless of their high associated costs, these activities are often being overlooked and not managed at best. To mention an example, one of the biggest cement manufacturers in Indonesia with market share of 43.3% should spend 923 billion Rupiah or about 40% of its total expense in 2012 for logistics related activities. This very huge logistics cost is frequently caused by inefficient operation (Madasari, 2012; Renspandy, 2013). Therefore, it is necessary to implement clever planning and good management of resource utilization to gain profits from the business (Christiansen et al., 2011). This means, the company should pay extra attention to lower the logistics cost in order to gain better performance and more profits.

While cements are distributed by both land and maritime shipment, this research focuses at the maritime line since there is huge inefficiency in the process, signaled by low vessels utilization and very long cycle time. Cycle time refers to time spent by a ship to finish the trip and back to depot. It starts from when a ship is assigned for departure in depot until it arrives back in depot. The focus of this research is at the system consisting of one depot (Port A) and two port destinations in which bulk cement are stored in silo and packed into bags to satisfy daily demand. These ports will then be referred to as packing plants. There are two packing plants considered in this system, Port B and Port C. To give a brief description of the maritime shipping, Figure 1.1 shows the system configuration of maritime cement distribution along with their supply and demand characteristics.

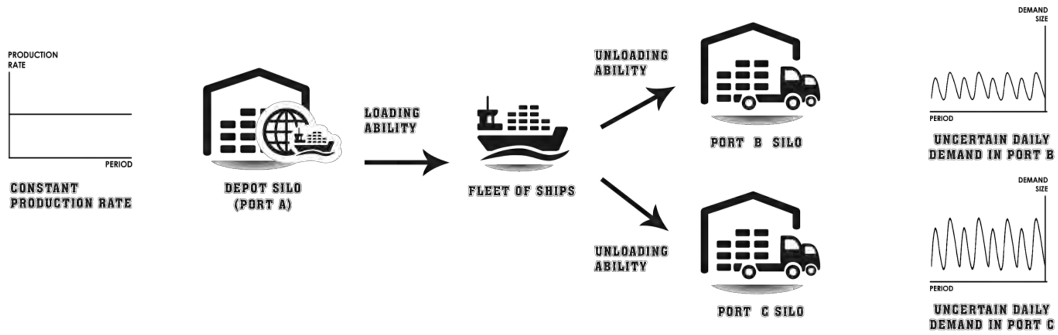

Figure 1.1 Maritime Line System Configuration for Distributing Bulk Cement

The production rate in Port A is constant due to continuous configuration. An estimated of 80% of this production capacity is allocated for in-bag products while the other 20% is allocated for bulk products. These 20% capacity is almost equal to total demand of two packing plants, which is about 4,200 tons per day. These bulk products will then be stored in a dedicated depot silo for maritime distribution with existing capacity of roughly 11,000 tons located close to dock to ease the loading process. The loading process is handled either by a conveyor at the rate of 400 tons per hour or by 6 trucks with total capacity of 150 tons per hour. In existing condition, the loading process can only start immediately if a ship is assigned between 7 am until 7 pm or at 12-hour operational time. Sometimes, this time window restricts the loading ability as ships have to wait in ports when arrives at non-operational time.

After being loaded to ship, these bulk cements are then shipped to packing plants using a fleet of 6 heterogeneous ships leased under time-charter scheme: 2 ships (Ship#1 and Ship#3) at 10,000 tons capacity, 1 ship (Ship#4) at 7,500 tons capacity, 2 ships (Ship#2 and Ship#6) at 6,000 tons capacity, and 1 ship (Ship#5) at 5000 tons capacity. Ship#1, Ship#3, and Ship#4 can only be assigned to Port C, Ship#2 can only be assigned to Port B, and Ship#5 and Ship#6 can be assigned to both packing plants. In addition, there is a very infrequent replenishment in Port B coming from additional depot delivered by a ship named Ship#7. Both packing plants can store bulk cements up to 11,000 tons in silo before packed into bags and released to fulfill customer demand. Whilst silo capacity is the same in both packing plants, demand in Port C is much higher than demand in Port B. This causes instable situation in Port C in terms of stock safety because the interval days of supply is very low. Therefore, a big number of in-transit inventories to Port C are needed to cope with this situation.

From this configuration, it is notable that there are three inventory pools whose capacities need to be balanced in order to minimize the cost while maintaining acceptable service level: silo in Port A, number of ships, and silos in packing plant. Port A can help pooling up decoupling stocks to flexibly synchronize fluctuating demand and constant production rate. Vessels can help carrying in-transit inventories to enable more frequent replenishment in both packing plants. Packing plants silo can help providing safety stocks and anticipation stocks to protect against demand and lead time uncertainties. However, holding these much inventories will result in inefficient operation. Too much stock in silo could result in unnecessary investment while too much in-transit stocks, or in other words too many ships, could result in more frequent and longer waiting times at both depot and packing plants. Moreover, this situation will be worse if loading can only be performed in some restricting time. In turn, this situation will lower the efficiency of the distribution process and increase the operational cost much further. An excess number of ships means more unnecessary money to spend while keeping this number too low will expose lower service level. Therefore, it is necessary to find the best combination of depot silo capacity, loading capacity, fleet number, and packing plants silo capacity in order to minimize the distribution cost while maintaining acceptable service level.

The purpose of this research is to build a model capable to optimize the integrated decision of storage and distribution as described above. In order to make the model valid - or in other words the model can mimic the condition of real world - various uncertainties need to be considered in the model such as uncertainty of demand rate and lead time. These uncertainties play important role in maritime distribution as these are what characterizing maritime problems

(Christiansen, Fagerholt, Nygreen, & Ronen, 2007). In contrast with most previous studies, this research builds a simulation-based model rather than an exact method to include those uncertainties and to investigate the inter-connected decision affecting the company performances (Kelton, Sadowski, & Sturrock, 2006). The simulation will evaluate several combinations of silo capacity, loading time windows, fleet numbers, and packing plant capacity in terms of distribution cost per ton and service level, analyze which factor affect these two performance measures significantly, and how to promote improvement for the company.

1.2 Problem Identification

Based on the background, this research is designed to answer the question of how to determine the best integrated decisions of storage and distribution including silo capacity, operating hours, and fleet number in such way that both cost and risk of having unacceptable service level in packing plants can be minimized.

1.3 Research Objectives

This research aims at several objectives, i.e. to:

1. Develop a number of combinations of depot silo capacity, loading capacity, number of vessels, and packing plants silo capacity, to satisfy demand constrain at packing plants and evaluate the impact in cost per ton and service level of the company
2. Analyze how these factors affect distribution cost per ton and service level

1.4 Research Benefits

The benefits of conducting this research are to:

1. Obtain the best combination of depot silo capacity, loading capacity, number of vessels, and packing plants silo capacity in bulk cement maritime distribution
2. Reduce distribution cost while maintaining acceptable service level

3. Determine which factor(s) significantly affect the cost and service level

1.5 Research Scope

The scope of this research is defined by limitation and assumption.

1.5.1 Limitation

Some limitations set for this research are:

1. Only two packing plants will be considered as destination ports: Port C and Port B, since only those two ports are actively supplied from Port A.
2. The impact of operational time extension is evaluated only at Port A.

1.5.2 Assumption

Some assumptions set for this research are:

1. Inventory movement, including depot replenishment, loading and unloading, demand release in packing plant, occurs hourly in 24-hour time basis.
2. In-house inventory cost per unit is equal to in-transit inventory cost per unit. This assumption makes the cost for holding inventory the same wherever it is located along the supply chain and therefore can be ignored in this research.
3. All processes, including shipping assignment, loading, and unloading can be done during weekends.
4. Ships reliability is high.
5. After departure from packing plants, each ship will directly go to depot and is ready to be assigned for another voyage.

1.6 Report Outline

The following systematic framework will be used in structuring the content of this research report.

CHAPTER I INTRODUCTION

This chapter describes the background, problem identification, objectives, benefits, and scope of this research. In the last part, the report outline will also be described.

CHAPTER II LITERATURE REVIEW

This chapter describes theories and concepts based on existing literatures that have been developed and are used as basis of this research. Some concepts and theories provided in this chapter are maritime logistics, inventory management in supply chain, flexibility in supply chain, and simulation.

CHAPTER III RESEARCH METHODOLOGY

This chapter describes all steps conducted in this research so that the research can be done systematically and well-organized. In general, the research methodology consists of data collection, data processing, model building, scenario generation and experiment, analysis and interpretation, and last, conclusion and recommendation.

CHAPTER IV DATA COLLECTION AND PROCESSING

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

CHAPTER V ANALYSIS AND INTERPRETATION

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

CHAPTER VI CONCLUSION AND RECOMMENDATION

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

CHAPTER II
LITERATURE REVIEW

This chapter describes theories and concepts based on existing literatures that have been developed and are used as basis of this research. Some concepts and theories provided in this chapter are maritime logistics, inventory management in supply chain, flexibility in supply chain, and simulation.

2.1 Maritime Logistics

Logistics is an activity of planning, performing, and controlling the flow and storage of materials effectively and efficiently from suppliers to end customers in accordance with customer demand (Gudehus & Kotzab, 2009). In other words, the logistics activities hold a very important role in a company to ensure the products reach the market on time, on right quantity, and on right quality. Therefore, logistics management should be a focus because it can support increased competitiveness of the company. However, the way to manage the logistics activities in certain companies differs and depends on the product, market area, and the level of supply chain integration (Cooper, Lambert, & Pagh, 1997). For a company operating in islands and covering a quite large area such as Indonesia, the logistics management of the company is in the form of maritime logistics.

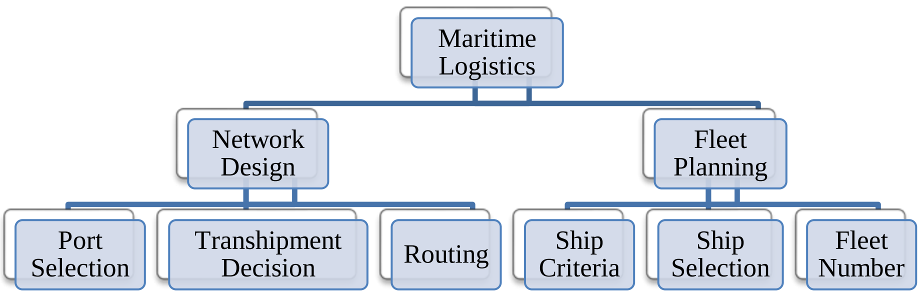

Figure 2.1 Research Area of Maritime Logistics

Maritime logistics is a branch of logistics management which aims to manage all deliveries shipped through huge river, sea, or ocean involving multiple islands by means of vessels or ships. The main interest in maritime logistics is to minimize the cost, fuel consumption, and emissions (Gudehus & Kotzab, 2009). Decisions made are generally related to network design and fleet planning. Activities that fall into network design are port selection, transshipment point location, and route determination for large ships as well as additional route for small vessels. Meanwhile, activities related to fleet planning are ship criteria determination, ship selection, and fleet number and scheduling, determination of capacity, speed, and loading and unloading technology.

To handle maritime operation, a company needs to either buy its own vessels or charter from other providers. Stopford (1997) explains when ships are chartered, the rate is either based on time or voyage. In time charter scheme, the vessels rate is then multiplied by how long the vessels are chartered in order to calculate the total chartering cost. On the other hand, in voyage charter, the chartering cost is determined either by a fixed cost or by freight capacity. The chartering scheme will distinguish what parameters need to be considered in determining how the vessels should be managed. In time charter scheme, some important decisions to make regarding where the ship should go, when it should start, and how many ships need to assign. The purpose of these is to minimize the cost while maximizing efficiency. Under time-charter scheme, no matter where the vessels are waiting, the rate is still incurred to the company and therefore the optimization should aim to minimize the cost by minimizing the number of fleet and to maximize the efficiency by implementing good scheduling so that the waiting activities can be avoided.

2.2 Inventory Management in Supply Chain

Inventory holds a very important role, especially for companies operating under a very dynamic environment, and serves a variety of purposes. Tersine (1994) defines several types of inventory according to purpose it serves. Some of those are working stock, pipeline stock, safety stock, and decoupling stock. Working stock is inventory held to be able to place an order under certain lot size to gain economies of scale. Pipeline stock or sometimes called in-transit stock is inventory put in-transit to allow for the time it takes to transfer material from supply point to demand point. Safety stock or buffer stock is inventory held in reserve to protect against uncertainty in demand or supply. Last, decoupling stock is inventory placed between dependent activities to reduce requirement for complete synchronous operations or in the other hand, to enable flexible operations between two dependent activities.

Regardless of importance of holding an inventory, improper management will cause excessive cost. Many big companies hold inventories of more than 25% of its total assets and therefore should pay a huge cost of money out of it (Pujawan & Mahendrawati, 2010). Therefore, inventory should be managed well to increase the advantages gained from holding inventory while avoiding unnecessary holding costs.

However, the way to manage inventory in single location such as manufacturing floor is quite different from managing inventory for multi-echelon supply chain. In multi echelon supply chains, there are multiple stages with possibly many players at each stage and each supplying another. The goal in this case is to synchronize orders at different stages in such way that there is no unnecessary inventory being held (Chopra & Meindl, 2007). Considering the supply chain model shown in Figure 1.1, there are three points at which inventories might be held: in depot silo in forms of decoupling stock, in vessels in forms of pipeline stock, and in packing plants silo in forms of safety stock.

One way to manage inventories in response to uncertainties is to determine when the replenishment should occur. Pujawan & Mahendrawati (2010) explains a technique to determine when the order needs to be put for replenishment by defining the threshold called reorder point (ROP). The replenishment policy is then to place and order of certain quantity whenever inventory level reaches ROP. Considering uncertainties, ROP can be determined using Equation 2.1.

$$ROP = demand\ during\ lead\ time + safety\ stock \qquad (2.1)$$

When demand is normally distributed, another way to calculate ROP is simply by determining desired service level and finding the associated ROP from the historical data plot. Figure 2.2 below shows the example on how to determine ROP using this approach.

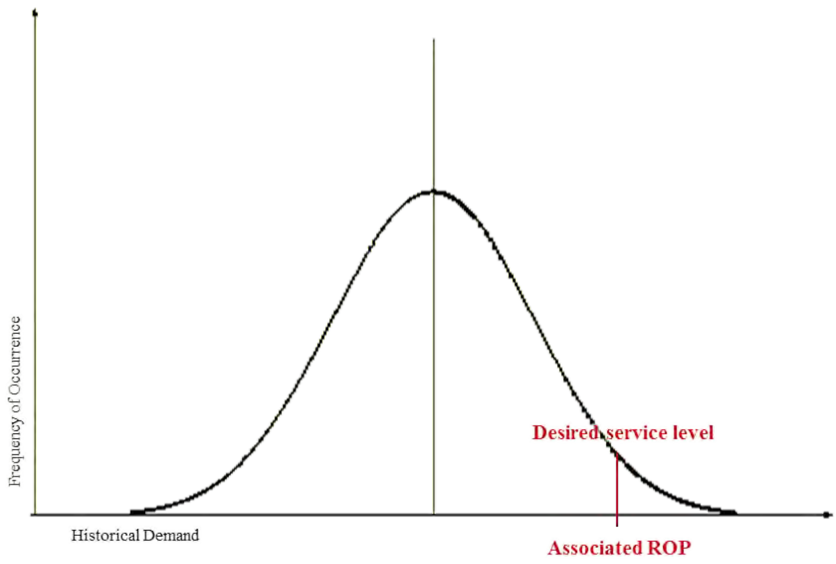

Figure 2.2 ROP Using Normal Distribution Approach (Pujawan & Mahendrawati, 2010)

Figure 2.2 shows that in order to be able to determine the ROP, the company should first determine the service level to satisfy but not to 100%. This means, under uncertain conditions, it is almost impossible to be able to cover all demands. Therefore, a portion of acceptable stock out probability should be allowed.

Service level is obtained by calculating the percentage of orders in one year that are able to be satisfied from stock. There are numerous ways to define service level, however this research refers the service level in terms of on time fulfilled orders or fill rate. Referring to Tersine (1994), service level is calculated by the formula in Equation 2.2.

$$Service\ level = 1 - \left(\frac{number\ of\ cycles\ with\ a\ stockout}{total\ number\ of\ order\ cycles}\right) \quad (2.2)$$

Service level in Equation 2.2 approaches the service level from number of outage since the total number of order cycles is the sum of number of cycles with stock out and number of cycles without the stock out. Thus, by subtracting this ratio from scale of 1, service level can be obtained.

2.3 Flexibility in Supply Chain

Uncertainty has become the nature of business and needs to be dealt with nowadays. Many companies have been deploying operations research concepts and have succeeded to be lean, but failed to be flexible enough to quickly accommodate uncertain demand. Suárez, Cusumano, and Fine (1991) defines flexibility as ability to respond to changes with little penalty in time, cost, quality, or performance. This definition was first meant to define flexibility in terms of manufacturing. To adopt this definition for supply chain, Duclos, Vokurka, and Lummus (2003) defines six dimensions of flexibility in a supply chain: operations system flexibility, market flexibility, logistics flexibility, supply flexibility, organizational flexibility, and information system flexibility.

Flexibility has been viewed in contrast with efficiency while both are very attractive for practitioners. However, due to intense competition in market, flexibility has been much more demanding because it provides competitive advantage to win the competition (Angkiriwang, Pujawan, & Santosa, 2014). A flexible supply chain will be able to quickly adopt changes and implement certain policies in order to satisfy market requirement and therefore the chances to acquire the market will be higher. Furthermore, Angkiriwang, Pujawan, and Santosa (2014) provide a couple of ways in which a supply chain can promote its flexibility: reactive or buffering strategy and proactive or redesign strategy. Reactive strategy is defined as strategy to promote flexibility by reacting to the uncertainty to maintain its certain service level. Several activities included in this strategy are providing safety stock, capacity buffer, supplier backups, and add safety lead times. Proactive strategy, on the other hand, is defined as strategy to promote flexibility by redesigning product, process, and networks. Activities included in this strategy are component commonality, postponement, risk pooling, sub-contracting, flexible supply contract, lead time and setup time reduction, and alternative routing. Both strategies aim to increase flexibility so that the supply chain can quickly respond and adapt to changes.

2.4 Simulation

Simulation is a method to mimic the behavior of real system using computer software (Kelton, et al., 2006). One of advantages why simulation is used to solve problems lies in its ability to accommodate stochastic behavior or real system which enables better validation of system modeling. Simulation is also very good in evaluating several scenarios without interfering with the real system so that both cost and time can be saved in the process (Kelton, et al., 2006). Besides that, time needed to generate an answer for complex system is relatively short compared to other analytical methods such as exact method, heuristics, and meta-heuristics. However, in terms of results, simulation can generate acceptable solution through exhaustive search because it is a descriptive model. Descriptive model produce estimates for a set of performance measure and that is what simulation does. Analytical model, on the other hand, provide the better solution by acting prescriptively, which seeks the optimal argument values for specified objective function under several constraints (Altiok & Melamed, 2007)

Distinguishing its characteristics, simulation can be categorized as static and dynamic based on stationarity of its parameter; continuous and discrete by the occurrence of event; and deterministic and stochastic by randomness of parameter (Altiok & Melamed, 2007). In this research, the problem will be simulated under discrete condition because variables and attributes are both needed to be analyzed only when an event occurs. This characterizes the problem as discrete event simulation.

Like other system modeling, simulation needs verification and validation steps before deployed to evaluate scenarios. Verification is conducted to ensure that the model is made in accordance with the logic and process flow by how it is expected. Validation, on the other hand, is conducted to ensure that the model is made in accordance with the real conditions of the observing field (Kelton, et al., 2006). Both steps are very important and thus need to be performed to make sure the model is valid and verified.

2.5 Hypothesis Testing and Analysis of Variance Statistical Test

Another important part of simulation is interpretation of results. When running a simulation model, several scenarios are often being developed. Thus, it is necessary to determine whether any factor significantly affect the output. Therefore, it is important to determine a significant difference among outputs of several simulation scenarios. If there are only two scenarios, a hypothesis testing can be performed to determine whether the result is significantly different. Hypothesis testing is performed by determining whether two means of variances of different population significantly different from each other. This is essentially important when there are only two different outputs to examine. Hypothesis testing will be performed in validation test to check whether the null hypothesis, simulation outputs are not significantly different from raw data, is statistically accepted. This is conducted by deploying a t-test since the number or sample is quite small due to data availability constrains. If the t-stat value falls between the interval of –t to +t obtained from t-student distribution table under desired confidence level, the null hypothesis is accepted.

In further analysis, a test following a full factorial design is needed to test the effect of every combination of factor levels. Therefore, there will be more than two scenarios to compare. Hence, an Analysis of Variance (ANOVA) should be carried out instead (Montgomery, Runger, & Hubele, 2011). ANOVA is used to test whether two or three populations have a specified means difference. The null hypothesis of this statistical test is that all population means are equal. Thus, when this hypothesis is accepted, it implies that mean value of tested variables are not significantly different. This method will be used in factor analysis, on which ANOVA will check whether any factor or combination of several factor result significantly different output. This analysis will provide leads to determine what factor affect simulations output significantly. This significant difference can be inferred from small p-value or large F-Value. The larger the F-Value or the smaller the p-value, the more significant the difference of simulation output as results of different scenario.

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CHAPTER III
RESEARCH METHODOLOGY

This chapter describes all steps conducted in this research so that the research can run in systematic way. In general, the research methodology consists of data collection, data processing, model building, scenario generation and experiment, ANOVA test, analysis, and interpretation, and last, conclusion and recommendation.

The flowchart of this methodology is given as follows.

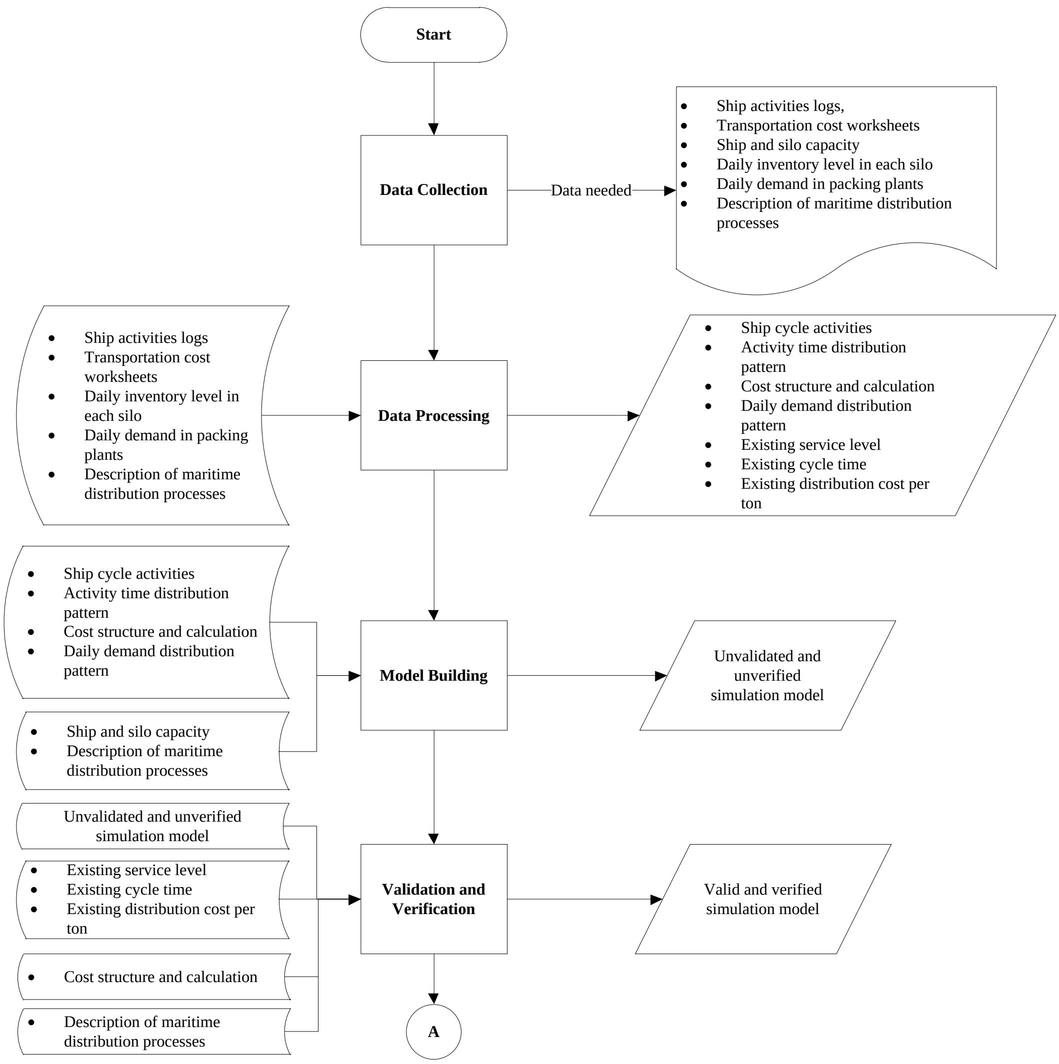

Figure 3.1 Flowchart of Research Methodology

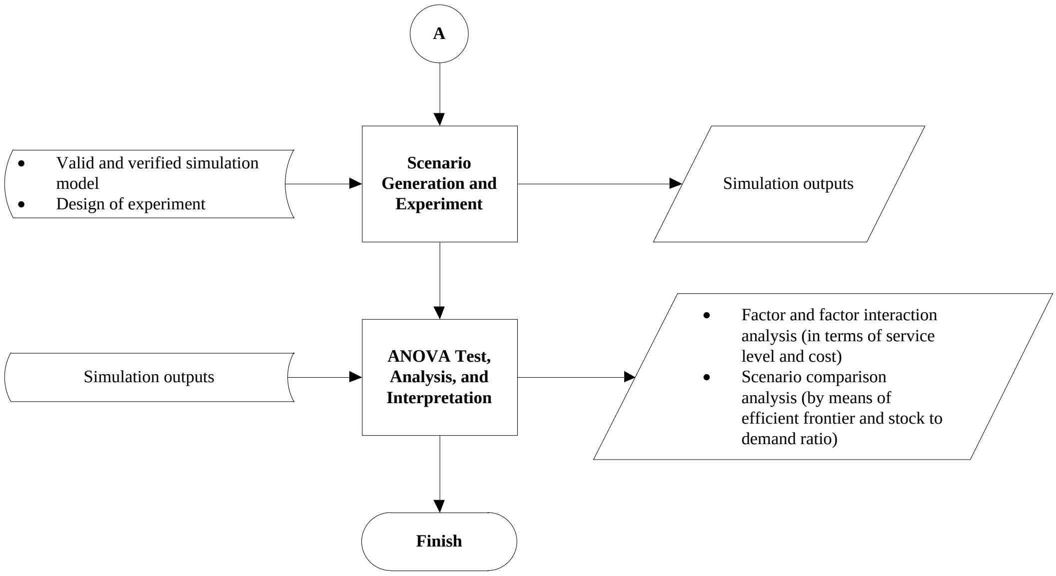

Figure 3.1 Flowchart of Research Methodology (continuation)

3.1 Data Collection

This step is carried out to obtain real data to get a picture of existing system. All data are obtained from the distribution and transportation department of a cement manufacturing company. In this research, ship activities logs, transportation cost worksheets, silo capacity, historical daily inventory level, and demand in packing plants, and description of cement maritime distribution processes are collected.

