TUGAS AKHIR – TI 141501

PERBAIKAN PROSES ANGKUT PHONSKA IN-BAG UNTUK DISWIL 2 MENGGUNAKAN METODE SIX SIGMA DMAIC DAN SIMULASI UNTUK MENGURANGI WAKTU ANGKUT DI PELABUHAN PT PETROKIMIA GRESIK

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FINAL PROJECT – TI 141501

IMPROVEMENT OF DISWIL 2 PHONSKA IN-BAG LOADING PROCESS USING SIX SIGMA DMAIC AND SIMULATION MODELING TO REDUCE LOADING DURATION IN PT PETROKIMIA GRESIK'S PORT

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APPROVAL SHEET

IMPROVEMENT OF DISWIL 2 PHONSKA IN-BAG LOADING PROCESS USING SIX SIGMA DMAIC AND SIMULATION MODELING TO REDUCE LOADING DURATION IN PT PETROKIMIA GRESIK'S PORT

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Student Name : Muchammad Andry Suryanata

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ABSTRACT

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The analysis results exhibited that low loading rate occurred due to the delay in loading process at both warehouse (upstream) and port (downstream). The stocks unavailability due to improper allocation turned out to be the most crucial factor in the warehouse. While in the port, the lack of supervision on the workers became the main factor. An improvement on both factors would increase the loading rate up to 13% and reduce the cost as big as 12% from monthly cost that the company usually spent. In addition, control actions for stock allocation and stevedore supervision were also developed as the internal guidance in maintaining the performance of improvement.

Keywords: Fertilizers Distribution, Loading process, Six Sigma DMAIC, Simulation, Port.

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PREFACE

Alhamdulillah, all praises belong to Allah SWT. By whose grace, guidance, and blessing the author can finish this research entitled “Improvement Of Diswil 2 Phonska In-Bag Loading Process Using Six Sigma DMAIC And Simulation Modeling to Reduce Loading Duration In PT Petrokimia Gresik’s Port” by the end of fourth year study in Industrial Engineering Department of Institut Teknologi Sepuluh Nopember Surabaya.

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

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

Surabaya, July 20th 2015

Author

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INTRODUCTION

The first chapter in this report contains of background of research, problem formulation, research's purposes and benefits, scope and outline which are used to conduct the research.

1.1 Research Background

Indonesia is an agricultural country with average productivity 5.16 tonnes/Hectare of food crop / year (Kementerian Pertanian, 2014). This condition places agricultural sector as one of important sectors in Indonesia. In 2013, food crops and plantations contribute 8.76% of the whole Product Domestic Bruto. It is continued by the achievement in 2014 as big as 8.53% (Badan Pusat Statistik, 2014). Another reason to call agricultural sector holds important role is because it has multiplier effect (forward and backward linkages) with other sectors such as manufacture and service industries (Daryanto, 2009). One of the effects is high demand of fertilizers. According to APPI (Indonesia Fertilizer Producers Association) the domestic consumption of fertilizer in Indonesia is dominated by majorly 2 parties which are agricultural and crop estate.

Total fertilizers demand shows positive trend which continues to increase year by year. The graph below shows the trend of total domestic consumption of fertilizers (Urea, NPK, phosphat, ect.) in 2007 – 2013.

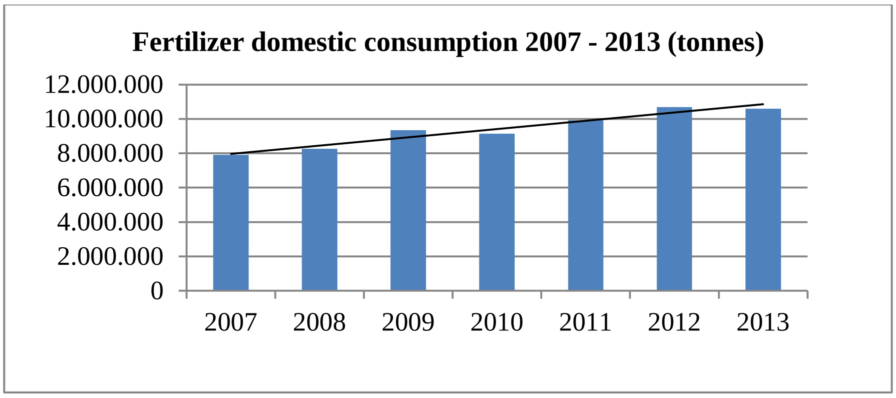


Figure 1.1Total fertilizers domestic consumption 2007-2013

Source : APPI (Asosiasi Produsen Pupuk Indonesia)

Fertilizers manufacturer companies and the distributors are all challenged to face this opportunity. This potential market should be balanced with good distribution process. This challenge is certainly confronted with classic problem when it meets the reality of Indonesian archipelago landscape. The distribution process cannot be conducted only by land road trucking, but also by sea transportation.

The importance of outside java fertilizer distribution congruent with data from Indonesian ministry of agriculture (KementerianPertanian) that showsin fact agricultural land in Indonesia is majorly located in outside java.

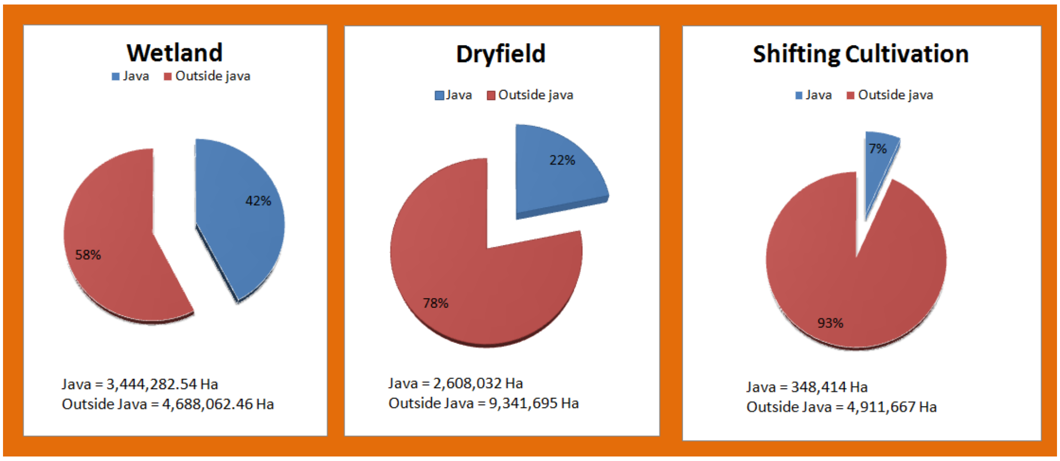


Figure 1.2Percentage of Java and Outside Java agricultural land

Source : Kementerian Pertanian Republik Indonesia 2013

The 58% of wetland, 78% of dry field, and 93% of shifting cultivation in Indonesia are spread outside java. Thus, the supplies for outside java region have to be considered as important. The late of fertilizer supplies can lead to failure of harvest.

PT Petrokimia Gresik is located in Gresik, East Java, Indonesia. Distribution of fertilizers by PT Petrokimia Gresik is divided intotwo regions, which are Diswil 1 and Diswil 2. Diswil 1(Distribution region 1) is Java-Bali zone. The demands from Diswil 1 are delivered by trucks through land road. While for the diswil 2, its covered area is the outside Java zone. It uses sea transportations to deliver the orders.

Order that comes to the port is not from public buyers. It comes from Diswil 2 Department which has authority to give assignment of distribution to distribution center or buffer warehouse located at outside java region. The assignment is then followed up through Port Department.

Port department as the executor of the assignment will prepare all of the equipment of distribution starts from vessel, truck, the workers (stevedores) and surveyor. The loading process of in-bag fertilizers is using flat trucks to load fertilizers from warehouses to port. This trucking system is vessel based system. It means one vessel will be served by one trucking group contains of 5 flat trucks. The truck will do the loading process until the specified quantity is all loaded.

In PT Petrokimia Gresik, the outside java demand is dominated by Phonskain-bag since it is the special product which only produced by PT Petrokimia Gresik. In earlier 2015, the cumulative demands of outside Java until period of April 2015 shows the value of phonska demand reach135,097.5 Tons. It is slightly higher than other types of fertilizer as shown in figure 1.3 below.