3.2 Data Processing

At this stage, obtained data are processed to get some specified parameters to picture the existing condition which then will be used to build simulation model. Ship activities logs are collected to determine ship cycle activities and distribution pattern of duration of each activity. This distribution fit is obtained by performing a goodness of fit test using ARENA ® InputAnalyzer to determine the best fit distribution along with its parameter. The pattern distribution will be used as an input parameter in simulation. Other important parameters to process are existing cycle time and total cost per ton. These will be used for validation purpose.

Other data to process at this stage is the historical data of inventory level in each packing plant. These data will then be used to determine the existing service level in each packing plant as a result of distribution system. Since the company does not have sufficient data to describe how many demands are not met, this research defines the service level based on inventory position and assumes that whenever stocks fall to zero, there should be unfulfilled demand during the day. This mechanism follows the service level calculation based on outage as proposed by Tersine (1994). The formula to calculate service level is shown in Equation 2.2.

After determining existing service level and the way to calculate it, the next important step is to determine the pattern of daily demand based of historical data. Since demand in both packing plant come every day in fluctuating size, goodness of fit test will be performed to define what distribution best describe the pattern. This goodness of fit test will also be carried out with ARENA ® InputAnalyzer. Last, level of inventory for each silo and ship master schedule is processed to define how the company schedules its shipping. This is also validated with an interview to company's employees.

3.3 Model Building

After obtaining all input parameters required to build the simulation model, the next step is to build the model itself. Combining input parameters, ship and silo capacity and specification, and details of maritime shipping process, an ARENA simulation model is built.

The model is built to examine the implementation of new rules of scheduling and assignment without ignoring uncertainty because it holds a very important role in maritime distribution. Therefore, a simulation model is chosen rather than exact or heuristics method. It is expected that by simulating the system with all its uncertainties, the integrated decision on storage and distribution can be examined, especially on how effective it can improve the system to make the distribution more efficient. However, in order to do so, a verification and validation model is necessary.

Model verification is conducted to ensure that the model is made in accordance with the logic and process flow by how it is expected. Validation, on the other hand, is conducted to ensure that the model is made in accordance with the real conditions in the observing field. The verification process is done in two stages. The first stage is conducted to make sure there is no error when the model runs. The second verification stage is conducted to make sure the logic of simulation flow makes sense, reasonable, and according the logical flow of how it is designed in the first place. This verification will also check whether and mathematical calculation is carried out correctly by the model. This process is done by evaluating ship scheduling mechanism and cycle time and service level.

The validation process is conducted by comparing simulation output with primary data obtained directly from the field. Technically, this process is done by comparing the cycle time, service level, and cost per ton for each packing plant as a result of distribution system. The comparison will deploy a hypothesis testing using t-test distribution to check whether the result of simulation significantly different with raw data. If the output of simulation result does not differ significantly from the existing data, it can be concluded that the simulation model is valid and therefore can be used for further experiment in the research.

3.4 Scenario Generation and Experiment

After building a validated and verified simulation model, some improvement scenarios are then developed. This research conducted a full factorial design in generating scenario. Therefore all combinations of possible silo capacity, operation time, and number of fleets will be evaluated.

3.5 Simulation Output and ANOVA Test

The simulation model is built to evaluate the impact of each combination of storage and distribution decisions on service level and distribution cost per ton. It is expected that operating lower number of ships is while maintaining acceptable service level is possible in one or more combination. Therefore, from each replication, the overall service level and distribution cost will be collected.

After obtaining simulation output, ANOVA test will be carried out to test whether any factor or combinations of factors significantly affect the output measures. Since there are two outputs to collect, the ANOVA will be performed for each output measure univariately. In each ANOVA test, the interaction of factors will be limited to two levels of interaction.

3.6 Analysis and Interpretation

Several analyses will then be carried out after performing ANOVA tests. First, an analysis of an analysis of factor significance will be carried out to determine which factors or interactions of factors provide significantly different output. From this analysis, it is expected that the most influencing factor can be identified to provide more insights to the company on how to obtain better performance in its maritime distribution.

Next, analysis of logistics efficient frontier will be performed based on scenario output. This analysis will compare all scenarios and choose several competing scenarios. These competing scenarios will then be analyzed further to determine which one provides better performance for the company.

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CHAPTER IV
DATA COLLECTION AND PROCESSING

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

4.1 Data Collection

As previously mentioned, several data are collected to describe the existing performance of the distribution system and to define several input parameters in order to build the simulation model. Several data to collect are ship activities logs, transportation cost worksheets, silo capacity, historical daily inventory level, and demand in packing plants, and description of cement maritime distribution processes.

4.1.1 Ship Activities Logs

In order to be able to describe the efficiency of existing system, it is important to know the set of activities as well as the duration of each activity performed by a ship when distributing the product in one cycle. Therefore, the ship activities logs for each voyage are collected. These logs are regularly updated by the staff of the company. By analyzing data from ship activities logs, some information describing the existing system can be obtained.

4.1.2 Transportation Cost Worksheets

Another important data to collect is the worksheet of transportation cost since cost is one of parameters used in validation process to make sure the model developed satisfies the condition of real system. Besides, this transportation cost calculation, more importantly the tariff per day, will be used to measure the performance of several scenarios of improvement.

From the worksheets, the cost component of transportation cost can be described. The transportation cost consists of charter cost, insurance cost, loading cost, and unloading cost. These cost components will be important input to calculate total cost of each scenario. However, not all costs will be considered in the simulation model as some associated costs are not affected by distribution performance, such as insurance cost and loading and unloading cost. Insurance cost is incurred in each shipment with a determined value and hence can be considered as fixed cost because not affected by any factor changed in any scenario. Similar to this, loading and unloading cost will also be ignored since its value has been fixed for every ton of shipment, not affected by factors being examined in this research.

4.1.3 Silo Capacity, Historical Daily Inventory Level, and Demand in Packing Plants

After collecting data related to ships, the next important data to collect are those about inventories as well as the capacity of silos and release in packing plants. These data are very important, from these sources, the service level, which is the most important parameter in logistics, can be derived. Besides, the historical data of release and the size of silo in depot and packing plants can be obtained from these data.

However, from company records, it is still very hard to obtain real on-hand inventory in silo. This is because the company considers in-transit inventory in ships arriving in packing plants as on-hand inventory, regardless they have been unloaded or not. Therefore, some stock levels can reach more than 11,000 tons, which is roughly the current capacity of silo in depot and all packing plants. This also causes confusions to determine when the stock out really occurs as the in-transit inventory hides those zero on-hand inventory.

4.1.4 Description of Cement Maritime Distribution Processes

Besides all data mentioned previously, some system description are also obtained from interviews with personnel of distribution and transportation division of the company. From these interviews, the existing rules of shipment, ship assignment and routing decision, and obstacles in operation are obtained.

In the current system, ships are dispatched whenever they are available in depot. This has been conducted in such way because the personnel realizes that the chartering rate is under time basis, therefore to maximally utilize the ship is a preferred decision, regardless of the inventory level in packing plants. Besides that, the fact that depot can only proceed arrival during an interval of 7 am to 7 pm has been stated from these interviews. It may be possible to extend this time windows, but no such critical suggestion has been made so far. Therefore, the time windows decision still takes place until now.

While the assignment of ship is handled by operational personnel, there is no fixed assignment rule to decide where the ships should go. The in-transit inventory so far has been neglected, making congestion often occurs in destinations. However, the personnel have realized that those bigger-capacity ships should be directed to packing plants with larger demands. Other very important information from these interviews is the availability of port in destination ports. The personnel show that port in Port B is dedicated to handle the company distribution, while port in Port C is chartered as it is operated by public agency. This makes the congestion is heavier and the waiting time is significantly longer.

4.2 Data Processing

As previously stated, the collected data are then processed to describe the existing performance of the distribution system and to define several input parameters in order to build the simulation model. Data to process are ship activities logs, transportation cost worksheets, and historical daily inventory level and release in packing plants. From each set of data, ship cycle activities and important parameter from each, chartering cost calculation, and daily demand pattern in each packing plant can be determined.

4.2.1 Ship Cycle Activities

First, the ship activities in one cycle can be mapped from ship activities logs, started by defining shipping stages. By classifying the activities into stages, it is easier to build the process block and to define the duration of each. In this research, activities are divided into 14 stages, each representing a set of activities. The stages are shown in block diagram in Figure 4.1.

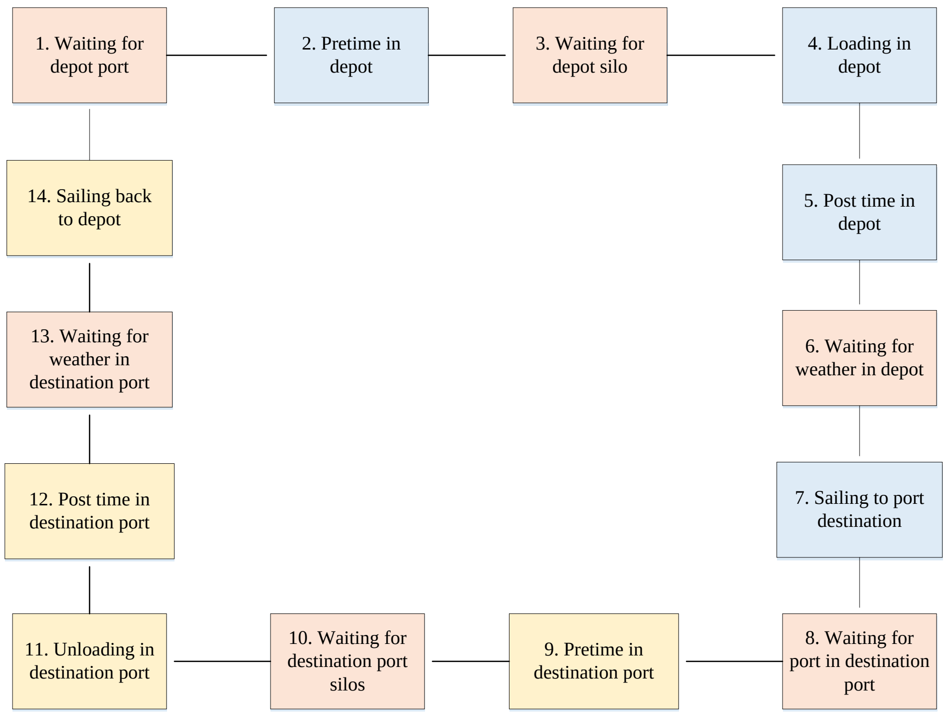


Figure 4.1 Block Diagram of Ship Activities

The description of each stage is given below.

1. Waiting for Port in Port A

   This stage occurs when a ship has to wait near the Port A before being able to port because of congestion. Congestion in Port A only happens when all ports are already occupied by ships assigned to handle shipment, making the coming ship cannot port immediately. This stage consists of unnecessary activity in form of waiting and therefore can be avoided by scheduling the ship arrivals so that the ships are not coming to Port A at the same time.

2. Pretime in Port A

This stage refers to a set of activities conducted to prepare porting and loading, including waiting the scout ship, surveying the draft, processing administrative and legal documents, and installing the loading equipment. Since all of these are required, this stage is considered necessary and will happen every time when a ship arrives in Port A. Therefore, the duration of pretime will be determined by distribution fit. This distribution fit test will be performed using InputAnalyzer in ARENA®. The data input for this is shown in Table 4.1.

Table 4.1 Data Input for Pretime in Port A

#	Pretime Port A	#	Pretime Port A	#	Pretime Port A
1	5.6	21	1.9	41	2.3
2	4.6	22	4.7	42	2.7
3	3.0	23	2.2	43	2.6
4	3.9	24	2.5	44	4.5
5	2.8	25	2.9	45	3.7
6	2.9	26	4.5	46	5.0
7	5.0	27	1.8	47	7.0
8	5.2	28	2.8	48	2.8
9	3.6	29	2.5	49	3.7
10	3.8	30	2.5	50	1.8
11	6.0	31	1.7	51	3.6
12	2.2	32	3.3	52	3.5
13	2.4	33	2.2	53	2.1
14	5.9	34	2.5	54	7.2
15	2.3	35	3.2	55	2.5
16	3.0	36	4.4	56	2.3
17	2.3	37	2.8	57	4.3
18	5.5	38	2.8	58	2.8
19	2.8	39	4.7	59	1.7
20	3.7	40	2.1	60	5.3

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

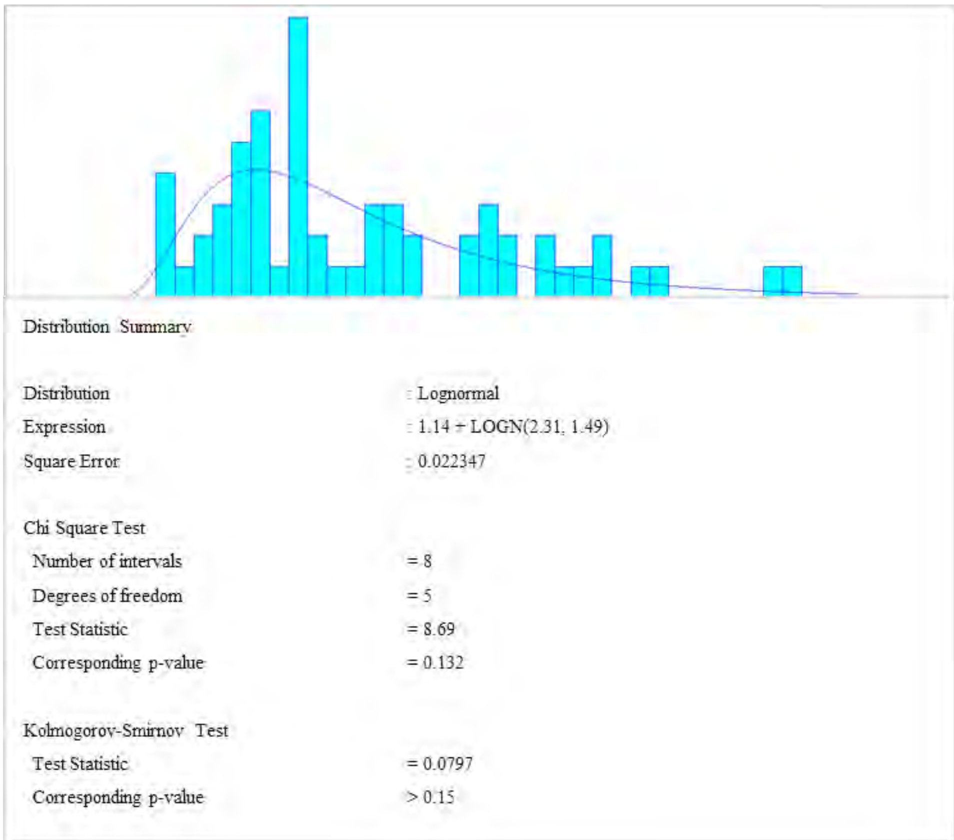


Figure 4.2 Distribution Fit for Pretime Port A

From Figure 4.2, the best fit distribution in terms of square error is lognormal distribution with log mean 2.31 and log standard deviation 1.49. The corresponding p-value from Kolgomorov-Smirnov (K-S) test is greater than 0.15, implying that this result has been proven statistically in more than 15% confidence level. Even so, the square error is quite low, only at 0.022. Therefore, this result can be proceeded further to input in the model.

3. Waiting for Port A Silo

   This stage occurs only when there are not enough inventories in Port A silo to load. A brief discussion with the company officer shows that the company will avoid starting the loading process when the inventory is not enough for full-loading. In other words, the loading process can only be started immediately when available inventory enables the loading process to occur continuously until the ship reaches full capacity. Since it has been stated previously that both silo replenishment and loading process occurs hourly, each at Replenishment Rate (RR) and the Loading Rate (LR) consecutively, the minimum starting Inventory Level for Loading (ILL) satisfying this condition can be derived.

To do so, let LT = loading process time. We are interested to find the IL such that the total of ILL and the replenished silo inventory during LT is minimally equal to ship capacity (SC).

$$ILL + RR \times LT = SC \tag{4.1}$$

Since

$$LT = {}^{SC}/_{LR} \tag{4.2}$$

or to put in words loading time is equal to ship capacity divided by loading rate, the equation 4.1 can be rewritten as

$$ILL + RR \times \frac{SC}{LR} = SC \tag{4.3}$$

Through algebraic manipulation, the IL can be expressed as

$$ILL = SC \times \left(1 - \frac{RR}{LR}\right) \tag{4.4}$$

Therefore, the waiting for silo Port A will occur only if when a ship reaches this stage, the inventory level is below the ILL calculated with Equation 4.3. The duration of this stage will then be the time required to build up inventory until it reaches the ILL.

4. Loading in Port A

   This stage refers to the process of loading the inventory into any assigned ship. The loading can be done either by conveyor at the rate of 400 ton per hour or by truck at 150 ton per hour, using 6 trucks. This stage is considered necessary activities, taking place at various times depending on the capacity of the ship. The time required for loading in Port A is the ship capacity divided by Port A loading rate as termed by LT previously.

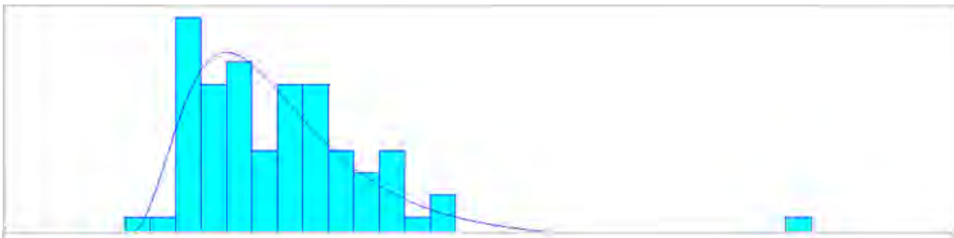
5. Post Time in Port A

   This stage refers to set of process conducted to uninstall loading equipment, to conduct post-loading draft survey, and to follow the scout ship. This stage occurs right after the loading process has finished. This stage is also considered necessary activities and will take place for each ship after the loading process in Port A. Data input for post time Port A is given in Table 4.2.

Table 4.2 Data Input for Pretime Port A

#	Posttime Port A	#	Posttime Port A	#	Posttime Port A
1	2.2	21	1.5	41	2.6
2	2.7	22	2.4	42	3.6
3	2.0	23	7.2	43	3.5
4	2.3	24	3.2	44	2.3
5	2.1	25	2.7	45	1.8
6	2.4	26	1.8	46	2.9
7	3.1	27	3.3	47	2.8
8	3.2	28	1.7	48	3.2
9	2.3	29	1.9	49	2.3
10	2.5	30	3.0	50	4.0
11	3.3	31	2.2	51	2.1
12	3.6	32	2.5	52	2.0
13	2.2	33	1.7	53	1.8
14	4.0	34	3.0	54	3.0
15	3.6	35	3.0	55	2.0
16	2.1	36	3.4	56	1.8
17	1.8	37	2.8	57	2.2
18	3.0	38	2.7	58	1.7
19	2.6	39	3.8	59	2.0
20	3.0	40	1.7	60	1.4

From these data, a goodness of fit test is performed to obtain distribution fit for post time Port A. The output of InputAnalyzer for this data is given in Figure 4.3.



Distribution Summary

Distribution	: Lognormal
Expression	: 1 + LOGN(1.64, 0.877)
Square Error	: 0.012037
Chi Square Test	
Number of intervals	= 7
Degrees of freedom	= 4
Test Statistic	= 3.17
Corresponding p-value	= 0.532
Kolmogorov-Smirnov Test	
Test Statistic	= 0.0899
Corresponding p-value	> 0.15

Figure 4.3 Distribution Fit Test for Post Time Port A

It is clearly from Figure 4.3 that lognormal distribution with log mean parameter of 1.64 and log STD 0.877 best fit the post time data, indicated by very low square error and very good corresponding p-value from chi-square K-S test.

6. Waiting for Weather in Port A

This stage occurs stochastically, only when the weather raises an alarming situation, which holds the ships to depart for safety reason or when the tides are too high or too low which will postpone the ship departure. This stage is unnecessary but also uncontrollable. Therefore, the occurrence of this stage will be randomized under specified probability according to historical data. Based on historical data, 13 out of 60 shipments (22% of the cases) from Port A encounter bad weather, causing the ships have to wait before departing. Distribution fit tests shows that of all 13 waiting cases, lognormal distribution with 2+LOGN(10.6, 13.6) is the best to describe the pattern.

7. Sailing to Packing Plants

   This stage is necessary, representing the activities of ships on-sea, travelling to ports of destination. The duration of this stage is based on the historical data to get to any destination. Since there are two port destinations, it is necessary to determine the distribution fit for sailing time to each of port. Based on 60 shipments during 7-month period (10 shipments to Port B and 50 shipments to Port C), the number of data input for distribution fit test for sailing time to each port is different.

   After performing distribution fit test, lognormal distribution with parameters of 21 + LOGN (7.2, 8.18) is obtained to be the best compared to others to describe the pattern of sailing to Port B. Although it is noticeable that the square error is quite big, indicating that the fit quality is not very good, but since there are only 10 data available, this will be considered acceptable to be utilized as input parameter for simulating sailing time from Port A to Port B in later model. Consequently, the best fit distribution for sailing time to Port C is normal with expression of NORM (39.8, 4.79). This results a very low square error and very high p-value from Chi Square test, indicating that it fits very well with data and therefore will be deployed later in the model.

8. Waiting for Port in Destination Port

   Port B is operated only to serve the company, making the situation is the same with Port A because only assigned ships come to the port. Different from that, in Port C congestion happens not only because of ships assigned by the company, but also by ships arriving for other companies and by conditions specified by port authorities. Therefore, waiting occurs more frequently and cannot be controlled by scheduling. From the data, it is summarized that in 30 out of 50 cases of shipments, waiting is caused by external factors. Therefore, it can be generalized that 60% out of total shipments will face waiting in Port C. The duration of waiting, when occurred, is determined from distribution fit for all 30 cases of waiting caused by external factors from Table 4.6. The result shows that triangular distribution with parameters of (10, 34.6, 256) results in very small value of squared error and high p-value. Therefore, this result will then be used as an input parameter in the model.

9. Pretime in Destination Port

   Similar with pretime in Port A, this stage is also dealing with activities of porting. However, regardless of loading, at this stage the pretime accounts for unloading purposes. Therefore, this stage refers to a set of activities conducted to prepare porting and unloading, including waiting for the scout ship, surveying the draft, processing administrative and legal documents, and installing the unloading equipment. This is also necessary activity. Distribution fit test shows that pretime in Port B has lognormal distribution with expression of 1 + LOGN (2.5, 2.4) while pretime in Port C follows a triangular distribution expressed as TRIA(1,1.92,7.69).