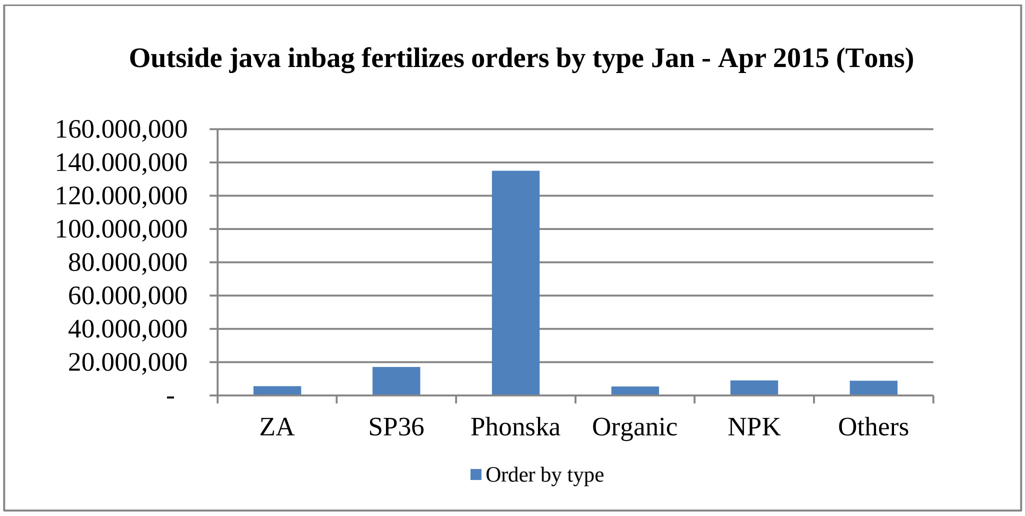


Figure 1.3PT Petrokimia Gresik outside Java orders based on fertilizers type

This high demand of Phonska In-bag is not followed by good achievement in loading process. The loading rate of Phonska in-bag in the port is commonly under the target. The specified target is 500 tons/vessel/day. In actual condition, the target is not constantly achieved. Target 500 tons/vessel/day means in one day it has to be fulfilled by 21 truck loads, since 1 truck capacity is 24 tons. The historical data shows loading achievement

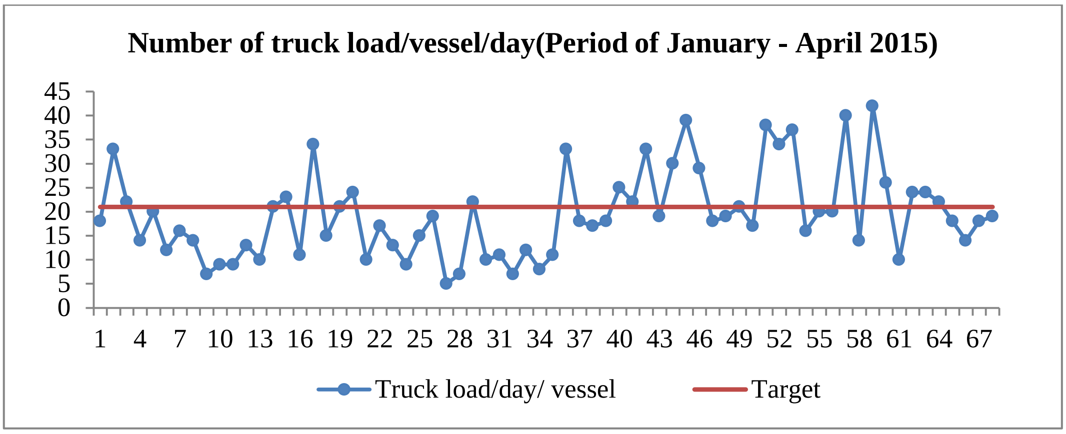


Figure 1.4Number of truck load/vessel/day

The daily truck load achievement is performed unstable. The vessels that served in period of January to April 2015 are indicatedto have significant variances in the loading rate achieved. Based on the graph above, some vessels are served with loading rates (number of daily truckload) far below the target, while the other vessels have loading rates beyond the target. There is imbalance of loading rate accomplished in the port.64% vessels are served below the targeted loading rate. The lower loading rate will impact on longer loading duration. The effect leads the company to pay higher stevedore costs.