10. Waiting for Destination Port Silo

    Waiting for destination silo refers to waiting for adequate space in packing plant silo for unloading. Therefore, this stage refers to waiting activities until the inventory in packing plant silo reaches the maximum level (or in other words until the empty space in silo reaches the minimum level), such that the unloading can be conducted continuously until ship cargoes are empty. To calculate this maximum Inventory Level for Unloading (ILU), let UT denotes Unloading Time, DR denotes Demand Rate, UR denotes Unloading Rate, and SS denotes Silo Size. ILU is then the inventory level such that the Empty Space of silo (ES) plus demand released during UT is equal to Ship Capacity (SC).

$$ES + DR \times UT = SC \tag{4.5}$$

While unloading time is equal to ship capacity divided by unloading rate, or mathematically expressed as

$$UT = {}^{SC}/_{UR} \tag{4.6}$$

Equation 4.5 can be rewritten as

$$ES + DR \times \frac{SC}{UR} = SC \tag{4.7}$$

Through algebraic manipulation, ES can be expressed as

$$ES = SC\left(1 - \frac{DR}{UR}\right) \tag{4.8}$$

Last, since $ILU = SS - ES$, ILU can be stated as follows.

$$ILU = SS - SC\left(1 - \frac{DR}{UR}\right) \tag{4.9}$$

Hence, if inventory level in packing plant silo is still higher than ILU, the ship should be waiting until the inventory reaches or fall below ILU. This is what causes the waiting for destination port silo happens only at certain condition and can be minimized by implementing inventory routing policy as what this research suggests.

11. Unloading in Destination Port
    This stage refers to activities of unloading in packing plants, which happens for duration of $UT = {}^{SC}/_{UR}$, as previously mentioned. This is

considered necessary activity because occurs for each ship in destination port.

12. Post Time in Destination Port

    This stage refers to process conducted to uninstall unloading equipment, to conduct post-loading draft survey, and to follow the scout ship. This stage occurs right after the unloading process has finished. This stage is also considered necessary activities and will take place for each ship after unloading process in Port A. Distribution fit test shows that post time in Port B follow a lognormal distribution expressed as 1+LOGN(2.14, 1.08) while in Port C follows a triangular distribution expressed as TRIA(1, 2.69, 7.69).

13. Waiting for Weather in Destination Port

    This stage refers to waiting until the weather allows the ship to start sailing to Port A or next destination in case the weather is in alarming situation. The bad weather happens stochastically and is determined by historical probability. In Port B, weather causes delay for 40% (4 out of 10 shipments) of shipments while in Port C, the number is 18% (9 out of 50 shipments). Distribution fit test shows that waiting duration in Port B follows an empirical distribution with parameters of (0.000, 2.000, 0.692, 29.200, 0.769, 56.400, 0.769, 83.600, 0.923, 110.800, 0.923, 138.000) while waiting in Port C follows a uniform distribution expressed as UNIF(1, 17).

14. Sailing Back to Port A

    This is the last stage in ship cycle, after all the processes, the ship will return back to Port A. However, some ships are assigned to another packing plant or to other places because of company's policy. However, this research assumes all ships will head back to Port A. Based on distribution fit test, sailing time back to Port A from Port B follows a lognormal distribution expressed as 19 + LOGN (13.7, 22.4) while from

Port C follows a triangular distribution with expressed as TRIA (29, 30.6, 48).

Determining these stages is very important to build the model in the next section. All these stages will then be converted into simulation logic in which each process will have the determined pattern of duration and probability.

4.2.2 Cost Calculation

After defining ship activities which build up the cycle, the next step is to define by how the costs are calculated in the system. This mechanism is summarized from the transportation cost worksheet and the use of engineering economics. First, it is clear that transportation cost is built from shipping cost. Second, to enable the comparison of building up another silo, either in Port A or packing plants or even both, the annualized cost of silo investment cost should be considered. Detail about each cost component is described as follows.

4.2.2.1 Shipping Cost

Shipping costs refers to payment for chartering a ship for duration of period. The calculation of this cost will be based on time-charter rate, meaning the rate is based upon the duration of chartering. However, the cost consists of two different rate apply for both on-road (moving) and off-road (non-moving) time of the vessels. During on-road time, the chartering rate includes the fuel cost (full chartering rate). When being off-road, the chartering rate only includes payment for ship owner (off-road chartering rate). The mathematical expression of the shipping costs (ShC) is as follows:

$$ShC = OCR \times OCT + FCR \times FCT \tag{4.10}$$

where SC = shipping cost in a cycle, OCR = daily off road chartering rate, ORT = off-road time in days, FCR = daily full chartering rate, and FCT = full chartering time in days. FCR is calculated based on average of historical data, since the rate is changing biweekly depending on fuel cost during the certain period. The FCR value for Ship#1, Ship#2, Ship#3, Ship#4, Ship#5, and Ship#6 consecutively is 184.5 billion, 126.7 billion, 193.1 billion, 155.4 billion, 125.5 billion, and 126.7 billion. Referring to explanation from the company officer, about 30-40 percent of the chartering rate is used for fueling up the ships. Therefore, in this model, the value of OCR is equal to 70% of FCR. OCT and FCT, on the other hand, will be calculated based on ship activities.

4.2.2.2 Silo Investment Cost

The last term of cost is the conversion of investment cost to annual cost using the assumption of 12% annual interest rate and 20 years of economic life. Let the silo investment is about 50 billion Rupiah, the investment cost for each silo ($\dot{IC}$), is given as follows.

$$\dot{IC} = P \times \left(\frac{A}{P}, i, n\right) \tag{4.11}$$

$$\dot{IC} = 50 \times \left(\frac{A}{P}, 12\%, 20\right)$$

$$\dot{IC} = 50 \times 0.1339 = 6.695 \text{ billion Rupiah}$$

Therefore, the silo investment cost (IC) for building a certain number silo, each with capacity of 11,000 tons, will be calculated as

$$IC = \dot{IC} \times S \tag{4.12}$$

where IC = total annualized investment cost, $\dot{IC}$= 6.695 billion, which is the amount of investment for each silo built, and S = number of new silo built. Therefore, to convert this total cost into cost per ton unit (CPT), the sum of both costs is then divided by the amount of shipment (AS).

$$CPT = \frac{IC+ShC}{AS} \tag{4.13}$$

4.2.3 Service Level Calculation

Based on historical data, Figure 4.4 and Figure 4.5 show inventory position in each packing plant in 8-months period.

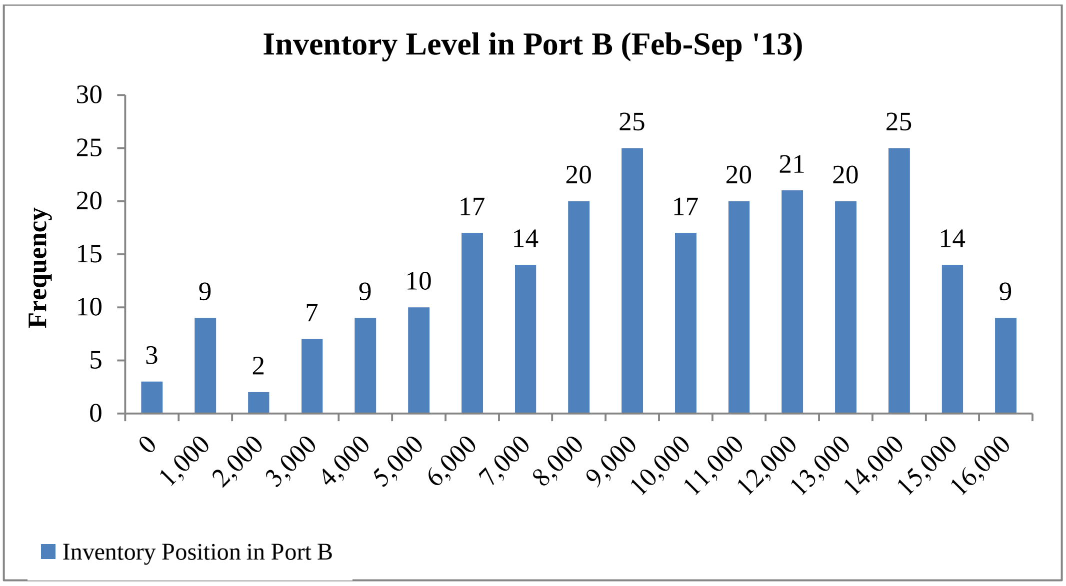


Figure 4.4 Inventory Position in Port B

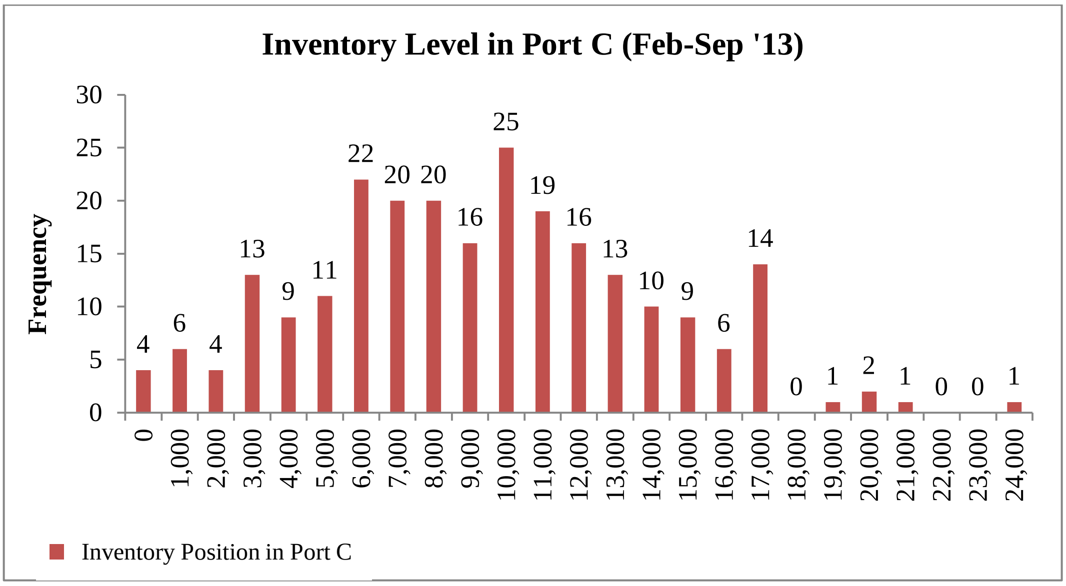


Figure 4.5 Inventory Position in Port C

Figure 4.4 and Figure 4.5 show several days with zero inventories. These days will be referred to as stock out days (SO). Hence, the service level is determined from the percentage of days in which all demands are satisfied (SD) to the total number of days in the period (SD + SO). Service level in packing plants will then be calculated by Equation 2.2.

To convert this into overall service level (OSL), average daily demand size in each packing plant will be considered. To do that, SL will be multiplied by the average demand in i-th packing plant (Di) for each packing plant and divided with the total average demand (D) as shown in Equation 4.14.

$$OSL = \frac{1}{D}\sum_{i=1}^{n} SL_i \times D_i \quad (4.14)$$

Using this formula, SL in Port B, SL in Port C, and the OSL can be determined.

$$SL\ BWI = \frac{239}{3+239} = 0.9876$$

$$SL\ CWD = \frac{238}{4+239} = 0.9835$$

$$\text{OSL} = \frac{(0.9876 \times 1020) + (0.9835 \times 3060)}{1020+3060} = 0.9845$$

It is clear that service level in both packing plants is very good, more or less 98%, which makes 98% overall service level. It is also notable that Port B accounts for roughly 25% or overall service level while Port C accounts for the rest 75%. This implies that Port C should have high service level to make the overall service level acceptable; otherwise it will fall to unsatisfying level.

4.2.4 Daily Demand Pattern

After determining existing service level and the way to calculate it, the next important step is to determine the pattern of daily demand based of historical data. Since demand in both packing plant come every day in fluctuating size, a goodness of fit test will be performed to define what distribution best describe the pattern. Therefore, the daily demand in each packing plant from February to September is tested using ARENA InputAnalyzer. The histogram of demand in both packing plants is shown in Figure 4.6 and Figure 4.7.

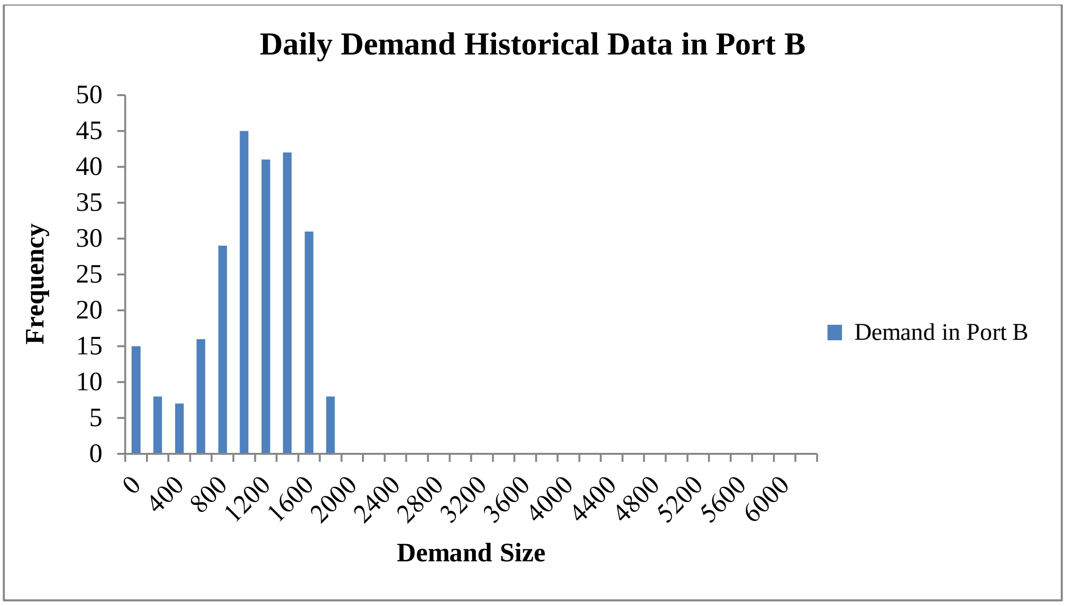


Figure 4.6 Histogram of Demand Size in Port B

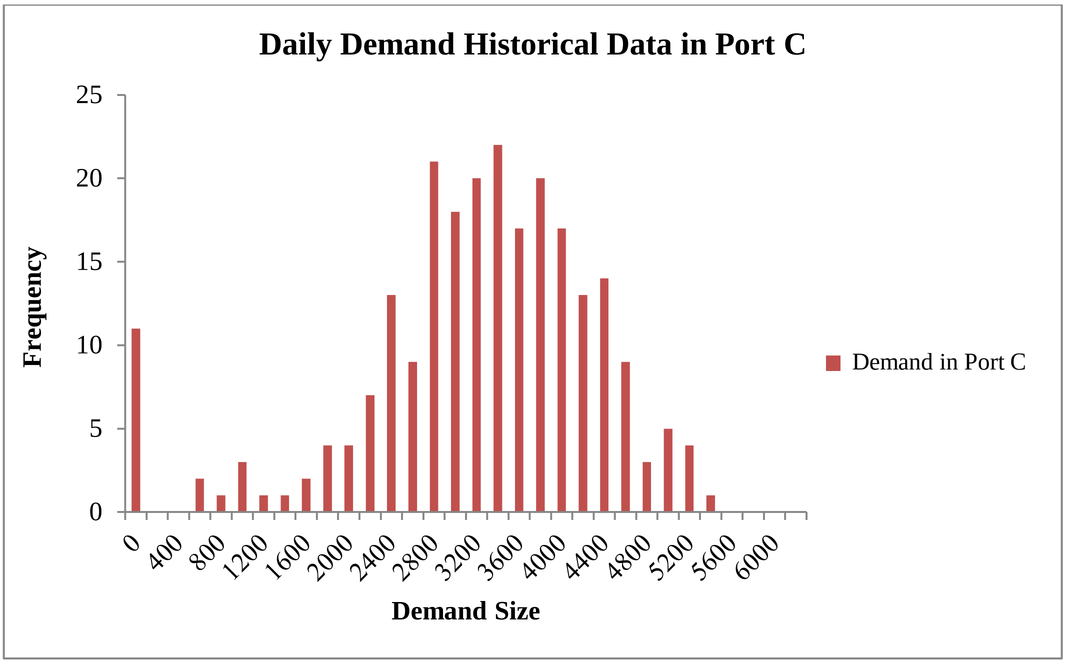


Figure 4.7 Histogram of Demand Size in Port C

From data used to generate histograms in Figure 4.6 and Figure 4.7, a distribution fit test then performed after removing all zero size demands. The goodness of fit test based on these data shows that demand in both packing plants follow normal distribution with mean of 1,020 tons and standard deviation of 383 tons in Port B and 3,330 tons and standard deviation of 827 tons in Port C. It is notable that demand in Port C is much higher than demand in Port B by ratio of 3 to 1.

4.3 Model Building

After obtaining all input parameters to simulate the system, the next step is to build the simulation model using ARENA ®. In general, the model is divided into six main submodels: (1) ship activities, (2) hourly-based event, (3) daily based event, (4) periodical based event, (5) replication based event, and (6) scenario performance writer. All these submodels play important role either for distribution modeling purposes or reporting purposes. Besides the six submodels, the simulation has been constructed along with main dashboard to ease monitoring purposes. The interface of this simulation model is shown in Figure 4.8.

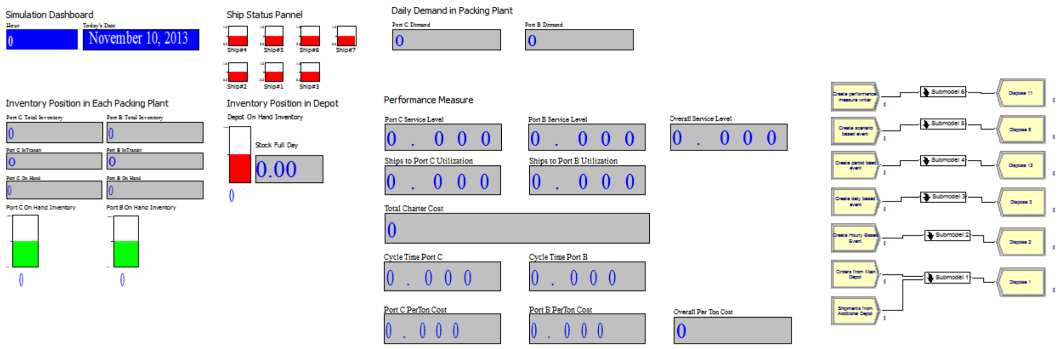


Figure 4.8 Simulation Model Interface

4.3.1 Submodel 1: Ship Activities

Submodel 1 consists of main model of simulation. It consists of all activities of ships in a cycle both for those assigned in Port A and other additional depot. This additional depot refers to other depot which sometimes supplies the packing plant with additional bulk cement. Therefore, the simulation accounts for two shipment sources as shown in Figure 4.9.

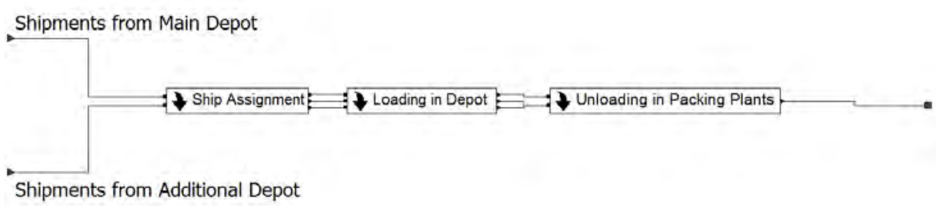


Figure 4.9 Two Sources of Shipments in Submodel 1

On existing system, whenever a ship is available in Port A, it will be assigned to packing plant directly. There is no main rule for determining which packing plant should be visited. However, the company has restricted the big ships (Ship#1, Ship#3, and Ship#4) to only depart to Port C because the demand is larger and the minimum draft constrain is satisfied. The other ships are free from any restriction. However, referring to historical data, Ship#2 is mostly assigned to Port B. The other two ships from Port A, Ship#5 and Ship#6 are undedicated, therefore can be assigned to any port. Last, ships from additional depot will only sail to Port B and only be processed if the inventory in Port B needed backup supply. The general flowchart of ship activities in the simulation process is shown in Figure 4.10.

Step 1. Start the cycle by assigning ships for delivering orders when all restrictions for dispatching ships are relieved. Ship assignment is the first main process in Submodel 1. It consists of a set of modules responsible for assigning the orders into shipments. All orders generated will first be held by hold module until a ship is ready to deliver it and criticality constrain is satisfied. When these conditions are met, which is checked by the hourly-event submodel (Submodel 2), a signal releasing the order from hold module will be sent and processed to choose the available ship and to load the shipment in the next process.

Step 2. Generate time for pretime activities then move the ship for pretime.

Step 3. *Check* whether all conditions restricting the ship for loading are relieved. If yes, proceed to loading. Otherwise, hold until all restrictions are relieved.

Step 4. *Proceed* to loading for duration of loading time, calculated using Equation 4.2. If the conveyor is available, use conveyor. Otherwise, use truck.

Step 5. *Update* on-hand inventory in Port A and in-transit inventory to destination. On-hand inventory = on-hand inventory – ship capacity and in-transit inventory to destination = in-transit inventory + ship capacity.

Step 6. *Generate* time for post time activities then proceed the ship for post time.

Step 7. *Check* whether the weather condition allows the ship to depart. If yes, proceed to departure. Otherwise, generate delay time and postpone the departure.

Step 8. Generate sailing time to destination and set sail.

Step 9. Check whether the ship may proceed to docking immediately. If yes, proceed to docking. Otherwise, hold until all restrictions are relieved.

Step 10. Generate time for pretime activities then process the ship for pretime.

Step 11. Check whether the space in packing plant silo is enough for unloading. If yes, proceed to loading. Otherwise, hold until the space is adequate.

Step 12. Proceed to unloading for duration of unloading time calculated Equation 4.3.

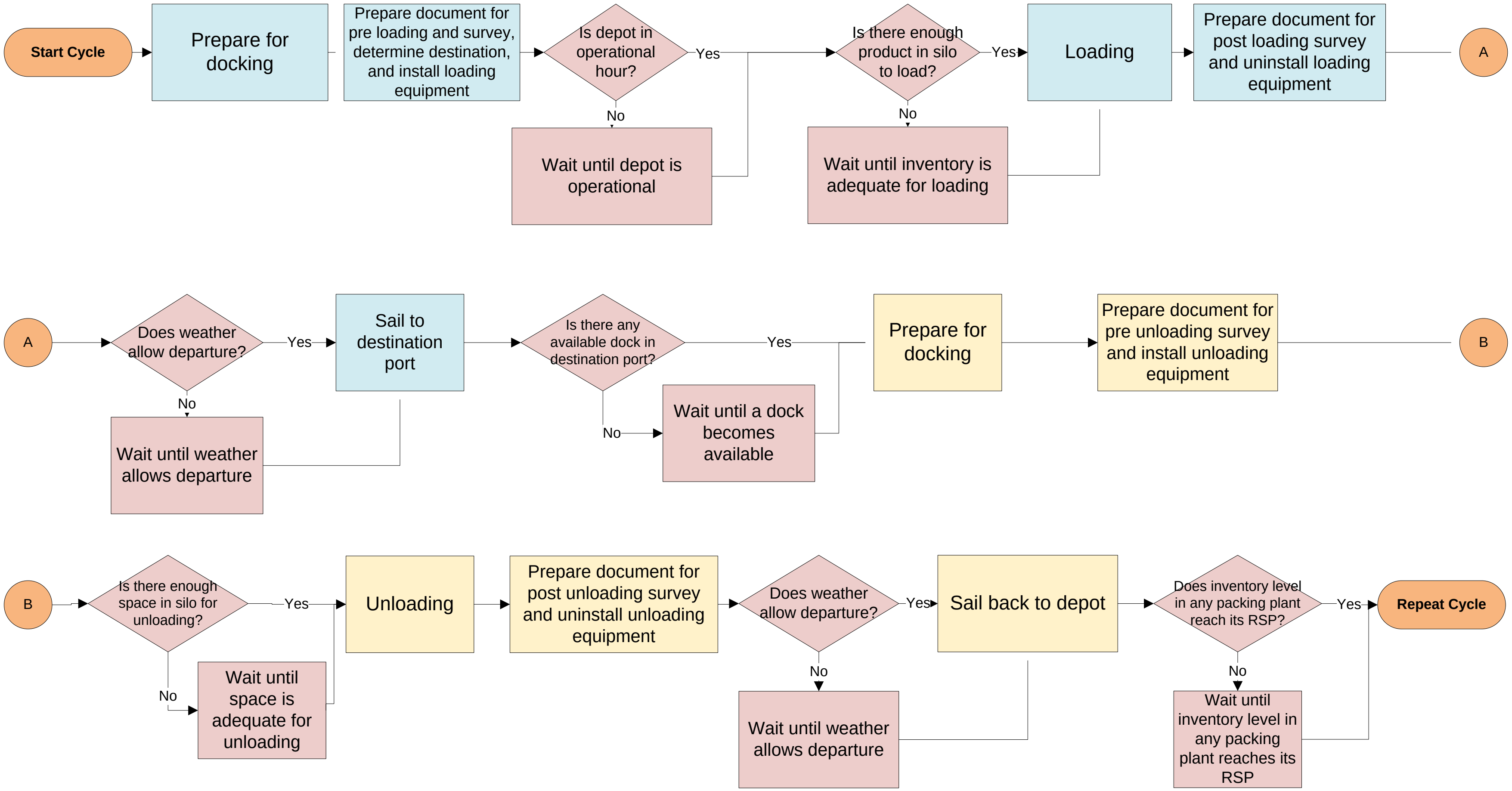


Figure 4.10 Ship Activities Flowchart

Step 13. Update on-hand inventory in packing plant silo and in-transit inventory to destination. On-hand inventory = on-hand inventory + ship capacity and in-transit inventory to destination = in-transit inventory - ship capacity.