Stevedores are the workers who load the fertilizers to the vessels. They are handled by PBM (Perusahaan BongkarMuat) that becomes a vendor partner of PT Petrokimia Gresik. The stevedores are working in group with vessel-based system (same with the trucking group). PTPetrokimia Gresik pays IDR 7,400,000/day/vessel to the PBM. The following graph shows different

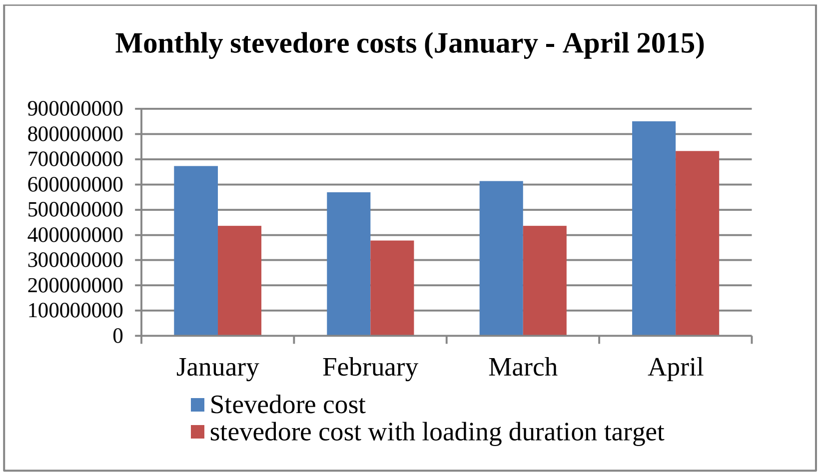


Figure 1.5 Monthly stevedore cost

Another implication is the berthing duration is longer than they should be.Vessels queuing can become longer too, and it will affect to the distribution timeline. This condition will make products are not delivered as they are scheduled.

Berthing duration is started when the vessel puts off its anchor and berths in the dock. It is finished when the loading process ends and vessel leaves the dock. The sequence of activity and its existing condition in PT Petrokimia Gresik's special port is given in figure 1.6 below.

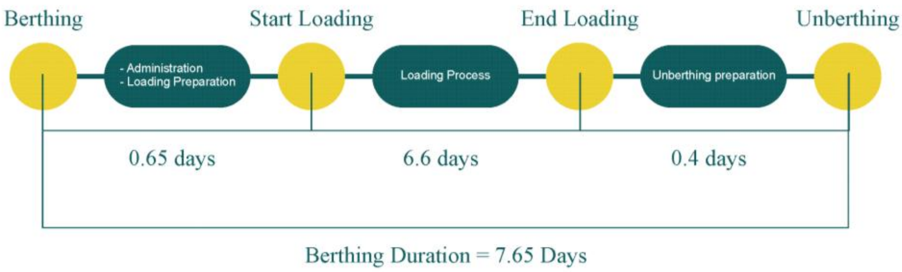


Figure 1.6 Existing time of berthing duration sequence

The actual berthing duration lays on 7.65 days in average. The time is mostly spent on the loading process which is 6.6 days. It is 86.8% of the total berthing duration. If the port department constantly achieves the target, which is 500 tonnes/vessel/day, the loading process time is estimated to be 5.08 days in average. It means that the berthing duration can be cut off more than one and a half days.

Recalling the challenge that the domestic consumption of fertilizer is predicted to be increasing and majorly the demands come from outside java, Port Department should improve the loading process performance. So that, the company can get bigger profits by the ability to fulfill the increasing demands and reducing the costs appear in the process.

Based on this condition, an investigation to find factors that causing long loading process / low loading rate should be developed. This standard will minimize contribution of wastes causing longer time to load the products. The factors which are causing imbalance of loading rate will be identified and analyzed. Six sigma approach is chosen because it is compatible to be applied to this problem. UsingSixsigma, the problem will be mapped and defined the root causes using DMAIC method. The result of this research can be used to build one standard operating procedure which helps the company to achieve better performance of loading process in PT Petrokimia Gresik's port.

1.2 Problem Formulation

Based on the background of research which is already stated before, the problem that will be investigated isimprovement of Phonska in-bag-fertilizer low loading rate in port. The research will use Six-sigma DMAIC philosophy to direct the investigation. The magnitude of wastes will be measured and find the improvement in order to reduce it. Several analysis such as Root cause analysis, Failure mode and effect analysis (FMEA), and value engineering will be developed to support the research. Comparison of existing condition with pre-improvement phase will be developed to see the change.