Step 14. Generate time for post time activities then process the ship for post time.

Step 15. Check whether the weather condition allows the ship to sail. If yes, sail back to Port A. Otherwise, generate delay time and postpone the departure.

Step 16. Sail back to Port A. Sailing back to Port A ends ship physical activities during unloading processes. However, in the model, the cost is calculated after the ship arrives back in Port A.

Step 17. Last process in simulation model is to update the status of ships after the voyage and to calculate the per ton cost of the distribution system. However, only those ships assigned from Port A after initialization period (or warm up) will be considered in this cost calculation. Shipments from additional silo and shipments assigned from initialization period will be ignored.

After surpassing all the steps, the order will be disposed from the system. The new order will then be processed when shipment signal is sent by the Submodel 2.

4.3.2 Submodel 2: Hourly-Based Event

Submodel 2 consists of events triggered hourly. Therefore, the entity running across this submodel is generated every hour constantly. There are four processes triggered by this entity: (1) inventory replenishment in Port A, (2) demand fulfillment in packing plants, (3) ship dispatching, and (4) clock counter updating. Figure 4.11 shows the four main processes in Submodel 2.

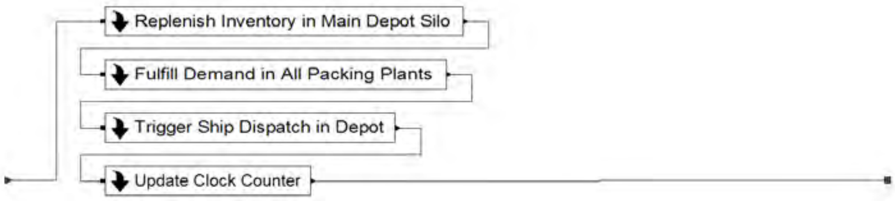


Figure 4.11 Processes in Submodel 2

Inventory in Port A is replenished every hour under constant rate of 185 ton per hour. Since inventory in silo is in form of resources, this entity release 185 resources every hour when used inventory is more than or equal to 185. Otherwise, it releases all used inventory, implying the silo is full.

After replenishing inventory, the entity will then trigger demand fulfillment in both packing plants. It first checks whether on-hand inventory can satisfy demand. If yes, then demand is fulfilled. Otherwise a portion of demand is unfulfilled, which later will be classified as stock out on Submodel 3 if it continues until the end of the day. After demand in all packing plants fulfilled, total inventory in both packing plants is updated, where total inventory = on-hand inventory + in-transit inventory.

After fulfilling demand, the entity will then trigger ship dispatch. In order to signal ship dispatch, two conditions should be satisfied. First, inventory in packing plant should fall under its critical level. Second, at least one of available ships in Port A can be assigned to the packing plant. When these conditions are met, the entity will send signal to hold module in Submodel 1 to release one of orders so that it can be proceeded further.

The last process of Submodel 2 is clock updating. Clock update enables incremental value of clock variable and reset it when the day ends. This clock update is used to determine whether a ship has to wait in Port A due to operational hour constrain.

4.3.3 Submodel 3: Daily-Based Event

Submodel 3 deals with daily events. The entity in the submodel generated constantly every day and mostly used to update variables or print out results in spreadsheets. Submodel 3 consists of three main processes: (1) determining daily demand (2) updating service level, and (3) printing demand and inventory position. Since the model built accommodates warm up period as initialization period, both updating service level and printing demand and inventory positions are only performed when the warm up period has passed.

Demands in packing plants are generated every day following normal distribution pattern as described previously. However, since the standard deviation is quite large relative to its mean, there is a chance that it generates negative number, which may cause error message during simulation. Therefore, demands in both packing plants need to be adjusted when it approaches zero. After adjusting these demands, the next step is to split them into hourly demand, since demands are fulfilled every hour, as previous stated in Submodel 2.

Besides generating demand, the daily-generated entity is used to calculate service level in both packing plant. To calculate service level, the number of days with full-satisfied demand (SD) and the number of days with stock out (SO) need to be calculated in each packing plant. The service level is then calculated daily following Equation 2.2 and Equation 4.14.

Last, the entity is used to trigger the collect several important measures and write them in the specified spreadsheet for later use. Since this research builds a distribution simulation, it is important to keep tracking demand and on-hand inventory level in both packing plants. Hence, this simulation study utilizes Read/Write module to record these data on a spreadsheet file.

4.3.4 Submodel 4: Period-Based Event

Submodel 4 consists of several modules; mainly handle the process of writing the output periodically into spreadsheet. This periodic outputs are such service level, which can be accumulated based on period. This is very important for validation purposes since service level on existing condition can be on tri-month period. Therefore, Submodel 4 deals with entity which comes every 90 days. Every time the outputs have been collected, all periodic variables will be reset.

4.3.5 Submodel 5: Replication Based Event

Submodel 5 only handles calculation of investment cost. This process actually can be handled manually. However, to ease the process, this task is included in the model. Submodel 5 deals with entity generated only once in one replication on the first period. This entity triggers the calculation of investment cost following the Equation 4.11.

4.3.6 Submodel 6: Scenario Performance Writer

Submodel 6 is built for the purpose of writing outputs. The simulation model will collect many performance measure, two of which will be used in analysis is distribution cost per ton and overall service level. Therefore, along with several other parameters, these two measures will be collected by Submodel 6 in the spreadsheet file.

4.4 Model Validation and Verification

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

4.4.1 Model Verification

Verification is performed in two steps. First, the model is tested for errors by ARENA model check to ensure the simulation can run. The result of this test is shown in Figure 4.12.

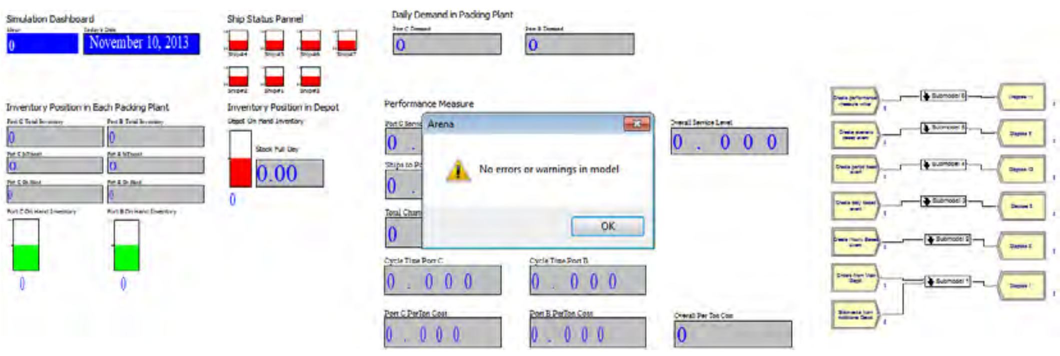


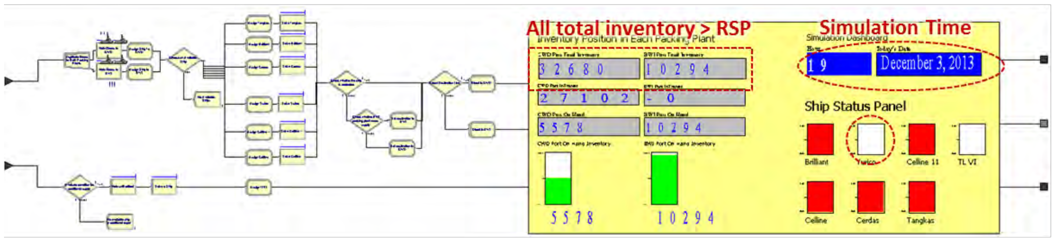
Figure 4.12 Error Check in ARENA

The second verification step is performed by examining several simulation processes separately to check whether the model behaves according to its design or all variables are updated to their new values correctly. Therefore, verification of logical expression and mathematical calculation will be performed. Hence, ship scheduling and calculation of cycle time and service level will be checked.

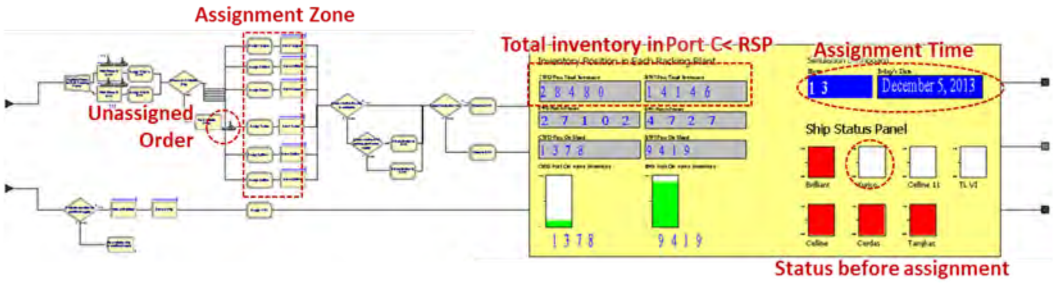
4.4.1.1 Ship Scheduling Verification

The task of controlling ship scheduling is carried out by ship assignment process in Submodel 1 and triggering ship dispatch process in Submodel 5. The rule is that ship can only be assigned when a ship is available and total inventory in the packing plant is below RSP. To ease the monitoring process, a dashboard describing status of each ship and inventory level in packing plant is built and posted in ship assignment process in Submodel 1 as shown in Figure 4.43. A red-colored box in ship status means the ship is already assigned while a white-colored box indicates the ship is available in Port A.

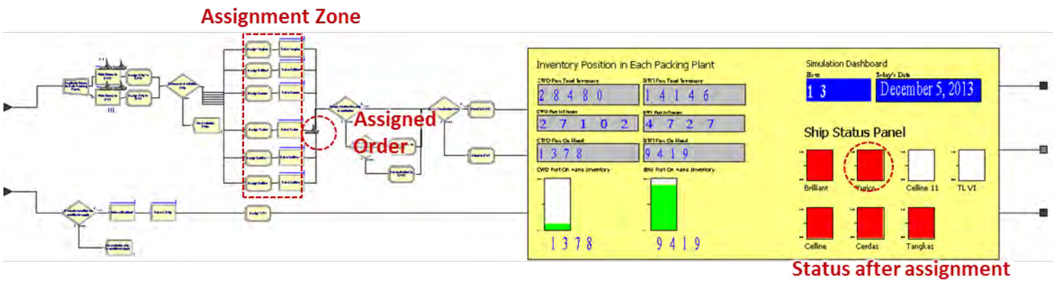
Figure 4.13 (a) shows a condition when there is an available ship in Port A but all packing plants have total inventory of more than their respective RSP, making the ship has to wait in Port A for an assignment. In this particular scenario, RSP for Port C is set to 28,500 and RSP for Port B is set to 7,312. The ship is then assigned two days later after total inventory in Port C drops to 28,480 as shown in Figure 4.13 (b). However, since during this time the ship has just been ordered to process the shipment, the status has not been updated yet. As shown in Figure 4.13 (c), when this ship has been assigned, the ship status changes into red and will be back to white after the shipment is made and ship returns home. This scheduling mechanism is applied for all ships delivering the product from the Port A.



(a)



(b)



(c)

Figure 4.13 Ship Status and Inventory Level in Packing Plants Dashboard

4.4.1.2 Cycle Time and Service Level Verification

Cycle time and service level are two of performance measures obtained from data and therefore can be tested later for validation by comparing the data with simulation output. Moreover, these measures will be analyzed further to obtain the best scenario and to determine what factors contribute the most to each one of these measures. Therefore, it is important to make sure that the model calculates these values correctly.

Cycle time is defined as time interval between ship assignment in Port A and ship arrival in Port A back after voyage. It includes all activities including waiting to be assigned. Verification is conducted by testing whether what is displayed in ARENA (which is calculated by ARENA system by TNOW at the time the cycle ends minus the time the ship has been assigned) is equal to the sum of output in the spreadsheet (which is the time for each process). The ARENA display of cycle time is shown in Figure 4.14 while output in the spreadsheet is shown in Figure 4.15.

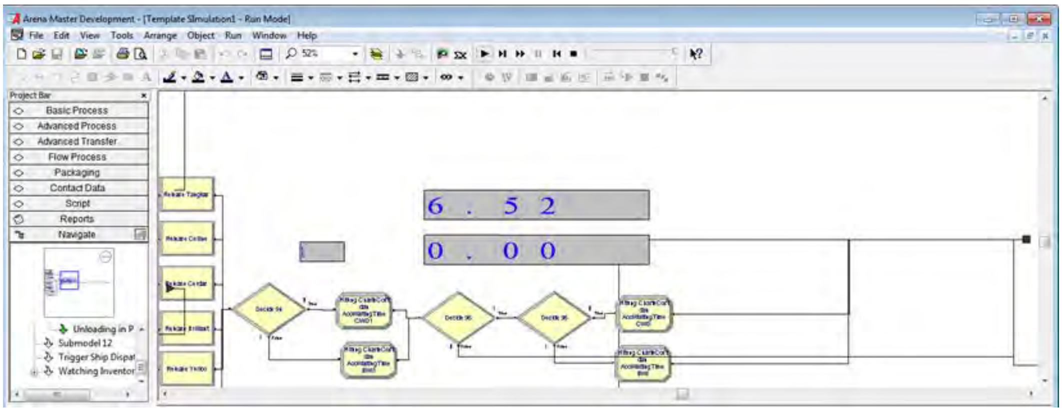


Figure 4.14 Cycle Time Output in ARENA

Waiting for Port in Port A and Assignment	Pretime in Port A	Waiting for Stock in Port A	Loading in Port A	Post Time in Port A	Waiting for Weather in Port A	Sailing Time to Port B
0.000	0.101	0.149	0.583	0.137	0.166	0.997

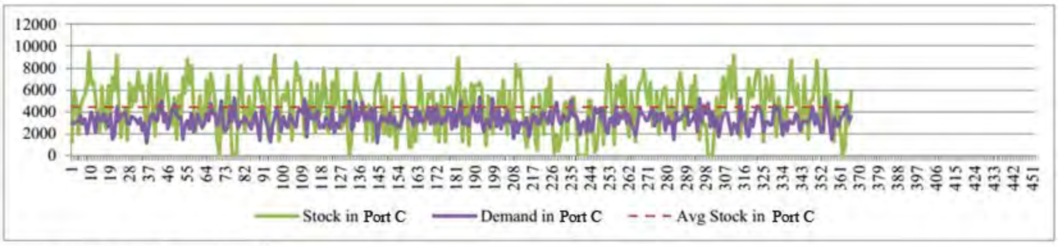
Waiting for Port in Port B	Pretime in Port B	Waiting for Silo in Port B	Unloading in Port B	Post Time in Port B	Waiting for Weather in Port B	Sailing Time Back to Port A
0.000	0.230	1.970	1.069	0.090	0.000	1.029

Cycle Time
6.521

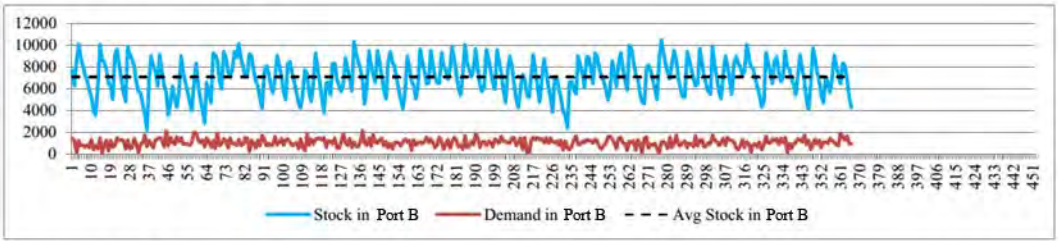
Figure 4.15 Process Time in Spreadsheet File

Since the calculation in ARENA is equal to sum of processes time in the spreadsheet, it can be concluded that the cycle time calculation is verified. Consecutively, service level will be checked by comparing the result of simulation output with the one calculated manually by looking at the inventory position profile during the simulation. The service level for 366 days of simulation in ARENA is given in Figure 4.16 while the daily inventory profile in spreadsheet is given in Figure 4.17.

Figure 4.16 Service Level in ARENA



Stock Outs in Port C 13



Stock Outs in Port B 0

Figure 4.17 Daily Inventory Profile in Spreadsheet

Using Equation 2.2, service level in each packing plant will then be calculated.

$$\text{SL in Port C} = 1 - \left(\frac{13}{366}\right) = 1 - 0.035 = 0.9645$$

$$\text{SL in Port B} = 1 - \left(\frac{0}{366}\right) = 1 - 0 = 1$$

Using Equation 4.14, the OSL will be calculated.

$$\text{OSL} = \frac{(0.9645 \times 3060) + (1 \times 1020)}{1020 + 3060} = \frac{2951.37 + 1020}{1020 + 3060} = \frac{3971.37}{4080} = 0.9734$$

The result of manual calculation of OSL to ARENA output is the same. Hence, the calculation of service level in ARENA has been verified. After verification, the model is then tested for validation to ensure the model can represent the real system.

4.4.2 Model Validation

Validation will be carried out by comparing cycle time (CT), service level (SL), and cost per ton (CPT) for each packing plant (Port B and Port C) obtained from company data and simulation output under existing situation (Scenario 0). To do this, the Scenario 0 I s set to run for 30 replications, each with warm-up of 30 days and replication length of one year (with total of 395 days, 365 days in a year plus 30 days of warm-up period). CT is collected per voyage, SL is collected per tri-month period, and CPT is collected per replication. These data are then tested for significant difference. Since there is very limited number of existing data, t-test is chosen with additional assumption of unequal variances. Using 95% of confidence level, a report of t-Test using Data Analysis of Microsoft Excel is generated and shown in Table 4.3.

For validation purposes, it is important to look at the t-Stat values and compare it with t-Critical two-tail values. Generally, all t-Stat values are within the range of negative value of t-Critical two-tail to its positive value, implying that under 95% confidence level, there is no statistically significant difference between simulation output and real data. These results validate the simulation model, meaning that it can represent the real system and therefore can be analyzed further.

Table 4.3 Statistical Significance T-Test Assuming Unequal Variance

	CT_PTB_SIM	CT_PTB_REAL	CT_PTC_SIM	CT_PTC_REAL
Mean	11.02	9.72	10.35	11.22
Variance	7.20	12.54	7.05	18.64
Observations	74	9	146	40
Hypothesized Mean Difference	0.00		0.00	
df	9		47	
t Stat	1.06		-1.22	
P(T<=t) one-tail	0.16		0.12	
t Critical one-tail	1.83		1.68	
P(T<=t) two-tail	0.32		0.23	
t Critical two-tail	2.26		2.01	

	SL_PTB_SIM	SL_PTB_REAL	SL_PTC_SIM	SL_PTC_REAL
Mean	1.00	0.99	0.96	0.99
Variance	0.00	0.00	0.00	0.00
Observations	50	3	50	3
Hypothesized Mean Difference	0.00		0.00	
df	2		2	
t Stat	1.00		-2.01	
P(T<=t) one-tail	0.21		0.09	
t Critical one-tail	2.92		2.92	
P(T<=t) two-tail	0.42		0.18	
t Critical two-tail	4.30		4.30	

	CPT_PTB_SIM	CPT_PTB_REAL	CPT_PTC_SIM	CPT_PTC_REAL
Mean	248,817.92	206,108.14	209,825.94	218,993.77
Variance	3,979,528,161.21	5,344,369,214.27	7,238,421,743.59	7,386,530,788.21
Observations	74	9	137	37
Hypothesized Mean Difference	0.00		0.00	
df	10		57	
t Stat	1.68		-0.58	
P(T<=t) one-tail	0.06		0.28	
t Critical one-tail	1.81		1.67	
P(T<=t) two-tail	0.12		0.57	
t Critical two-tail	2.23		2.00	

4.5 Scenario Generation and Experiment

This study tries to find alternative ways to reduce the logistics costs while maintaining acceptable service level. The basic idea is that there is an interrelationship between the capacity of silo at Port A, the number (and total capacity) of ships, and the capacity of silo at the packing plants. Those three stages are treated as interconnected activities that should have balanced capacity in order to improve the throughput, that is, to serve the demand better at lower costs. It may be the case that reducing the number of ships is possible but larger storage capacity would be needed to maintain an acceptable service level. However, given the problem complexity, how those factors interact each other are not quite obvious and hence simulation experiments with scenario generations would be necessary. Some of the alternatives explored in this simulation are:

1. Reducing the number of ships, which will directly reduce the transportation costs, but it may also reduce the service level. It is the point of interest to find out whether or not working with fewer ships would still be acceptable from service level point of view. As pointed out earlier, there are six ships from Port A to handle the distribution, each with different specification on capacity and destination. Table 4.4 shows the specification of each ship.

   Table 4.4 Specification of Each Ship

No	Ship Code	Capacity	Destination
1	Ship#1	10,000 ton	Port C
2	Ship#2	6,000 ton	Port B
3	Ship#3	10,000 ton	Port C
4	Ship#4	7,500 ton	Port C
5	Ship#5	5,000 ton	Port C & Port B
6	Ship#6	6,000 ton	Port C & Port B

   In this research, 3 levels of "number of ships", namely 6, 5, and 4 are examined. Six-ship level refers to situation where all ships are chartered. Five-ship level means one of undedicated ships will be laid off, in this case, Ship#5. Last, four-ship level means both of the undedicated ships will be laid off.
2. Adding storage capacity at the Port A and in one of the destinations (in this case silo in Port C because of its high demand and large proportion of ship waiting due to silo capacity constraint). This will obviously increase storage costs in terms of additional investment. For this purpose, the annualized cost for silo investment has been calculated and included into the total logistics cost. The two alternatives of silo capacity are: (i). 11,000 tons which is the current capacity level and (ii). twice of the current capacity, which means that the company has to build one more silo with the same capacity with the existing one.

3. Dispatching ship only if the inventory position, that is, the on-hand inventory in the silo plus the in-transit inventory, falls below the reshipment points (RSP) that have been calculated based on 98 percentile of demand during lead time, which is in contrast to the current practice where any available ship is loaded and dispatched (i.e., the RSPs have unlimited values). This is expected to bring better performance to the system as the ship waiting at the Port A is creating better flexibility compared to a ship waiting at the packing plants.
4. Ports are operating with longer times for each day. Currently some ports are operating only 12 hours a day. This study tests the impact of extending the working time in each port to 24 hours a day. This is expected to reduce waiting time of ships in all ports and hence would have substantial impact on distribution cost per ton of product.

Combining these alternatives, a full factorial simulation experiment is performed. As mentioned above, as well as shown in Table 4.5, there are five factors included in the experiments, each with two or three levels, giving a total of 48 experimental cells. The number of replications in each experimental cell is five, leading to 240 individual experiments. In addition, further experiments for four selected treatments to obtain insight on how each of these results in different performance (costs and service level) are carried out.

Table 4.5 Experimental Design

Factors	Levels	Number of Levels
RSP Port B and Port C (RS)	1 = Unlimited; 2 = at 98 percentile;	2
Silo capacity in port of origin (DE)	1 = 11,000; 2 = 22,000;	2
Operating hours of ports (OT)	1 = 12; 2 = 24;	2
Number of ships (NS)	1 = 6 ships; 2 = 5 ships; 3 = 4 ships	3
Silo capacity in Port C (PC)	1=11,000; 2= 22,000;	2
Total number of experimental cells		**48**
Replications		**5**
Number of experimental cells		**240**

The detail of every combination making the 48 scenarios is shown in Table 4.6. Scenario 0 represents existing condition.

Table 4.6 Details of Scenario Parameter

RS	**DE**	**PC**	**NS = 4**		**NS = 5**		**NS = 6**	
			OT=12	**OT=24**	**OT=12**	**OT=24**	**OT=12**	**OT=24**
1	**1**	**1**	32	44	16	28	**0**	12
1	**1**	**2**	40	36	24	20	8	4
1	**2**	**1**	42	46	26	30	10	14
1	**2**	**2**	34	38	18	22	2	6
2	**1**	**1**	41	45	25	29	9	13
2	**1**	**2**	33	37	17	21	1	5
2	**2**	**1**	43	47	27	31	11	15
2	**2**	**2**	35	39	19	23	3	7

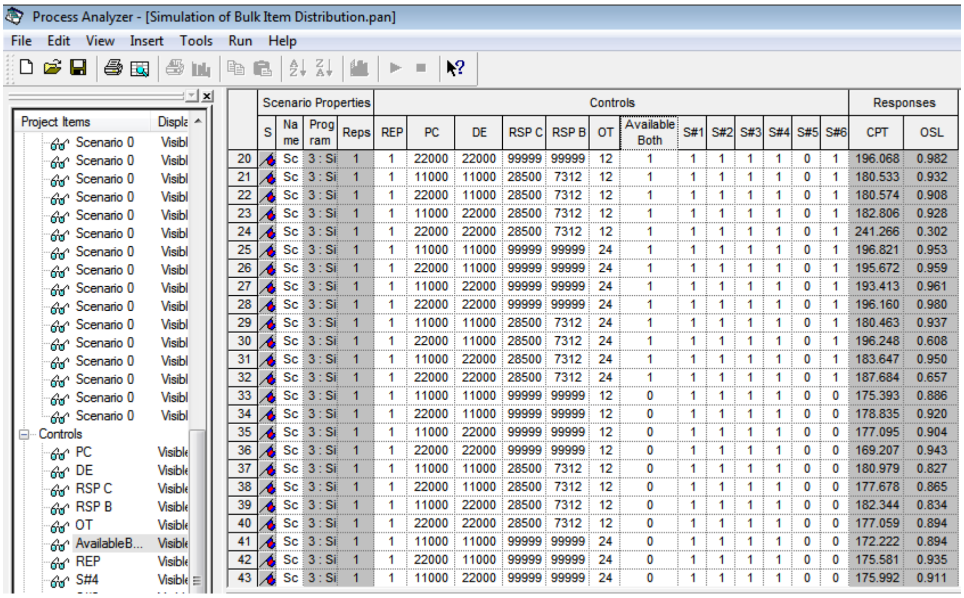
4.6 Simulation Output and Significance Test

After generating all possible scenarios, the next step is then to run the simulation. Since there are 240 experiments to run, with 48 different scenario, ARENA® ProcessAnalyzer is deployed to help setting the parameters in each scenario and replication. Figure 4.18 shows the ProcessAnalyzer model which is built to assist the running process.

Utilizing ProcessAnalyzer, the value for each factor in each scenario is defined as control variables while the output is termed as response variables. To suit the purpose of this study, the control variables are:

1. PC. This represents the size of silo in Port C, which can have the value of either 11,000 or 22,000.
2. DE. This control variable represents the size of silo in depot or Port A, which is either 11,000 ton or 22,000 ton, depending on the scenario.
3. RSP B and RSP C. These two variables represent the reshipment level in packing plants (RS). When set to 99,999 (or unlimited), this means the

company ignores stock criticality in ship scheduling. If these control variables are set to 98% percentile of demand (which is 7,312 for Port B and 28,500 for Port C), it means the stock criticality is considered in scheduling process.



	Scenario Properties				Controls														Responses	
	S	Name	Program	Reps	REP	PC	DE	RSP C	RSP B	OT	Available Both	S#1	S#2	S#3	S#4	S#5	S#6	CPT	OSL
20		Sc	3 : Si	1	1	22000	22000	99999	99999	12	1	1	1	1	1	0	1	196.068	0.982
21		Sc	3 : Si	1	1	11000	11000	28500	7312	12	1	1	1	1	1	0	1	180.533	0.932
22		Sc	3 : Si	1	1	22000	11000	28500	7312	12	1	1	1	1	1	0	1	180.574	0.908
23		Sc	3 : Si	1	1	11000	22000	28500	7312	12	1	1	1	1	1	0	1	182.806	0.928
24		Sc	3 : Si	1	1	22000	22000	28500	7312	12	1	1	1	1	1	0	1	241.266	0.302
25		Sc	3 : Si	1	1	11000	11000	99999	99999	24	1	1	1	1	1	0	1	196.821	0.953
26		Sc	3 : Si	1	1	22000	11000	99999	99999	24	1	1	1	1	1	0	1	195.672	0.959
27		Sc	3 : Si	1	1	11000	22000	99999	99999	24	1	1	1	1	1	0	1	193.413	0.961
28		Sc	3 : Si	1	1	22000	22000	99999	99999	24	1	1	1	1	1	0	1	196.160	0.980
29		Sc	3 : Si	1	1	11000	11000	28500	7312	24	1	1	1	1	1	0	1	180.463	0.937
30		Sc	3 : Si	1	1	22000	11000	28500	7312	24	1	1	1	1	1	0	1	196.248	0.608
31		Sc	3 : Si	1	1	11000	22000	28500	7312	24	1	1	1	1	1	0	1	183.647	0.950
32		Sc	3 : Si	1	1	22000	22000	28500	7312	24	1	1	1	1	1	0	1	187.684	0.657
33		Sc	3 : Si	1	1	11000	11000	99999	99999	12	0	1	1	1	1	0	0	175.393	0.886
34		Sc	3 : Si	1	1	22000	11000	99999	99999	12	0	1	1	1	1	0	0	178.835	0.920
35		Sc	3 : Si	1	1	11000	22000	99999	99999	12	0	1	1	1	1	0	0	177.095	0.904
36		Sc	3 : Si	1	1	22000	22000	99999	99999	12	0	1	1	1	1	0	0	169.207	0.943
37		Sc	3 : Si	1	1	11000	11000	28500	7312	12	0	1	1	1	1	0	0	180.979	0.827
38		Sc	3 : Si	1	1	22000	11000	28500	7312	12	0	1	1	1	1	0	0	177.678	0.865
39		Sc	3 : Si	1	1	11000	22000	28500	7312	12	0	1	1	1	1	0	0	182.344	0.834
40		Sc	3 : Si	1	1	22000	22000	28500	7312	12	0	1	1	1	1	0	0	177.059	0.894
41		Sc	3 : Si	1	1	11000	11000	99999	99999	24	0	1	1	1	1	0	0	172.222	0.894
42		Sc	3 : Si	1	1	22000	11000	99999	99999	24	0	1	1	1	1	0	0	175.581	0.935
43		Sc	3 : Si	1	1	11000	22000	99999	99999	24	0	1	1	1	1	0	0	175.992	0.911

Figure 4.18 ProcessAnalyzer Module to Ease the Simulation

4. OT. This control variable represents the operating time for Port A, which is set to 12 and 24, depending on the scenario.
5. Status of each ship and AvailableBoth. Status of each ship is a set of 6 control variables consisting status of each ships (1 = operated, 0 = laid off). AvailableBoth is a variable represents the number of undedicated ships to operate besides all 3 dedicated ships (2 = total of 6 operating ships, 1 = total of 5 operating ships, and 0 = total of 4 operating ships). This two set of control variables represent the number of ships to operate (NS).

On the other hand, response variables in this study are: (1) SLTot, which represents overall service level and (2) CPT, which represents total cost per ton.

4.6.1 Summary of Simulation Output

From the simulation outputs, a set of data containing performance measures of 240 replication cells are obtained. The data is shown in Appendix C. From these data, the summary of each scenario in terms of service level and cost per ton is generated and shown in Table 4.7 and Table 4.8. The value in each cell represents the average of all five replications for each scenario.

Table 4.7 Average Service Level for Each Scenario

RS	DE	PC	NS = 4		NS = 5		NS = 6	
			OT=12	OT=24	OT=12	OT=24	OT=12	OT=24
1	1	1	0.903	0.901	0.928	0.929	**0.970**	0.968
1	1	2	0.920	0.920	0.950	0.966	0.974	0.988
1	2	1	0.909	0.940	0.944	0.974	0.983	0.982
1	2	2	0.949	0.967	0.994	0.984	0.993	0.978
2	1	1	0.909	0.925	0.916	0.924	0.940	0.969
2	1	2	0.927	0.912	0.929	0.963	0.965	0.980
2	2	1	0.922	0.930	0.927	0.962	0.980	0.987
2	2	2	0.960	0.964	0.973	0.985	0.990	0.983

Table 4.8 Average Cost Per Ton for Each Scenario

RS	DE	PC	NS = 4		NS = 5		NS = 6	
			OT=12	OT=24	OT=12	OT=24	OT=12	OT=24
1	1	1	181.761	175.530	203.850	195.786	**220.601**	217.721
1	1	2	182.421	176.065	199.952	196.142	224.625	220.680
1	2	1	181.944	174.637	200.156	193.176	224.095	220.481
1	2	2	179.321	171.572	199.095	196.092	227.166	225.002
2	1	1	180.751	170.727	199.604	190.220	216.449	213.883
2	1	2	181.180	178.128	197.122	192.426	217.665	214.065
2	2	1	181.473	174.019	197.498	188.020	215.927	211.087
2	2	2	176.410	169.802	195.900	188.234	210.008	210.710

4.6.2 Summary of ANOVA Test

The simulation outputs are then tested for ANOVA. This test is meant to determine the effect of a certain parameter change to the total cost per ton and service level. Table 4.9 shows the ANOVA table for service level while Table 4.10 shows the ANOVA table for total cost per ton. Although it is possible to generate all interaction factors, only two level interactions are given for summary. From these ANOVA test summary, an analysis will be performed later to determine which factor, or combination of factors, significantly affect both performance measures. The detail for all possible interaction is given in Appendix.

Table 4.9 ANOVA Table for Service Level

Source	Type III Sum of Squares	Mean Square	F	Sig.
RSP (RS)	.000	.000	11.991	.001
Capacity of silo at Port A (DE)	.005	.005	270.467	.000
Operating hours of ports (OT)	.001	.001	48.762	.000
Silo capacity in Port C (PC)	.007	.007	332.139	.000
Number of ships (NS)	.011	.005	266.735	.000
RS * DE	3.037E-6	3.037E-6	.150	.698
RS * OT	.000	.000	15.909	.000
RS * PC	2.640E-5	2.640E-5	1.308	.254
RS * NS	.002	.001	58.170	.000
DE * OT	.001	.001	35.384	.000
DE * PC	.000	.000	16.278	.000
DE * NS	.001	.001	33.201	.000
OT * PC	.000	.000	16.024	.000
OT * NS	.001	.000	22.873	.000
PC * NS	.004	.002	102.738	.000

Table 4.10 ANOVA Table for Total Cost per Ton

Source	Type III Sum of Squares	Mean Square	F	Sig.
RSP (RS)	6072.153	6072.153	6.449E3	.000
Capacity of silo at Port A (DE)	151.485	151.485	160.886	.000
Operating hours of ports (OT)	817.172	817.172	867.884	.000
Silo capacity in Port C (PC)	315.525	315.525	335.106	.000
Number of ships (NS)	79912.159	39956.079	4.244E4	.000
RS * DE	60.117	60.117	63.848	.000
RS * OT	50.099	50.099	53.208	.000
RS * PC	27.458	27.458	29.162	.000
RS * NS	2626.992	1313.496	1.395E3	.000
DE * OT	1.779	1.779	1.890	.171
DE * PC	.333	.333	.354	.553
DE * NS	132.239	66.120	70.223	.000
OT * PC	18.030	18.030	19.149	.000
OT * NS	51.551	25.775	27.375	.000
PC * NS	138.650	69.325	73.627	.000

It is quite clear that almost all single factors significantly affect the performance measures, indicated by small p-value. However, it is quite obvious that some of factor combinations do not provide significant effect. Further analysis will be carried out in the next chapter.

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CHAPTER V
ANALYSIS AND INTERPRETATION

This chapter includes analysis and interpretation of the results of simulation output for all scenarios generated. Several analyses will be carried out including ANOVA tests of factor combination and frontier efficient analysis.

5.1 Analysis of Factor Effect to Service Level

From Table 4.7, it is notable the use of four ships would be unable to deliver acceptable service level if silos are in the capacity of 11,000 ton. However, with 24 hours operating time and storage capacity extension to 22,000 tons in Port A and packing plant, it would be possible to achieve a 96% service level. When the number of ships is increased to five, there is a substantial improvement in service level, moreover one of scenario using five ships achieves service level of 99%. This means that operating 5 ships will provide a very good service level to the company. A further look at this table reveals that increasing the number of operating ships to six does not provide significantly higher service level, as what is shown by increasing from four to five. This implies that operating 5 ships have been adequate to handle the company's need in terms of securing service level, while keeping it to six, as what it is, will be a waste.

The impact of extending the working hour from 12 to 24 on service level is marginal, but it in major cases, it provides better service level although not in significant way. However, in the case of operating 5 ships, this option provides better service level. Relating this to analysis of number of ships, this study recommends increasing the number of operating time to 24. The ANOVA table also confirms the interaction effect between operating time and number of ships on service level. This means that the effectiveness of extending operation time from 12 to 24 hours is not the same for different number of operating ships.

The use reshipment point (RSP) is also marginal. In most cases, RSP lower the service level, unless the number of operating ships is small. The idea of setting up RSP value is to avoid a ship waiting too long at the packing plants due to insufficient empty space in the silo at the time the ship arrives. With the RSP value, a ship is departed to a destination only if the inventory position at the port of destination is equal or below the RSP value. Therefore, it is not always better to hold ships at the port of origin until the stock at the port of destination reaches reshipment point rather than dispatching the ships whenever they are available. This is true only if the number of ships is small. This means, when the number of ships is small, it is wise to hold ships in Port A and only dispatch them when a packing plant needs replenishment. This will ensure that ships only depart to packing plant needs the replenishment. When adequate or even higher than needed, in terms of service level, it is better, in terms of service level, to dispatch them whenever they are available.

Increasing silo capacity is probably the most influential factor in this study in terms of service level. Increasing silo size, be it in Port A, Port C, or both, provides better service level. ANOVA test give a very high F-value for silo size increase. In Port A, this indicates either the 20% production dedicated for bulk shipments is too low or the silo capacity is too small. Whichever happens, this causes lack of available on-hand stocks in Port A, resulting a ship frequently has to wait. On Scenario 0, 161 out of 222 (about 72.5%) shipments made from Port A results in waiting for stock. Histogram plot of duration of these 161 cases is shown in Figure 5.1.

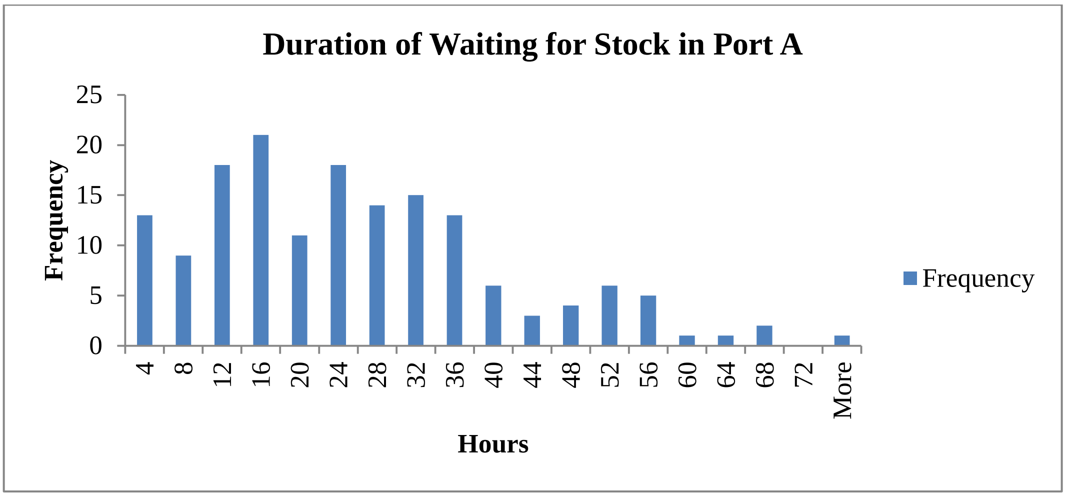


Figure 5.1 Histogram of Waiting for Stock in Port A in Scenario 0

It is very clear from Figure 5.1 that increasing on-hand inventory in Port A can shorten waiting for stock in Port A. In this study, an option this increase is achieved by extending the size of Port A silo. As expected, the service level due to this extension is generally higher because less waiting means less cycle time and therefore the replenishment in packing plants can occur in shorter time.

Extending the size of silo in Port C is also favorable to achieve higher service level. A further analysis of simulation outputs in Table 4.7 and ANOVA results in Table 4.9 supports the premise that silo capacity Port C is too small relative to its daily demand. Therefore, increasing the size will add more safety to the operations and will enable the company to reduce the number of ships while maintaining acceptable service level.

5.2 Analysis of Factor Effect to Cost per Ton

In terms of distribution cost per ton, all factors are very influential. However, reducing number of ships and implementing RSP in scheduling are two factors with highest F-value. Reducing number of operating ships is clearly can cut out the costs because of time-charter costing policy, which implies the lower number of operating ships at a time, the lower the cost incurred to the company. The impact of implementing RSP in scheduling to the cost, on the other hand, is quite interesting. This supports the premise that it is better to hold ships at the Port A until the stock at the port of destination reaches reshipment point rather than dispatching the ships whenever they are available on all levels of number of ships. Unlike adding silo capacity which is an expensive investment, the use of RSP is just a change in the dispatching rule which does not cost the company anything. Therefore, it is advisable that the company set the RSP for scheduling mechanism.

Other factors, such as extending operating time and increasing the silo size, are also worth implementing, whenever is possible. Operating time extension and silo size increase will enable ships to process the shipments immediately in Port A and packing plants and hence can cut the cycle time which will enable more shipments to make. Although silo size increase will result in more investment cost, the impact of more shipments made is greater and resulting in lower distribution cost. This means the increase in efficiency gained by increasing silo size outweigh the additional costs associated with it. Therefore, this outcome suggests that the company should place additional silo to reduce its cost.

5.3 Efficient Frontier Analysis

The trade off between cost and service level is well known in logistics. However such relationships is mostly obvious when the level of inventory under uncertain supply and demand is varied, i.e., higher inventory normally results in higher service level. In this study it is suspected that there is also a strong trade-off between costs and service level. The reasons is that, the higher the storage capacity, the higher stock availability should be. However, the investment cost associated with this scheme is also higher. On the other hand, the decision to reduce the number of ships would save costs but result in lower stock availability. Given that there are many interrelated factors, the trade-off is not that obvious and some complex interactions present. For example, port operating hours also affect service level. There is a case of higher service level attained by extending operations time to 24 hours even if silo capacity is lower.

In Figure 5.2, a plot of cost per ton (vertical) against the service level (horizontal) for each experiment is presented. The general pattern shows that there is a correlation between cost and service level, i.e., higher service level is achieved with higher costs. From this figure it is an approximate frontier line that connects the most competitive options (which is shown by the dotted curve at the bottom part of the graph) is also plotted. The points which are far from the frontier curve are dominated options. The frontier curve can be used to guide the cost and service level targets for the company. It is interesting to see which combination of levels that lead to efficient frontiers and which ones are mostly dominated. It is important to note however, that there should be a lower limit of acceptable service level. In this study, the service level threshold is set to 90%.

Figure 5.2 shows a clustered pattern in the plots. Figure 5.3 emphasize the cluster of solution based on cost–like level from Figure 5.2. Comparing the plots in Figure 5.3 and details of each scenario in Table 4.8, it is justifiable to conclude that the impact of number of ships on cost is very clear. The more the operating ship, the higher the cost is and the better the service level is. However, the service level performance can be improved by setting other factors to more safe level, i.e. to setting the silo capacity to higher level and setting the operating time and RSP accordingly.

Besides, Figure 5.2 also shows that the output performance of each scenario varies one another by the position of dots representing each scenario. As pointed out earlier, the closer the solution dots to the frontier curve, the better the solution is. Scenario 0 produces solution whose dots are quite far from frontier curve. This implies that existing situation can be improved by implementing other scenario whose dots are closer to the curve. Therefore, scenario 3, scenario 23, and scenario 39 are qualified to bring improvement to existing policy in terms of cost and service level.

However, it is important to note that the simulation models a situation characterized by high uncertainty. First, demand coming to each silo is stochastic. Second, ship movement is encountering uncertainties in almost any stage of the process cycle. For example, at the time a ship is ready to depart at Port A, there maybe a weather problem that prevents it to depart immediately. In the case of weather problems, the waiting time could be substantial which then affects the cycle time, and hence cost and the service level. Hence, it is important to see not just the average value of the cost and service level as Table 4.7 and Table 4.8 present, but also to get an idea how different is the average cost from one situation to the other. For this purpose 35 replications of the four scenarios, taken out from the 48 treatments, one is representing the existing condition (called scenario 0), and the other three are represeting three competing points at the efficient frontier in Figure 5.2, namely scenarios 3, 23, and 39, are run. For clarity, Table 5.1 shows the definition of those 4 scenarios.

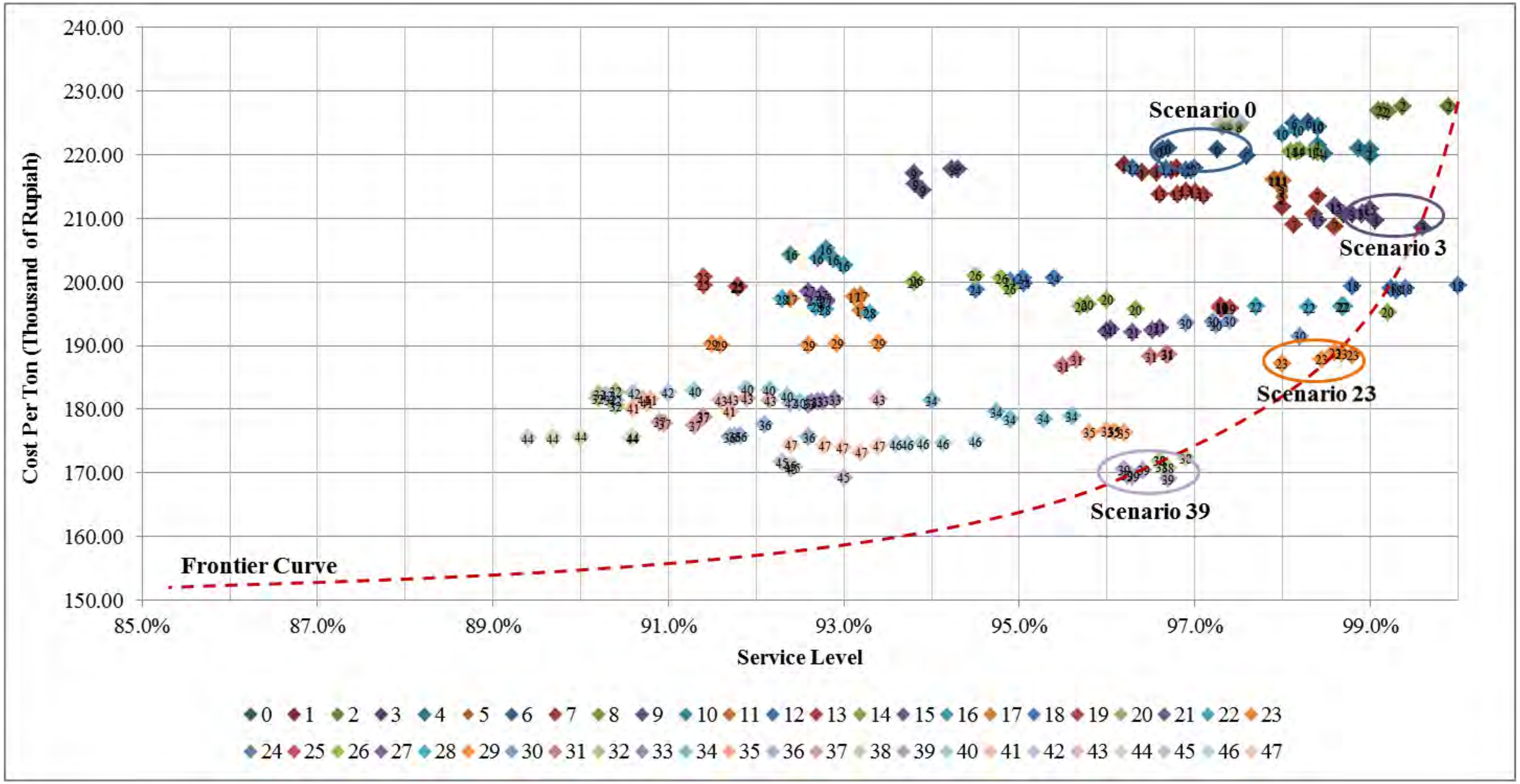


Figure 5.2 Position of Scenario Performance Relative to the Frontier Curve

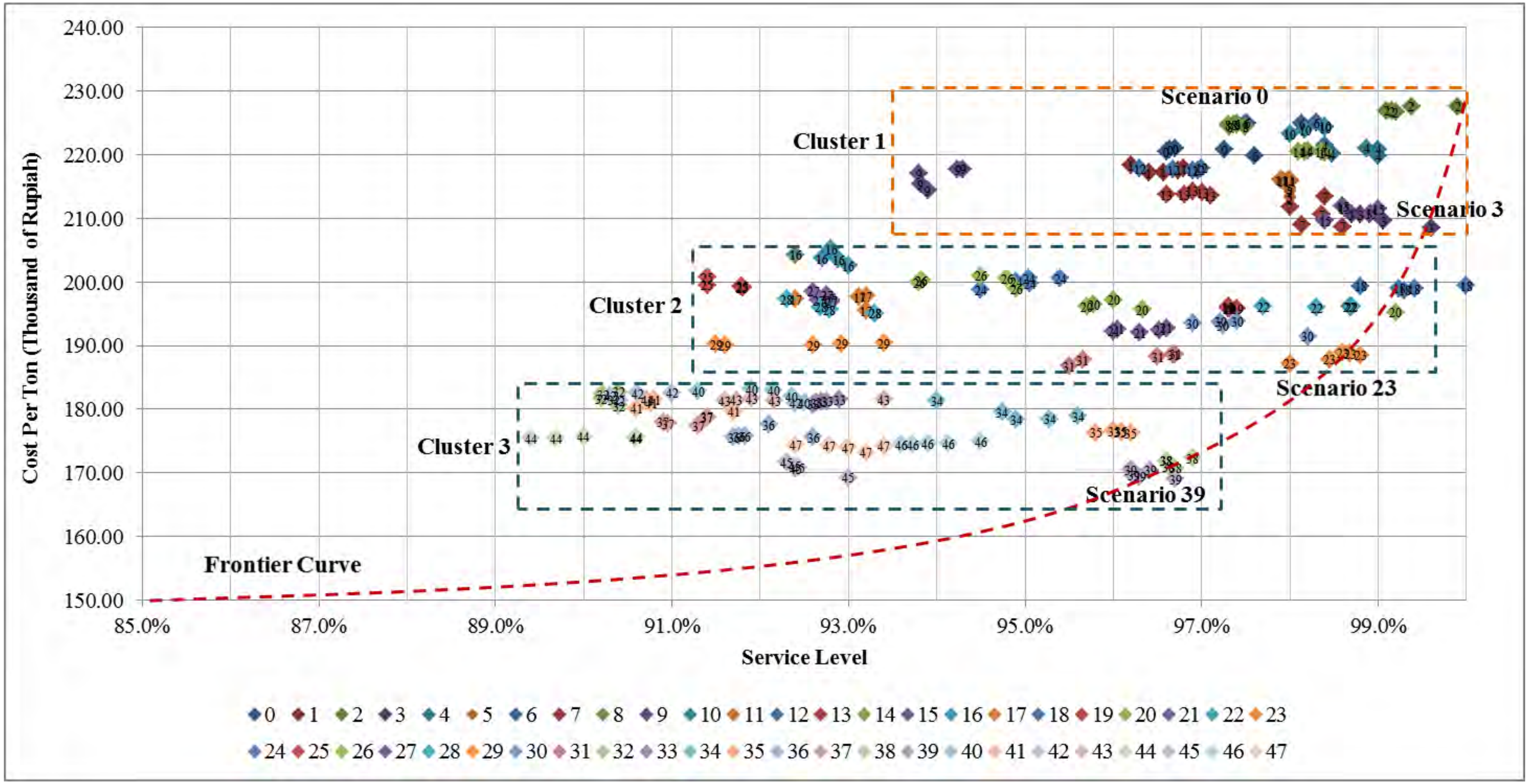
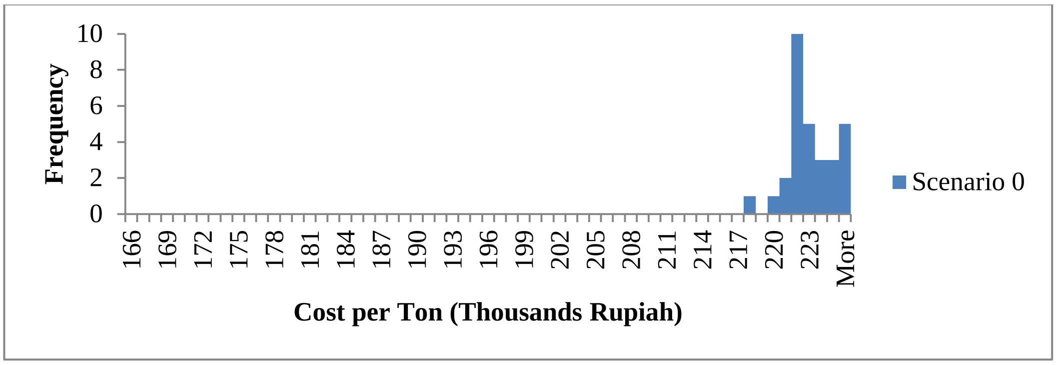