1.3 Research Objectives

The purposes ofconducting this research are mentioned as follows:

1. Identify the performance of waste that impacting on low Phonska-inbag loading rate achievement through simulation.
2. Identify the factors which are causing the low performance of Phonska in-bag-fertilizer loading rate to the vessels.
3. Develop improvement solutions to increase loading rate of Phonska in-bag-fertilizer loading process.

1.4 Research Benefits

The benefits of conducting this research are mentioned as follows:

1. The company will get some applicable solutions for the existing low loading rate problem.
2. The company will get improvement of loading process.
3. Company's performance will increase as the improvement solutions are implemented to the problem identified.

1.5 Scope of Research

The scope of research contains of limitations and assumptions that are used to conduct the research.

1.5.1 Limitations

The limitations that are used in the research are mentioned as follows :

1. The data gathering is executed in April-May 2015.
2. The loading process observed is only for Diswil 2 (Distribution Region 2) for outside Java.
3. The type of product observed is onlyPhonska in-bag fertilizer.

1.5.2 Assumptions

The assumptions that are used in the research are mentioned as follows :

1. The loading rate target set by the company is 500 tons/vessel/day
2. The recorded data loading performance of year 2015 (historical data) is valid.
3. Velocity of trucks for every transport involved is the same.

1.6 Report Outline

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

CHAPTER 1 : INTRODUCTION

This chapter describes the background, problem formulation, objectives, benefits, and scope of this research. In the last part of this chapter, report outline of the research is explained.

CHAPTER 2 : LITERATURE REVIEW

This chapter explains theories and concepts based on existing literatures that have been developed and are used for the research. Some concepts and theories provided in the literature review are Six sigma DMAIC, Lean service, Stopwatch Time Study,7 wastes, RCA, FMEA and Simulation.

CHAPTER 3 : RESEARCH METHODOLOGY

This chapter describes all phases conducted in this research so that the research could be done systematically. Generally, the research methodology follows DMAIC (Define, Measure, Analysis, Improve, and Control) method to find the waste/s on loading process for vessels. It also contains observation and literature study, data collection and processing, data interpretation and analysis, conclusion and recommendation/s.

CHAPTER 4 : DATA COLLECTION AND PROCESSING

This chapter elucidates all processes including data collection, data processing,wastes identification of existing problem, simulation development to measure the wastes.

CHAPTER 5 : ANALYSIS AND SIMULATION MODELING

This chapter includes analysis and interpretation of the result wastes measurement.The critical to quality (CTQ) factor/s which is causing wastes will then be determined. A simulation model will then be developed as the implementation of improvement. This will test the application of solution/improvement in a model which represents the system.

CHAPTER 6: CONCLUSION AND RECCOMENDATION

This chapter concludes the whole research and contains recommendations for further researches. The conclusions answer the objectives of research. The recommendations are made to give suggestions for next researcher in conducting research in the same field.

CHAPTER II
LITERATURE REVIEW

In this second chapter several literatures related to the research topic is given. Those literatures are used to support the research as knowledge enrichment. The concepts and theories used in this research are Lean Service, Six sigma DMAIC, Failure Modes and Effect Analysis (FMEA), Root cause Analysis, Simulation modeling, and Standard Operating Procedure (SOP).

2.1 Six Sigma-DMAIC

Various ways can be accomplished in order to increase performance as it is targeted to be. In this research, six sigma will be used as an approach to conduct the exploration of existing condition. It is aimed to eliminate the waste/s of existing process.

Six Sigma, a trademark of Motorola, was introduced more than 20 years ago and has been characterized as the latest management fad to repackage old quality management principles, practices, tools and techniques (Clifford, 2001).

The origin of Six Sigma comes from statistic terms. Six Sigma is described as producing less than 3.4 defects per one million of opportunity of defect occurences. It means that the success rate of Six Sigma is 99.9997% of the whole opportunities. Sigma is a term used to represent the variation about the process average (Antony and Banuelas, 2002).

Six Sigma can be categorized into two types based on its methodology. They are Six sigma-DMAIC (Define, Measure, Analyze, Improve, Control) and Six Sigma-DMADV (Define, Measure, Analyze, Design, Verify). In this research, method which is used is Six Sigma DMAIC. Six Sigma-DMAIC is applied to business process which already exists before (Selvi, 2014). DMAIC contains of five main steps explained below :

(a) **Define** the problem, improvement activity, opportunity for improvement, the project goals, and customer (internal and external) requirements.

(b) **Measure** process performance. There are three important things included in this step, which are :

1. Choosing the characteristics of Critical to Quality (CTQ) related to the problem
2. Defining measurement standards.
3. Assuring the measurement method is valid to use.

(c) **Analyze** the process to determine root causes of variation, poor performance (defects).

(d) **Improve** process performance by addressing and eliminating the root causes.

(e) **Control** the improved process and future process performance.

2.2 Stopwatch Time Study

Stopwatch time study measures how long it takes an average worker to complete a task at a normal pace. This type of work measurement is used to find the time required to carry out the operation at a defined level of activity (Russell, Taylor, 2005). The used of stopwatch time study is to find standard time of certain process or activity. This standard time is the time achieved by normal operator in at the actual work. Normal operator here is described as qualified, experienced, working under normal circumstances and condition of workstation. The steps to develop standard time using stopwatch time study are given below :

1. Process mapping.

   This process will define the sequence of activities, so it can be easier to develop the scheming and measurement levelling in parallel or series form.

2. Time record and sampling.

   This step is about to measure the related activities using stopwatch to get the data of time taken.

3. Conformity test

   This test is used to eliminate the unconforming data which are outliers. The outliers data are the data which outside the control limits. Whether lower or upper, which means that the value is far below or beyond the normal data.

4. Data adequacy test

   The number of sample have to be tested whether it is enough to run the determination of standard time or not. The calculation is following this formula :

$$N' = \left[\frac{Z.S}{\overline{\overline{X}}.k} \right]^2$$

   where :

   N' = Number of sample data needed

   Z = The value of Z in specified confidence level

   S = Standard deviation

   $\bar{x}$ = Average of data

   k = Error level

5. Allowance formulation

   Allowance of working is determined using the formula below :

$$\%\text{Allowance} = \frac{\sum \text{Allowance}}{\sum \text{Allowance} + \sum \text{Operation} + \sum \text{MaterialHandling}} \times 100\%$$

6. Normal time calculation

   Normal time is determined using this formula :

   Normal time = total actual time x performance rating

7. Standard time calculation

   Standard time is the normal time added by allowance. The formula of calculation is given below :

$$\text{Standard time} = \frac{\text{normal time} \times 100\%}{100\% - \%\text{Allowance}} (\text{hour/unit})$$

2.3 Root Cause Analysis (RCA)

In analyzing a problem, the way to find reasons causing it is very important. Finding the factors that contribute to problem occured is have to give serious attention. It can help the company to make improvement solutions, so that the possibility of same problem occurs will be prevented. In order to identify the causes of problem, root cause analysis (RCA) is chosen to use is this research.

Root cause analysis (RCA) is a process which is build with the purpose to investigateand categorize the root reasons of activities with safety, health, environmental, quality, reliability and production impacts (Tomić, 2011). The activities stated above is the events that possibly produce some problems with consequencies for the company / related party. RCA will identify not only what and how an event of failure occurred, but the most important is why it happened. In hope that the investigators can understands the reasons so that it can be deeply analyzed and prevent it to occur again.

There are some techniques to run the RCA. Some of them are "5 why" method, Cause-effect (fishbone) diagram, fault tree diagram. In this research, author chooses the 5 why method to analyze the root cause of problem.

5 why is a method which that track down the root cause of problem with asking "why" the problem can appear until 5 sequence. This method is well-known as lean tool. Using 5 why method the tracking process of cause will be easier.

Why 1 : Symptom

Why 2 : Excuse

Why 3 : Blame

Why 4 : Cause

Why 5 : Root cause

2.4 Failure Modes and Effect Analysis (FMEA)

The Failure Modes and Effects Analysis is a systematic method to identify some potential failures that possibly appear in a product or process. This method analyzes and identified the object, so that the potential failures can be anticipated through certain control actions. The effects captured can also be minized or even eliminated. FMEA is a crucial reliability tool that helps company or related party to avoid costs incurred from product or process failure and liability. This failure and its effects, if continues to happen, it can affect on the decreasing of process or product quality.

In conducting FMEA, there are some steps to be followed. This is aimed to get a systematic analysis which sequencially ordered. It will gives the better identification process and the rating assesment. the steps in conducting FMEA is considered below :

Step 1: Identify components and associated functions

The first step of an FMEA is to identify all of the components to ben evaluated. This may include all of the parts that constitute the product or process. The identification should describe all the functions of part within the product or process.