Figure 5.3 Clustered Pattern of Scenario Performance

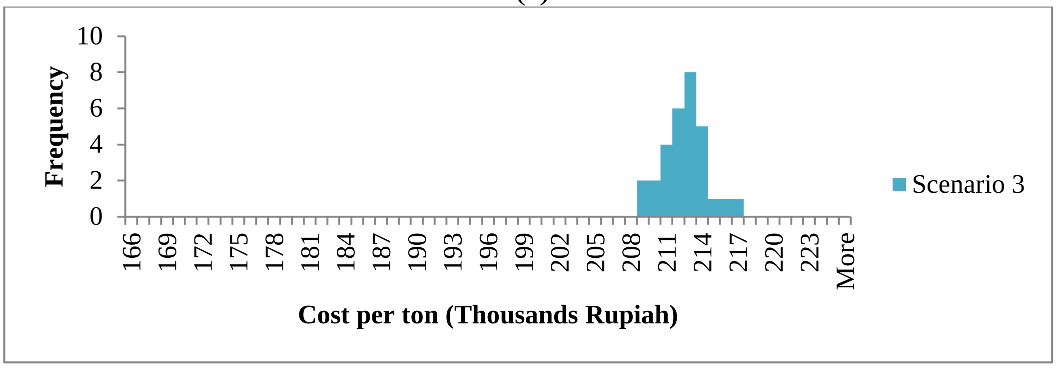
Table 5.1 Scenario Details for Chosen Points to Simulate

Factors	Scenario 0	Scenario 3	Scenario 23	Scenario 39
RSP level (RS)	1	2	2	2
Silo capacity in Port A (DE)	1	2	2	2
Operating hours (OT)	1	1	2	2
Number of ships (NS)	1	1	2	2
Silo capacity in Port C (PC)	1	2	2	3

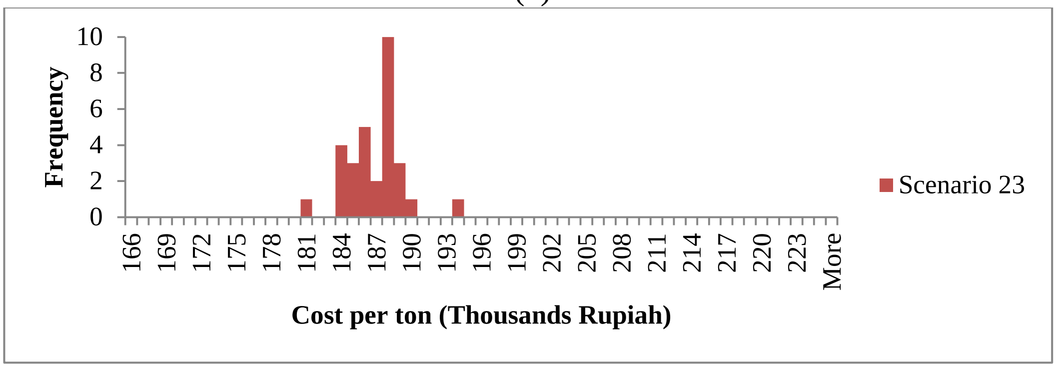
Figure 5.4 shows the distribution of cost per ton of the four scenarios. The results of the 35 replications for each scenario indicate that the three alternative scenarios (3, 23, and 39) result in significantly lower cost per ton compared to the existing scenario (scenario 0). In other words, there is a policy that results in substantially lower logistics costs compared to the existing policy. This strengthens the analysis before from efficient frontier. It is interesting to note that even though extending the silo capacity is costly, doing so results in lower overall costs as it helps the ships to move faster along the transportation cycle. The distribution of service level is exhibited in Figure 5.5. It is obvious from the graph that the range of service level from one run to the other could be significantly different. Comparing the four scenario, it is obvious that only scenario 3 that exhibits superior service level compared to the existing situation while scenario 23 and 39 provides almost the same service level. Looking at both cost and service level, it is obvious that all three scenario 3, 23, and 39 are superior compared to the existing situation because they produce lower cost and better or at least the same profile of service level.



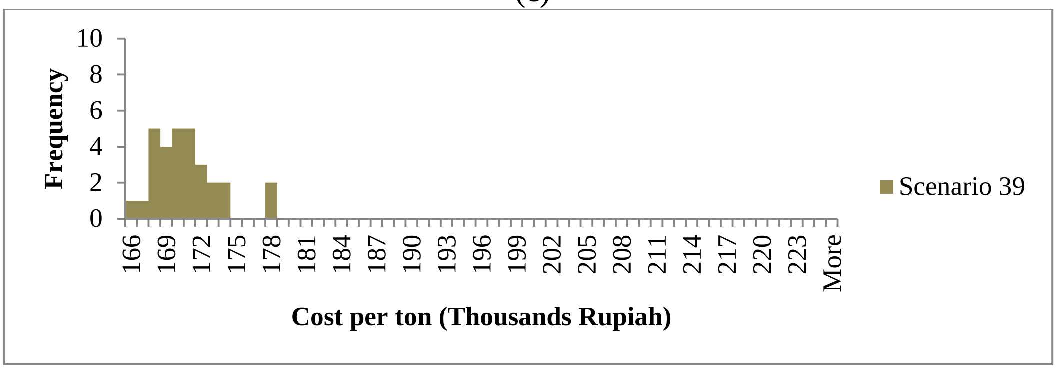
(a)



(b)

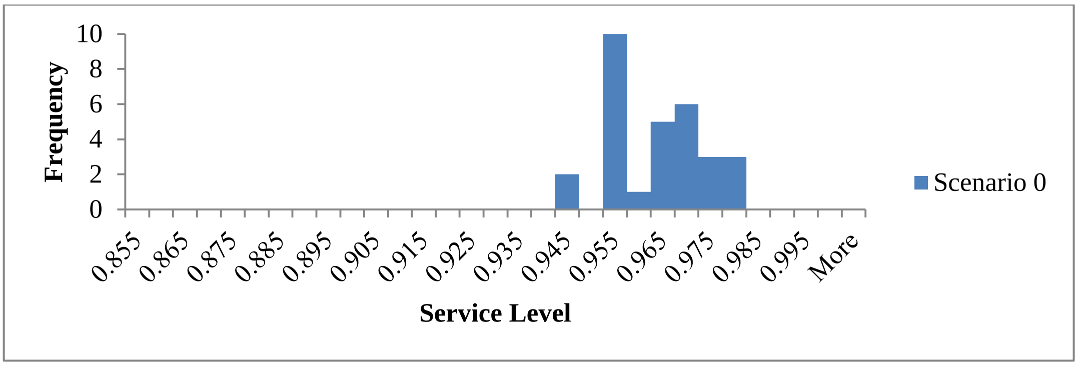


(c)

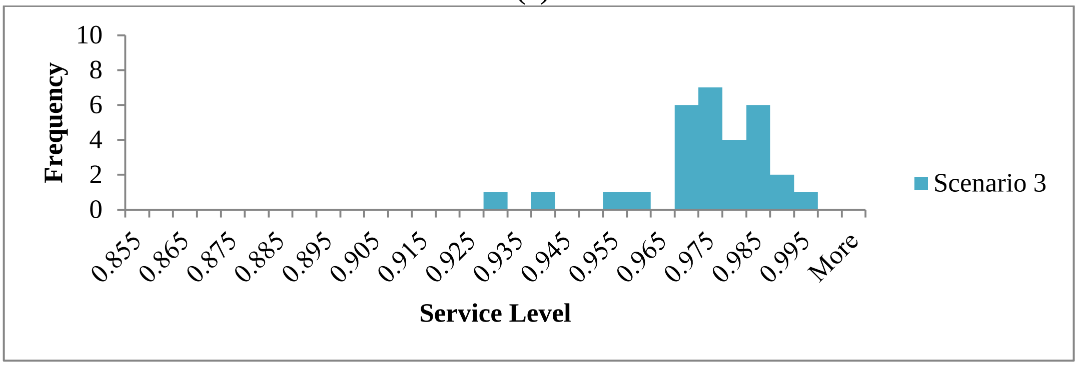


(d)

Figure 5.4 Distribution of Cost per Ton of the Four Scenarios



(a)



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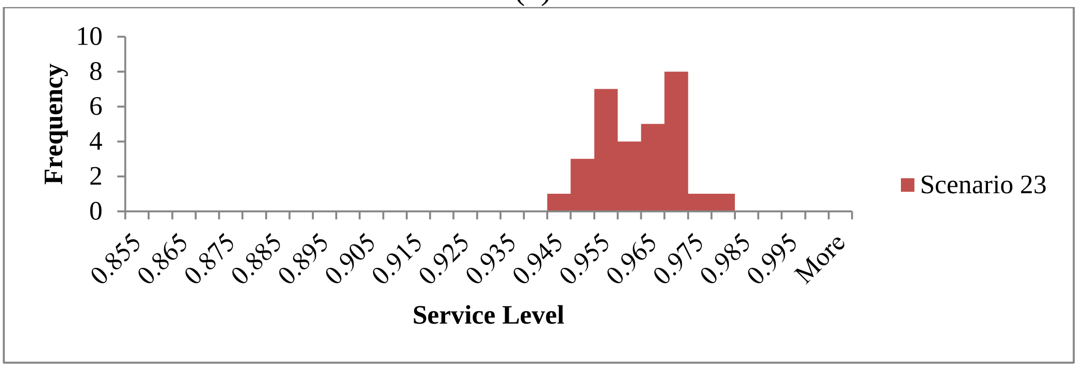

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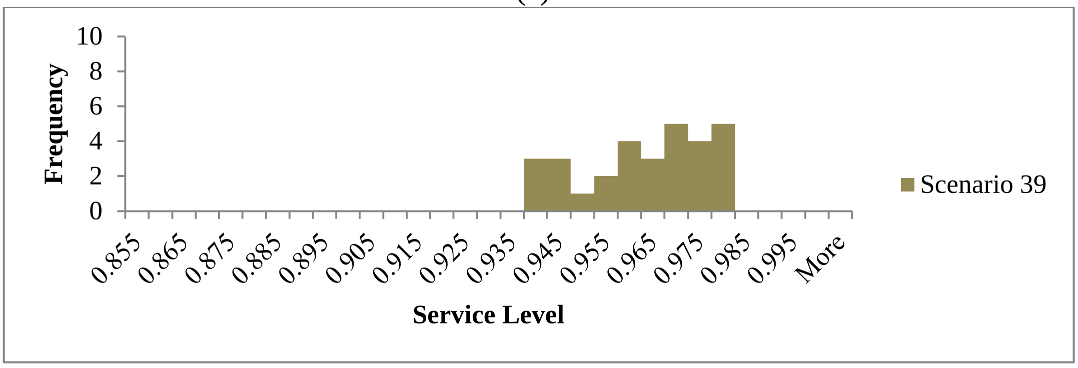

(d)

Figure 5.5 Distribution of Service Level of the Four Scenarios

5.4 Stock to Demand Ratio

Although the three competing scenario look pretty similar in terms of cost and service level, a closer look at the inventory profile at the two packing plants suggests something different. While inventory profile produced by the three scenarios in Port B is very much identical as shown in Figure 5.6, there is a clear difference in Port C, where scenario 3 keeps much higher inventory compared to scenario 23 and 39 as exhibited by Figure 5.7.

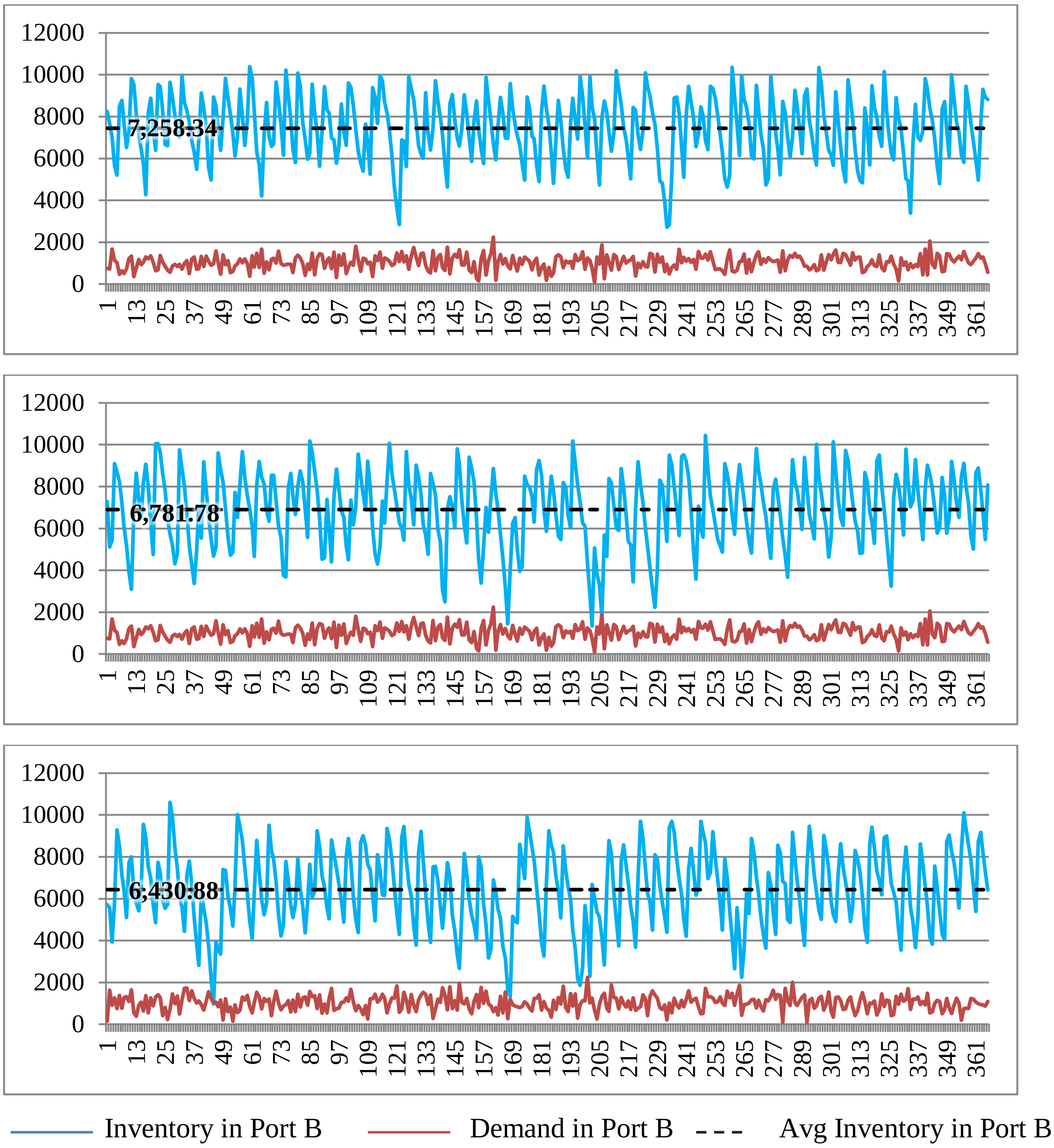

Figure 5.6 Plotting of Demand and Inventory Level in Port B for the Three Competing Scenarios (3, 23, and 39)

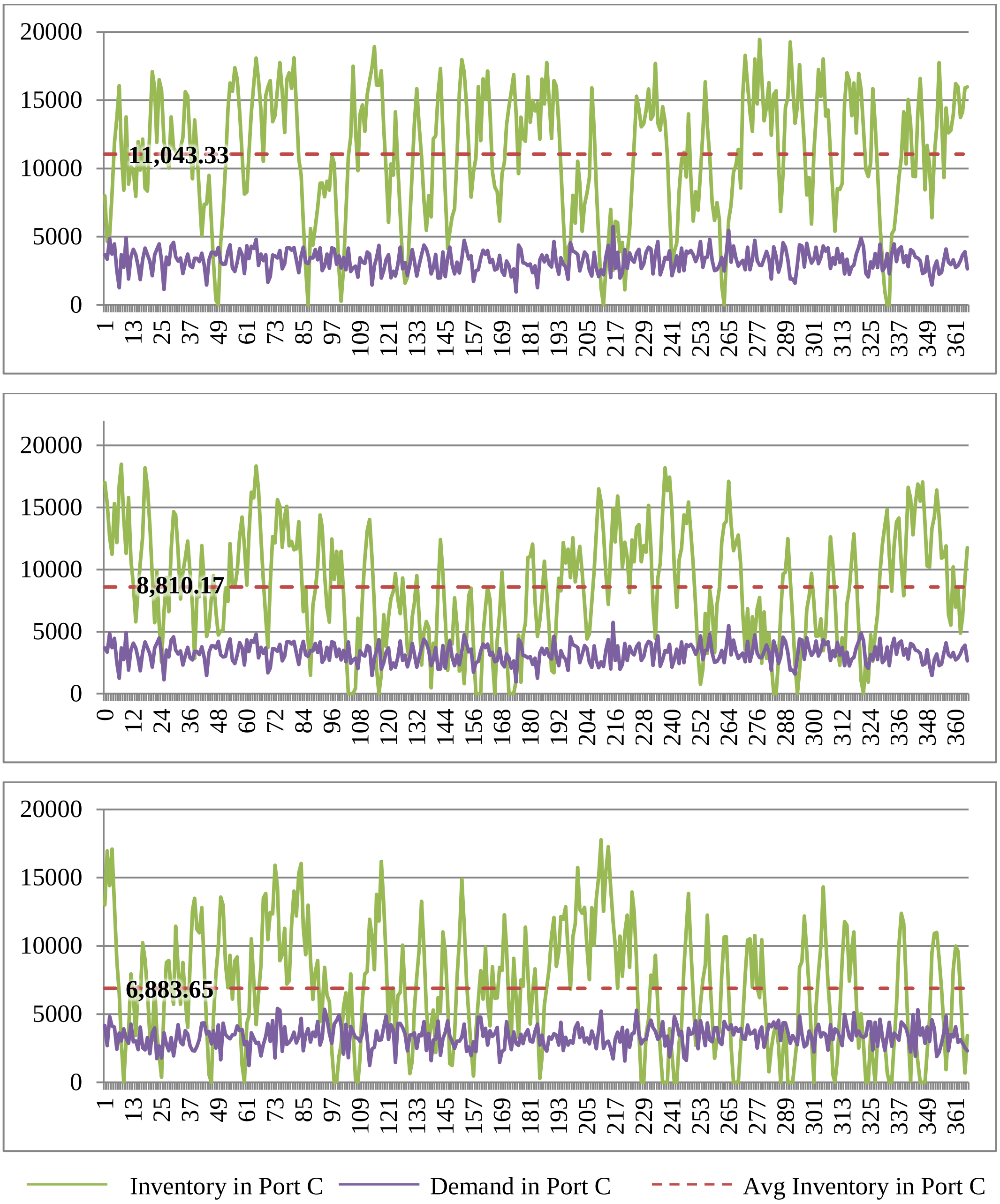

Figure 5.7 Plotting of Demand and Inventory Level in Port C for the Three Competing Scenarios (3, 23, and 39)

In all three compared scenarios, the size of all silos is equal, but the number of operating ships varies. Although it is approximately the same in terms of service level, the stock to demand ratio provides better insights in terms of stock safety and flexibility in packing plants, especially Port C whose demand is higher. Operating 6 ships provides about 5.5 - 7 days of demand in Port B and 3 -

3.5 days of demand in Port C. Operating 5 ships provides 4.5 – 6 days of demand in Port B and 2.5 – 3 days of demand in Port C. Operating 4 ships provides 5.5 – 6.5 days of demand in Port B and 1.5 – 2 days of demand in Port C. Hence, the safety level in Port B is very good while the safety in Port C varies according to number of operating ships significantly. Therefore, it is reasonable to consider the shipping lead time to Port C, which is about 4 days including pretime in Port A and packing plant, loading in Port A, post time in Port A, sailing time, and unloading in packing plant, in determining the best scenario. Therefore, it is reasonable to determine scenario 3 as the best solution although the average stock can last slightly lower than the lead time. This solution, in turn, will give a lower cost, better service level, and more safety in packing plants.

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CHAPTER VI
CONCLUSION AND RECOMMENDATION

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

6.1 Conclusion

After conducting this research, several conclusions to present are:

1. The model developed in this research has been able to evaluate several possible combinations of silo capacity, operating time, and number of vessel. It is clear that existing situation (scenario 0) can be improved by implementing a certain combination of these interrelated decisions. Whereas there are numerous options for improvement in terms of lower cost and still-satisfying service level, the operations safety and flexibility is put in higher risk as stock to demand ratio in packing plants become lower. Therefore, to achieve a lower cost, acceptable service level, and safe and flexible operation, the combination of silo capacity of 22,000 ton, 24-hour operating time, and operating 6 ships (scenario 3) is selected to as the best chosen scenario to improve the existing situation.
2. All factors considered in this study have significant impact in terms of cost and service level. Most factor combinations also show significant impact on both performance measures. Therefore, it is clear that the factors are interrelated and decisions taken regarding these measures should be integrated. However, it is notable that silo capacity in Port A and packing plants and number of ships are of the most influential factors in terms of service level while number of ships and reshipment point implementation in scheduling are two most influential factors in terms of cost per ton. Therefore, determining number of operating ships will have biggest impact in both performance measures.

6.2 Recommendation

For future researches, it is advisable from this research to:

1. Extend the number of Port A and destination port so that interaction among Port A can be evaluated.
2. Evaluate several scenarios of both homogeneous and heterogeneous ships in terms capacity, loading and unloading rate, and berth constrains.

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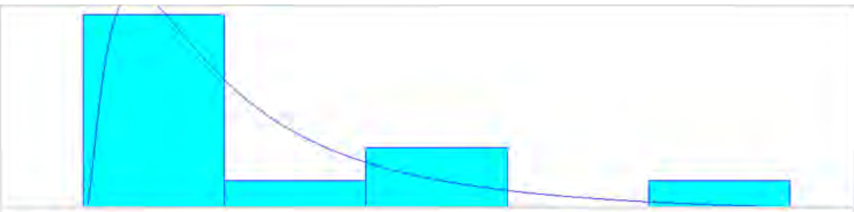
APPENDIX

DISTRIBUTION FIT TEST DATA INPUT AND RESULTS

Data Input for Duration of Waiting for Weather in Port A

#	Waiting for Weather in Port A
1	5.8
2	137.5
3	34.7
4	6.3
5	6.5
6	104.0
7	92.4
8	16.1
9	8.1
10	16.8
11	13.3
12	7.4
13	2.7

Result of Distribution Fit Test for Waiting for Weather in Port A



Distribution Summary

Distribution:	Lognormal
Expression:	2 + LOGN(10.6, 13.6)
Square Error:	0.049686

Kolmogorov-Smirnov Test

Test Statistic	= 0.195
Corresponding p-value	> 0.15

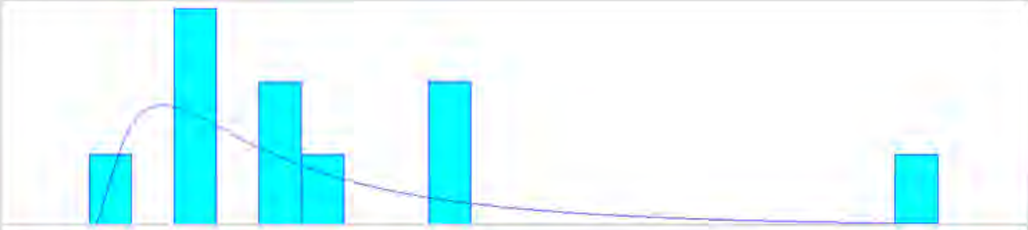
Data Input for Duration of Sailing Time to Both Packing Plants

#	Sail Time to Port B
1	26.4
2	31.3
3	21.7
4	27.2
5	44.1
6	23.9
7	26.4
8	30.6
9	23.7
10	23.6

#	Sail Time to Port C
1	46.1
2	39.3
3	36.0
4	49.6
5	43.9
6	38.0
7	49.3
8	38.8
9	43.5
10	39.6
11	38.5
12	37.1
13	41.7
14	48.4
15	37.7
16	39.2
17	39.9
18	36.7
19	37.5
20	38.4
21	38.3
22	35.7
23	47.9
24	41.7
25	47.0

#	Sail Time to Port C
26	36.2
27	37.1
28	42.1
29	41.6
30	36.0
31	41.8
32	44.0
33	37.2
34	44.6
35	42.1
36	38.0
37	43.3
38	45.0
39	46.9
40	40.8
41	41.0
42	33.0
43	33.4
44	41.2
45	38.5
46	31.7
47	32.0
48	32.8
49	30.3
50	31.3

Result of Distribution Fit Test for Sailing Time to Port B

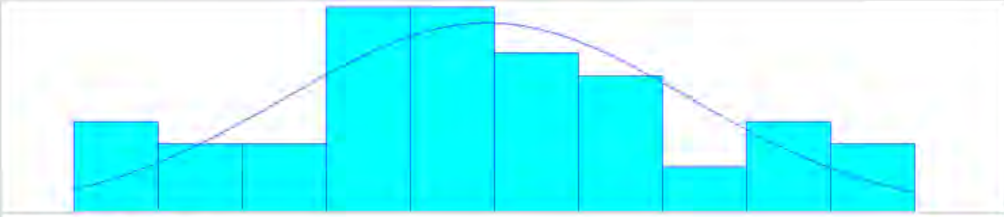


Distribution Summary

Distribution : Lognormal
Expression : 21 + LOGN(7.2, 8.18)
Square Error : 0.119208

Kolmogorov-Smirnov Test
Test Statistic = 0.156
Corresponding p-value > 0.15

Result of Distribution Fit Test for Sailing Time to Port C



Distribution Summary

Distribution	: Normal
Expression	: NORM(39.8, 4.79)
Square Error	: 0.011115

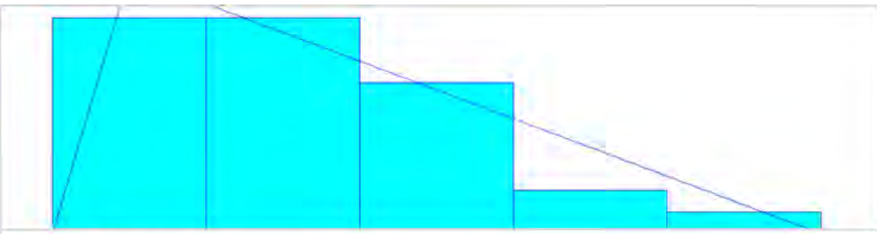
Chi Square Test

Number of intervals	= 6
Degrees of freedom	= 3
Test Statistic	= 1.18
Corresponding p-value	> 0.75

Kolmogorov-Smirnov Test

Test Statistic	= 0.0687
Corresponding p-value	> 0.15

Result of Distribution Fit Test for Waiting for Port in Port C



Distribution Summary

Distribution	: Triangular
Expression	: TRIA(10, 34.6, 256)
Square Error	: 0.007160

Chi Square Test

Number of intervals	= 4
Degrees of freedom	= 2
Test Statistic	= 1.29
Corresponding p-value	= 0.53

Kolmogorov-Smirnov Test

Test Statistic	= 0.123
Corresponding p-value	> 0.15

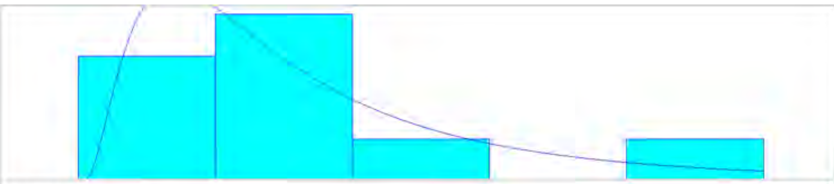
Data Input for Pretime at Both Packing Plants

#	Pretime Port B
1	13.0
2	3.1
3	1.3
4	3.5
5	4.1
6	3.1
7	7.2
8	2.2
9	2.0
10	3.7

#	Pretime Port C
1	2.1
2	2.5
3	4.0
4	3.6
5	2.5
6	4.2
7	3.1
8	2.5
9	4.2
10	3.4
11	1.7
12	4.1
13	1.9
14	5.2
15	2.2
16	2.9
17	3.7
18	1.5
19	3.6
20	3.1
21	1.9
22	6.5
23	3.2
24	2.0
25	4.1

#	Pretime Port C
26	3.6
27	2.5
28	1.8
29	3.5
30	1.9
31	6.9
32	4.2
33	3.5
34	3.7
35	2.7
36	1.2
37	5.4
38	4.0
39	6.6
40	1.8
41	3.4
42	7.1
43	1.6
44	2.1
45	1.3
46	4.8
47	4.0
48	1.6
49	3.8
50	5.2

Result of Distribution Fit Test for Pretime at Port B



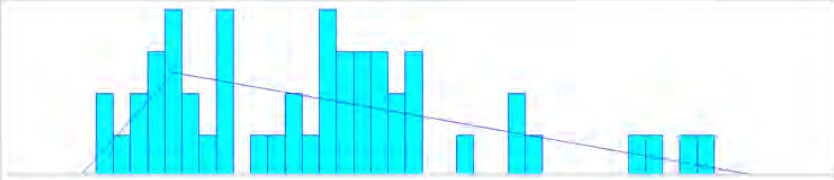
Distribution Summary

Distribution	: Lognormal
Expression	: 1 + LOGN(2.5, 2.4)
Square Error	: 0.025724

Kolmogorov-Smirnov Test

Test Statistic	= 0.24
Corresponding p-value	> 0.15

Result of Distribution Fit Test for Pretime at Port C



Distribution Summary

Distribution	: Triangular
Expression	: TRIA(1, 1.92, 7.69)
Square Error	: 0.017102

Chi Square Test

Number of intervals	= 8
Degrees of freedom	= 6
Test Statistic	= 10.9
Corresponding p-value	= 0.0936

Kolmogorov-Smirnov Test

Test Statistic	= 0.116
Corresponding p-value	> 0.15

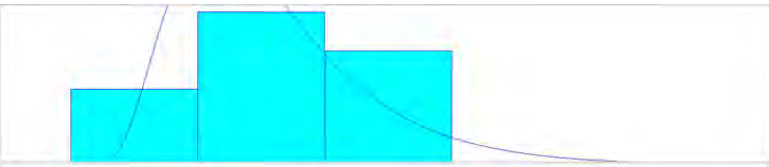
Data Input for Post Time at Both Packing Plants

#	Posttime Port B
1	1.7
2	3.0
3	3.8
4	3.6
5	4.5
6	2.3
7	2.5
8	2.6
9	4.0
10	8.4

#	Posttime Port C
1	1.6
2	3.5
3	2.5
4	3.1
5	3.3
6	3.0
7	3.3
8	3.4
9	3.0
10	7.3
11	4.4
12	8.5
13	2.7
14	4.1
15	5.6
16	10.0
17	2.6
18	5.2
19	5.6
20	2.2
21	5.0
22	5.9
23	3.3
24	2.3
25	5.3

#	Posttime Port C
26	6.4
27	2.1
28	1.6
29	3.2
30	3.4
31	3.4
32	3.6
33	3.5
34	4.5
35	2.5
36	2.3
37	4.3
38	1.7
39	3.7
40	3.3
41	6.0
42	4.0
43	3.4
44	1.8
45	9.3
46	6.8
47	4.5
48	4.6
49	5.9
50	3.6

Result of Distribution Fit Test for Pretime at Port B



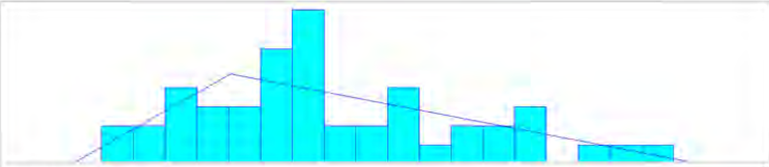
Distribution Summary

Distribution	: Lognormal
Expression	: 1 + LOGN(2.14, 1.08)
Square Error	: 0.033310

Kolmogorov-Smirnov Test

Test Statistic	= 0.186
Corresponding p-value	> 0.15

Result of Distribution Fit Test for Pretime at Port C



Distribution Summary

Distribution	: Triangular
Expression	: TRIA(1, 2.69, 7.69)
Square Error	: 0.016726

Chi Square Test

Number of intervals	= 6
Degrees of freedom	= 4
Test Statistic	= 6.48
Corresponding p-value	= 0.181

Kolmogorov-Smirnov Test

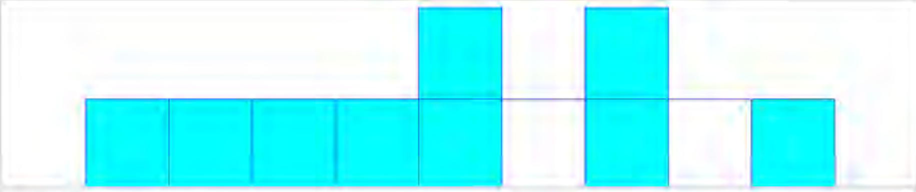
Test Statistic	= 0.087
Corresponding p-value	> 0.15

Data Input for Waiting for Weather in Both packing Plants

#	Waiting for Weather in Port B
1	2.4
2	6.8
3	67.2
4	5.9

#	Waiting for Weather in Port C
1	12.3
2	9.7
3	4.0
4	12.3
5	6.0
6	6.9
7	16.5
8	1.3
9	8.3

Result of Distribution Fit Test for Waiting for Weather in Port C



Distribution Summary

Distribution	: Uniform
Expression	: UNIF(1, 17)
Square Error	: 0.049383

Kolmogorov-Smirnov Test

Test Statistic	= 0.123
Corresponding p-value	> 0.15

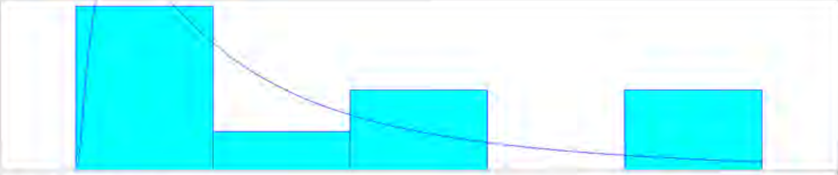
Data Input for Sailing Time to Port A from Both Packing Plants

#	Sail Time from Port B
1	27.5
2	23.9
3	21.2
4	35.9
5	31.7
6	49.3
7	22.2
8	19.9
9	48.5

#	Sail Time from Port C
1	30.5
2	37.2
3	30.6
4	32.1
5	37.4
6	33.2
7	39.0
8	29.7
9	31.9
10	37.0
11	31.5
12	34.8
13	35.5
14	36.0
15	34.8
16	34.6
17	33.2
18	34.1
19	34.8
20	38.9

#	Sail Time from Port C
21	34.8
22	41.7
23	37.4
24	38.0
25	37.0
26	47.9
27	43.8
28	43.1
29	40.8
30	47.9
31	38.2
32	42.3
33	31.5
34	32.2
35	36.1
36	30.2
37	30.6
38	31.4
39	31.9
40	31.4

Result of Distribution Fit Test for Sailing Time Back to Port A from Port B



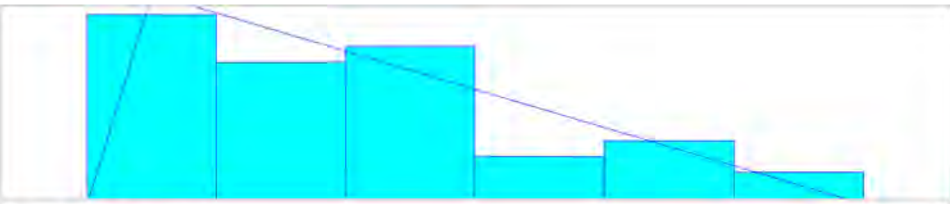
Distribution Summary

Distribution	: Lognormal
Expression	: 19 + LOGN(13.7, 22.4)
Square Error	: 0.064931

Kolmogorov-Smirnov Test

Test Statistic	= 0.136
Corresponding p-value	> 0.15

Result of Distribution Fit Test for Sailing Time Back to Port A from Port B



Distribution Summary

Distribution	: Triangular
Expression	: TRIA(29, 30.6, 48)
Square Error	: 0.013353

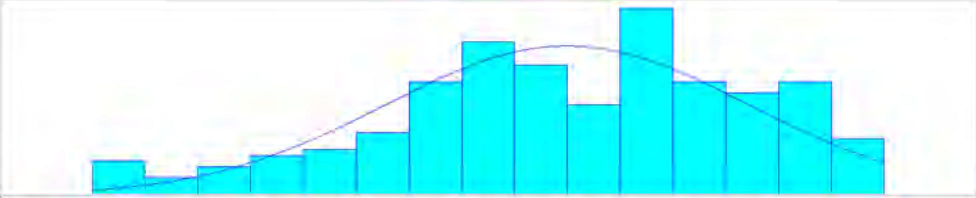
Chi Square Test

Number of intervals	= 4
Degrees of freedom	= 2
Test Statistic	= 3.03
Corresponding p-value	= 0.229

Kolmogorov-Smirnov Test

Test Statistic	= 0.0794
Corresponding p-value	> 0.15

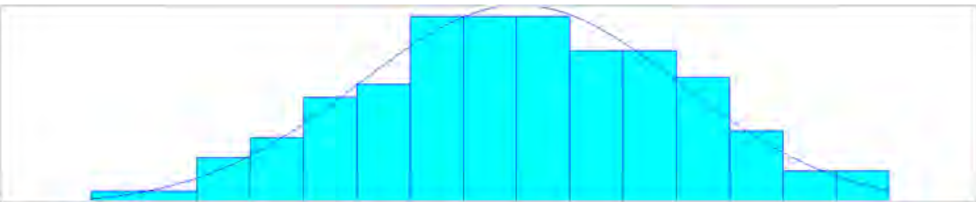
Result of Distribution Fit Test for Daily Demand Pattern in Port B



Distribution Summary

Distribution:	Normal
Expression:	NORM(1.02e+003, 383)
Square Error:	0.006768
Chi Square Test	
Number of intervals	= 11
Degrees of freedom	= 8
Test Statistic	= 26.9
Corresponding p-value	< 0.005
Kolmogorov-Smirnov Test	
Test Statistic	= 0.0604
Corresponding p-value	> 0.15

Result of Distribution Fit Test for Daily Demand Pattern in Port B



Distribution Summary

Distribution:	Normal
Expression:	NORM(3.33e+003, 827)
Square Error:	0.001012
Chi Square Test	
Number of intervals	= 10
Degrees of freedom	= 7
Test Statistic	= 2.49
Corresponding p-value	> 0.75
Kolmogorov-Smirnov Test	
Test Statistic	= 0.0274
Corresponding p-value	> 0.15

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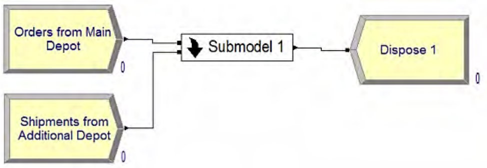
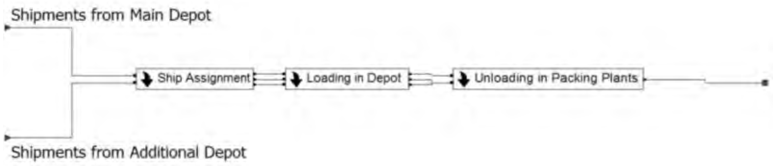
SIMULATION MODEL

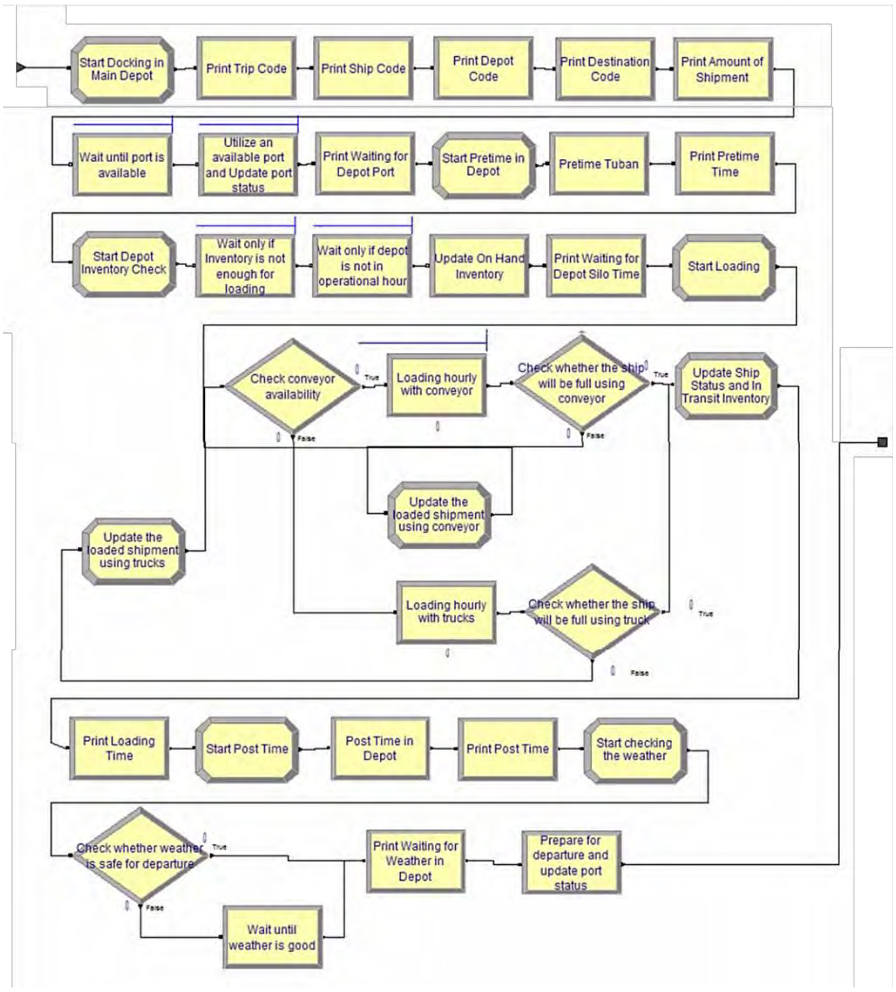
SUBMODEL 1: SHIP ACTIVITIES

Processes in Submodel 1

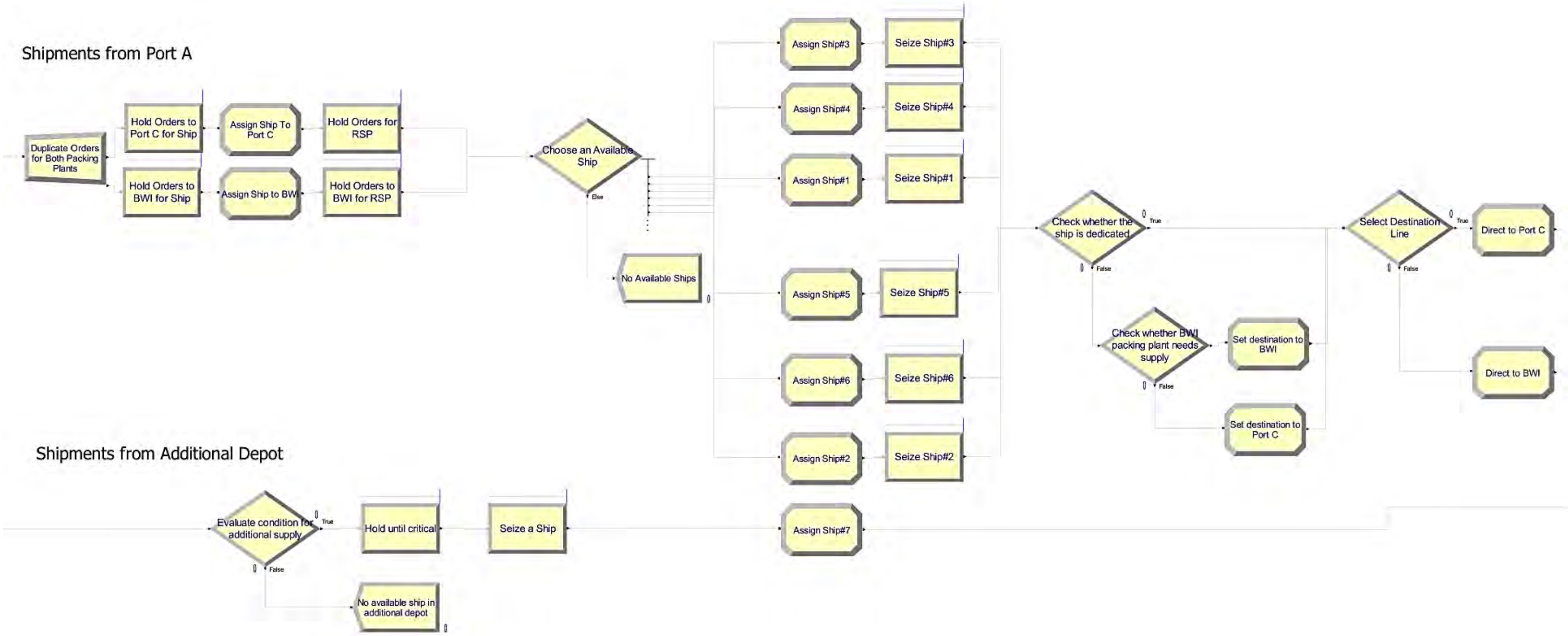




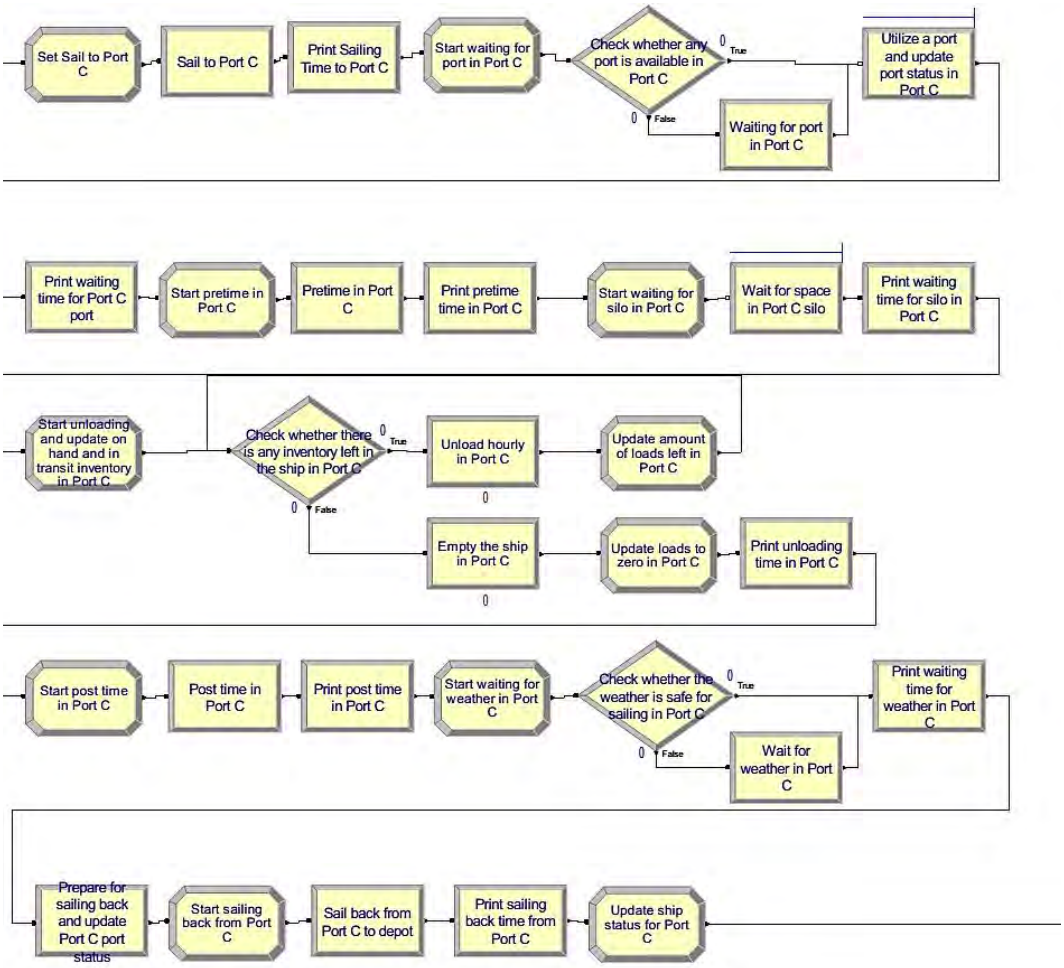
Loading in Port A



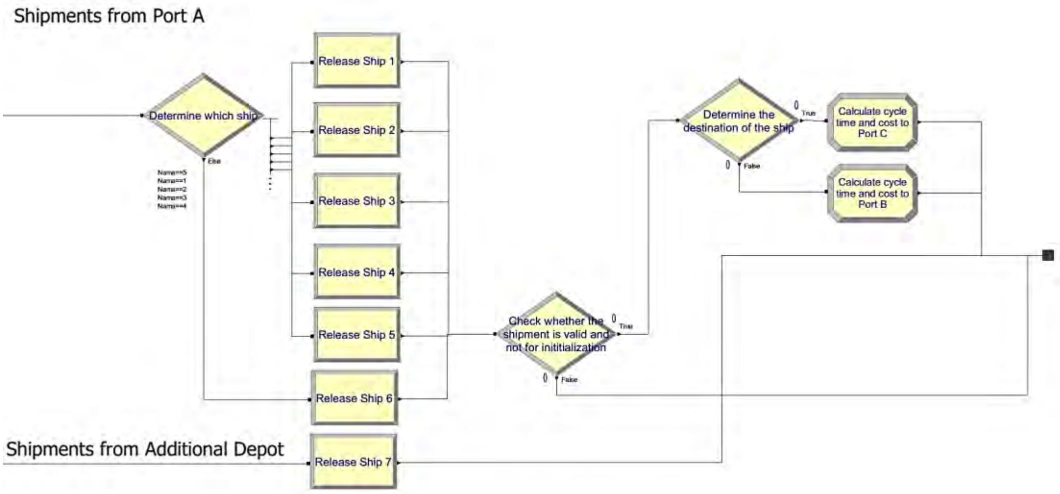
Assigning Ship



Unloading in Packing Plant

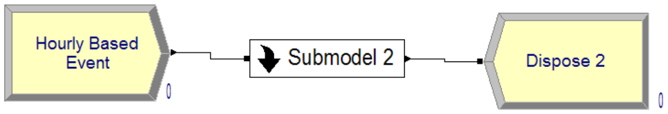


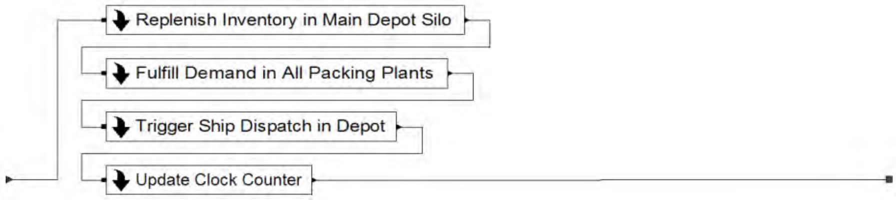
Calculating Cost at the End of Process



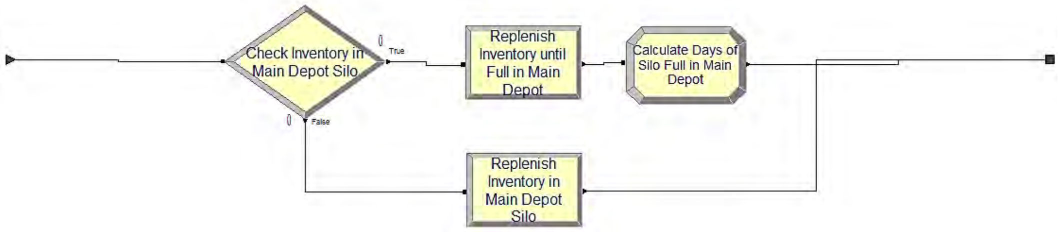
SUBMODEL 2: HOURLY-BASED EVENT

Processes in Submodel 2

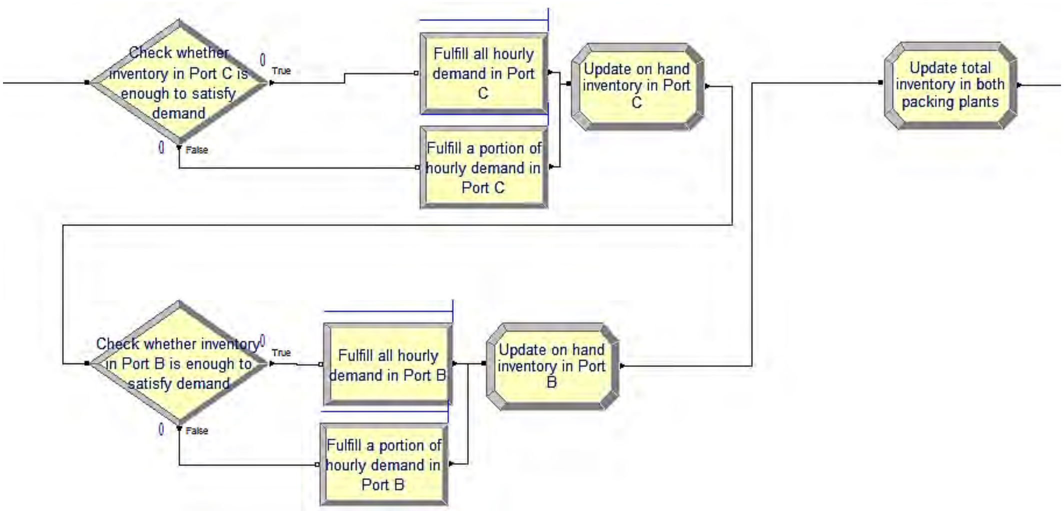




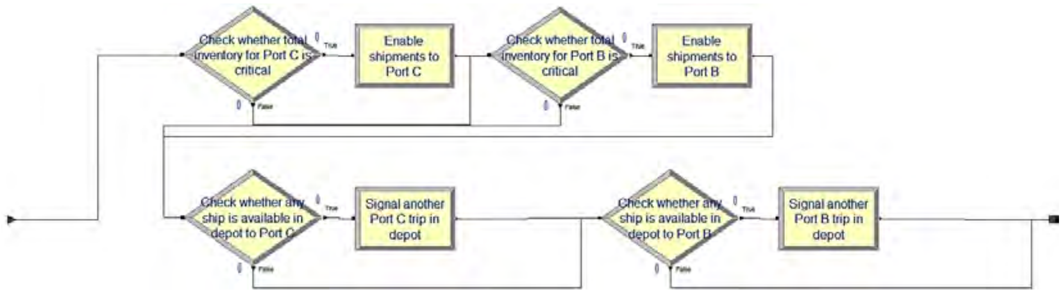
Replenishing Inventory



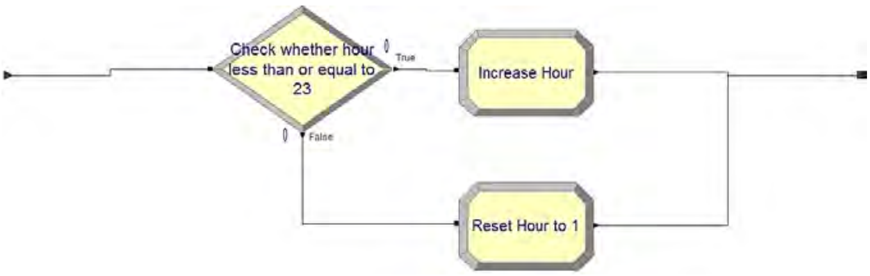
Fulfilling Demand



Triggering Ship Dispatch

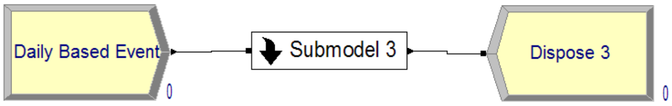


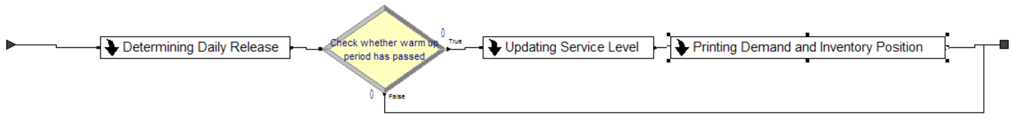
Updating Clock



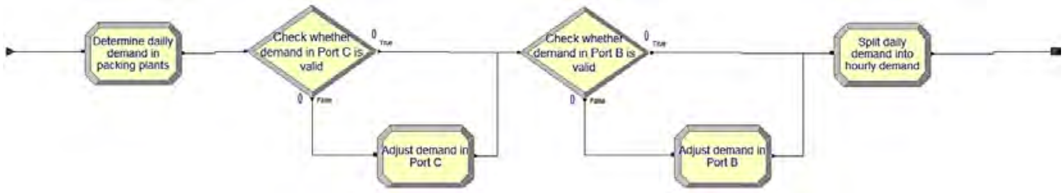
SUBMODEL 3: DAILY-BASED EVENT

Processes in Submodel 3

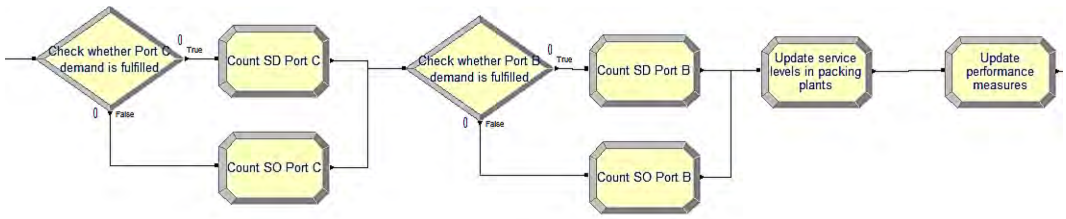




Determining Daily Demand

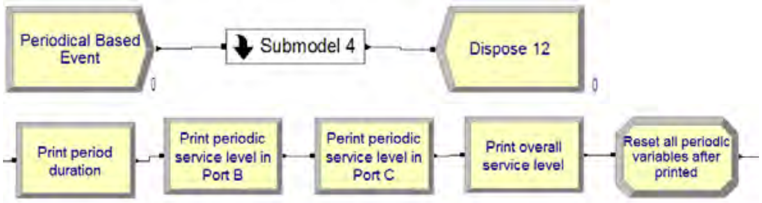


Updating Service Level



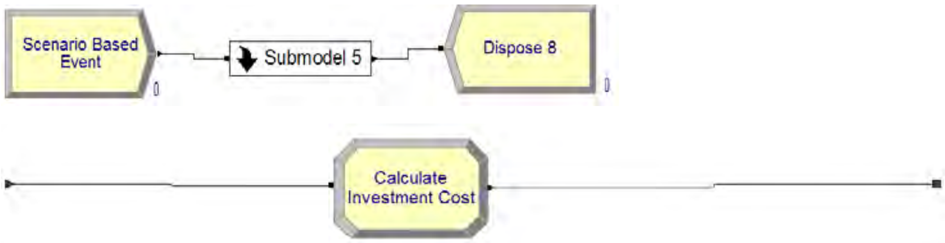
SUBMODEL 4: PERIOD-BASED EVENT

Processes in Submodel 4



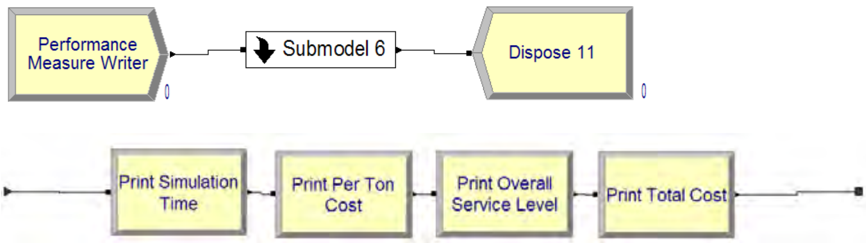
SUBMODEL 5: REPLICATION BASED EVENT

Processes in Submodel 5



SUBMODEL 6: SCENARIO PERFORMANCE WRITER

Processes in Submodel 6



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SIMULATION OUTPUT

Scenario #	Service Level	Cost per Ton
0	97.6%	219.84
0	96.6%	220.54
0	96.7%	221.00
0	97.3%	220.77
0	96.6%	220.85
1	96.2%	218.31
1	96.4%	217.25
1	96.8%	217.88
1	96.7%	217.59
1	96.6%	217.30
2	99.9%	227.63
2	99.2%	226.69
2	99.1%	227.00
2	99.4%	227.62
2	99.2%	226.90
3	99.6%	208.58
3	98.7%	210.58
3	98.9%	210.70
3	99.1%	209.60
3	98.8%	210.59
4	99.0%	219.80
4	99.0%	220.88
4	98.4%	221.47
4	98.5%	220.21
4	98.9%	221.04
5	98.0%	214.70
5	98.0%	214.70
5	98.0%	213.29
5	98.0%	213.40
5	98.0%	214.23
6	97.5%	224.96
6	97.4%	224.97
6	98.3%	225.10
6	97.5%	225.02
6	98.1%	224.97
7	98.4%	213.45
7	98.0%	211.73
7	98.6%	208.74
7	98.4%	210.66
7	98.1%	208.97
8	97.5%	224.38
8	97.3%	224.80
8	97.4%	224.72
8	97.3%	224.48
8	97.4%	224.75
9	93.9%	214.35
9	93.8%	217.04
9	94.3%	217.77
9	93.8%	215.35
9	94.2%	217.73
10	98.0%	223.32
10	98.4%	224.51
10	98.4%	224.31
10	98.2%	223.92
10	98.4%	224.42
11	98.0%	215.89
11	98.0%	215.83
11	97.9%	216.04
11	97.9%	215.85
11	98.0%	216.03
12	96.3%	217.89
12	97.0%	217.93
12	96.9%	217.54
12	96.7%	217.65
12	97.0%	217.60
13	96.9%	214.34
13	96.6%	213.71
13	97.1%	213.59
13	97.0%	214.07
13	96.8%	213.70
14	98.4%	220.33
14	98.1%	220.47
14	98.2%	220.64
14	98.4%	220.47
14	98.2%	220.49
15	98.4%	209.62
15	99.0%	211.42
15	98.6%	211.94
15	98.9%	210.79
15	98.6%	211.66

Scenario #	Service Level	Cost per Ton
16	92.8%	205.16
16	92.4%	204.29
16	93.0%	202.61
16	92.7%	203.69
16	92.9%	203.50
17	93.2%	195.52
17	92.4%	197.25
17	93.2%	197.77
17	93.1%	197.63
17	92.8%	197.45
18	100.0%	199.44
18	99.3%	198.72
18	98.8%	199.34
18	99.4%	198.94
18	99.2%	199.03
19	97.3%	196.10
19	97.3%	195.80
19	97.4%	195.80
19	97.3%	196.00
19	97.3%	195.80
20	99.2%	195.24
20	96.0%	197.20
20	95.7%	196.12
20	96.3%	195.63
20	95.8%	196.52
21	96.3%	192.01
21	96.6%	192.79
21	96.0%	192.28
21	96.5%	192.45
21	96.0%	192.61
22	97.7%	196.19
22	98.3%	195.95
22	98.7%	196.11
22	98.7%	196.13
22	98.7%	196.09
23	98.0%	187.20
23	98.6%	188.87
23	98.8%	188.53
23	98.5%	187.84
23	98.7%	188.74
24	94.5%	198.75
24	95.4%	200.64
24	94.9%	200.04
24	95.1%	199.73
24	95.0%	200.60
25	91.4%	200.70
25	91.8%	199.17
25	91.4%	199.52
25	91.8%	199.34
25	91.8%	199.29
26	93.8%	199.90
26	94.5%	201.02
26	94.9%	199.00
26	93.8%	200.22
26	94.8%	200.64
27	92.8%	197.14
27	92.8%	196.81
27	92.6%	198.52
27	92.7%	197.09
27	92.8%	197.93
28	92.3%	197.29
28	93.3%	195.09
28	92.7%	196.08
28	92.8%	195.68
28	93.3%	195.09
29	91.5%	190.25
29	92.6%	190.02
29	93.4%	190.43
29	91.6%	190.10
29	92.9%	190.30
30	98.2%	191.47
30	97.4%	193.86
30	96.9%	193.52
30	97.2%	193.24
30	97.2%	193.79
31	95.5%	186.76
31	96.5%	188.25
31	96.7%	188.68
31	95.7%	187.78
31	96.7%	188.64

Scenario #	Service Level	Cost per Ton
32	90.4%	180.54
32	90.4%	182.75
32	90.2%	181.67
32	90.3%	181.48
32	90.2%	182.37
33	92.9%	181.56
33	92.6%	180.81
33	92.7%	181.18
33	92.8%	181.29
33	92.6%	181.06
34	94.0%	181.32
34	94.9%	178.40
34	95.6%	178.88
34	94.7%	179.54
34	95.3%	178.47
35	95.8%	176.34
35	96.2%	176.25
35	96.0%	176.56
35	96.1%	176.50
35	96.1%	176.39
36	92.6%	175.57
36	91.7%	175.65
36	92.1%	177.54
36	91.8%	175.74
36	91.8%	175.82
37	91.4%	178.83
37	91.3%	177.38
37	90.9%	177.99
37	91.4%	178.74
37	91.0%	177.70
38	96.9%	172.34
38	96.6%	171.91
38	96.7%	170.76
38	96.6%	171.91
38	96.6%	170.96
39	96.7%	169.08
39	96.3%	169.46
39	96.2%	170.46
39	96.4%	170.41
39	96.2%	169.61
40	91.3%	182.88
40	92.5%	181.08
40	91.9%	183.12
40	92.2%	182.96
40	92.4%	182.07
41	91.7%	179.62
41	90.8%	181.55
41	90.6%	180.14
41	90.7%	181.48
41	90.8%	180.97
42	92.4%	180.97
42	90.3%	182.22
42	91.0%	182.59
42	90.4%	181.38
42	90.6%	182.57
43	93.4%	181.52
43	91.9%	181.67
43	91.6%	181.30
43	92.2%	181.41
43	91.7%	181.46
44	90.0%	175.69
44	89.4%	175.39
44	90.6%	175.62
44	89.7%	175.49
44	90.6%	175.47
45	93.0%	169.30
45	92.4%	170.70
45	92.3%	171.67
45	92.4%	170.90
45	92.4%	171.08
46	94.5%	174.96
46	93.6%	174.47
46	93.9%	174.61
46	94.1%	174.64
46	93.7%	174.51
47	93.4%	174.23
47	92.4%	174.39
47	93.2%	173.24
47	93.0%	173.98
47	92.8%	174.26

ANOVA TEST COMPLETE RESULTS

Dependent Variable: CPT

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Model	8.796E6[a]	48	183254.956	1.946E5	.000
RS	6072.153	1	6072.153	6.449E3	.000
DE	151.485	1	151.485	160.886	.000
OT	817.172	1	817.172	867.884	.000
PC	315.525	1	315.525	335.106	.000
NS	79912.159	2	39956.079	4.244E4	.000
RS * DE	60.117	1	60.117	63.848	.000
RS * OT	50.099	1	50.099	53.208	.000
RS * PC	27.458	1	27.458	29.162	.000
RS * NS	2626.992	2	1313.496	1.395E3	.000
DE * OT	1.779	1	1.779	1.890	.171
DE * PC	.333	1	.333	.354	.553
DE * NS	132.239	2	66.120	70.223	.000
OT * PC	18.030	1	18.030	19.149	.000
OT * NS	51.551	2	25.775	27.375	.000
PC * NS	138.650	2	69.325	73.627	.000
RS * DE * OT	21.877	1	21.877	23.235	.000
RS * DE * PC	12.458	1	12.458	13.231	.000
RS * DE * NS	103.224	2	51.612	54.815	.000
RS * OT * PC	9.210	1	9.210	9.781	.002
RS * OT * NS	161.231	2	80.616	85.619	.000
RS * PC * NS	33.289	2	16.645	17.678	.000
DE * OT * PC	13.941	1	13.941	14.806	.000
DE * OT * NS	68.220	2	34.110	36.227	.000
DE * PC * NS	21.456	2	10.728	11.394	.000
OT * PC * NS	22.558	2	11.279	11.979	.000
RS * DE * OT * PC	.055	1	.055	.058	.810
RS * DE * OT * NS	86.444	2	43.222	45.904	.000
RS * DE * PC * NS	47.646	2	23.823	25.301	.000
RS * OT * PC * NS	.533	2	.267	.283	.754

Dependent Variable: CPT

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
DE * OT * PC * NS	17.691	2	8.846	9.394	.000
RS * DE * OT * PC * NS	10.277	2	5.138	5.457	.005
Error	180.781	192	.942		
Total	8796418.657	240			

a. R Squared = 1.000 (Adjusted R Squared = 1.000)

Dependent Variable: SL

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Model	223.994a	48	4.667	2.312E5	.000
RS	.000	1	.000	11.991	.001
DE	.005	1	.005	270.467	.000
OT	.001	1	.001	48.762	.000
PC	.007	1	.007	332.139	.000
NS	.011	2	.005	266.735	.000
RS * DE	3.037E-6	1	3.037E-6	.150	.698
RS * OT	.000	1	.000	15.909	.000
RS * PC	2.640E-5	1	2.640E-5	1.308	.254
RS * NS	.002	2	.001	58.170	.000
DE * OT	.001	1	.001	35.384	.000
DE * PC	.000	1	.000	16.278	.000
DE * NS	.001	2	.001	33.201	.000
OT * PC	.000	1	.000	16.024	.000
OT * NS	.001	2	.000	22.873	.000
PC * NS	.004	2	.002	102.738	.000
RS * DE * OT	.001	1	.001	38.599	.000
RS * DE * PC	2.993E-6	1	2.993E-6	.148	.701
RS * DE * NS	.001	2	.001	25.463	.000
RS * OT * PC	.000	1	.000	20.329	.000

Dependent Variable: SL

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
RS * OT * NS	.001	2	.000	15.129	.000
RS * PC * NS	.001	2	.000	24.305	.000
DE * OT * PC	.001	1	.001	41.917	.000
DE * OT * NS	.000	2	.000	5.409	.005
DE * PC * NS	.001	2	.000	16.509	.000
OT * PC * NS	.000	2	.000	9.726	.000
RS * DE * OT * PC	4.455E-5	1	4.455E-5	2.207	.139
RS * DE * OT * NS	.001	2	.001	32.670	.000
RS * DE * PC * NS	.000	2	.000	8.376	.000
RS * OT * PC * NS	.000	2	.000	8.690	.000
DE * OT * PC * NS	.000	2	.000	9.671	.000
RS * DE * OT * PC * NS	.001	2	.000	17.149	.000
Error	.004	192	2.018E-5		
Total	223.998	240			
Model	223.994a	48	4.667	2.312E5	.000

AUTHOR'S BIOGRAPHY

The author, Mansur Maturidi Arief, was born in Sungguminasa on September 8th, 1991. Being the third child of Bapak Arief Halim and Ibu Nuraini Mahdin, the author went to TK Aisyiyah, Gowa (1996-1997) for kindergarten and continued to SDN Sungguminasa 1, Gowa (1997-2003) for elementary school. The author then continued to Pesantren Modern Pendidikan Al-Qur'an IMMIM Putra Makassar, where he sits for junior high school (2003-2006) and senior high school (2006-2010). During his high school years, the author participated in an exchange study and went to Milford High School, DE (2008-2009) as a senior year student where he intensely learns English. After returning home and finishing his high school at SMA Pesantren IMMIM Putra Makassar, the author applied for a college scholarship named Program Beasiswa Santri Berprestasi (PBSB) funded by Ministry of Religious Affairs (Kementerian Agama) of Republic of Indonesia and passed as a student in Department of Industrial Engineering of Institut Teknologi Sepuluh Nopember (ITS) Surabaya.

As a college student, the author had actively engaged in several communities and interests. The author worked as a staff in ITS Foreign Language Society (IFLS), KESMA CSS MoRA ITS and DIKESMA HMTI ITS (2011-2012) and became Head of CSS MoRA ITS (2012-2013). The author is also a laboratory assistant in Laboratory of Logistics and Supply Chain Management (LSCM) of Department of Industrial Engineering where he helped the faculty members in laboratory engagement activities for students and industrial practitioners (2012-2014). To solidify his interest in Logistics and Supply Chain Management field of studies, the author works for PT Kamadjaja Logistics Department of Domestic and Freight Forwarding during his internship course work (2013). During his last year of study, the author has also worked for ITS International Office as a part-timer to be a part of ITS endeavor to achieve international recognition.