Step 2: Identify failure modes

The potential failure mode(s) for each part are identified. Failure modes can include but are not limited to:

- Complete Failures
- Intermittent Failures
- Partial Failures
- Failures Over Time
- Premature operation
- Incorrect Operation
- Failure to cease functioning at allotted time
- Failure to function atallottedtime.

Step 3: Identify effects of the failure modes

For each failure mode identified, the consequences or effects on process or product, property and people are listed. This is aimed to generate the option of effects to be used in further FMEA process.

Step 4: Determine severity of the failure mode

The severity or criticality rating indicates how significant of an impact the effect is on the customer. Severity gives the effect identified a range from insignificant to risk of fatality. Depending on the FMEA method employed, severity is usually given either a numeric rating or a coded rating.

Table 2.1Severity Rating

Rating	Category	Explanation
1	None	Effect will be undetected by customer or regarded as insignificant.
2	Very minor	A few customers may notice effect and may be annoyed.
3	Minor	Average customer will notice effect.
4	Very low	Effect recognised by most customers.
5	Low	Product is operable, however performance of comfort or convenience items is reduced.
6	Moderate	Products operable, however comfort or convenience items are inoperable.
7	High	Product is operable at reduced level of performance. High degree of customer dissatisfaction.
8	Very high	Loss of primary function renders product inoperable. Intolerable effects apparent to customer. May violate non-safety related governmental regulations. Repairs lengthy and costly.
9	Hazardous – with warning	Unsafe operation with warning before failure or non-conformance with government regulations. Risk of injury or fatality.
10	Hazardous – without warning	Unsafe operation without warning before failure or non-conformance with government regulations. Risk of injury or fatality.

Step 5: Identify cause(s) of the failure mode

For each mode of failure, causes are inputted. These causes can be design deficiencies that result in performance failures, or induce manufacturing errors.

Step 6: Determine probability of occurrence

This step involves determining or estimating the probability that a given cause or failure mode will occur. The probability of occurrence can be determined from field data or history of process. If this information is not available, a subjective rating is made based on the experience and knowledge of the cross-functional experts.

Two of the methods used for rating the probability of occurrence are a numeric ranking and a relative probability of failure. As with a numeric severity rating, a numeric probability of occurrence rating can be used in further calculation.

Table 2. 2Occurence Rating

Rating	Category	Explanation
1	Unlikely	≤ 1 in 1.5 million (≤ .0001%)
2	Low (Few failures)	1 in 150,000 (≤ .001%)
3		1 in 15,000 (≤ .01%)
4	Moderate (Occasional failures)	1 in 2,000 (0.05%)
5		1 in 400 (0.25%)
6		1 in 80 (1.25%)
7	High (Repeated faailure)	1 in 20 (5%)
8		1 in 8 (12.5%)
9	Very High (Relatively consistent failure)	1 in 3 (33%)
10		≥1 in 2 (≥ 50%)

Step 7: Identify controls

Identification of current control which is used to detect the failure is the next step. The better controls implemented, the better its detectability. It means that the faailure can be prevented and tracked the cause easier. Preventative controls also either eliminate the cause or reduce the rate of occurrence. Controls that detect the cause allow for corrective action while controls tha detect failure allow for interception of the product before it reaches subsequent operations or the customer.

Step 8: Determine effectiveness of current controls or detectability

The detectability rating estimates how well the cause or failure mode can be detected. If more than one control is used for a given cause or failure mode, an effectiveness rating is given to the group of controls. Detectability ratings can be customised provided the guidelines as previously outlined for severity and occurrence are followed.

Table 2.3Detectability Rating

Rating	Category	Explanation
1	Excellent	control mechanisms are foolproof.
2	Very high	some question about effectiveness of control.
3	High	unlikely cause or failure will go undetected.
4	Moderately high	control effective under certain conditions.
5	Moderate	Control effective but some failures are not detected
6	Low	Less effective control but still able to detect several failures
7	Very low	Insufficient control but several failures are still detected
8	Poor	control is insufficient and causes or failures extremely unlikely to be prevented or detected.
9	Very poor	Insufficient control and the failures are majorly not detected.
10	Ineffective	causes or failures almost certainly not prevented or detected.

Step 9: Calculate Risk Priority Number (RPN)

The RPN is a step that used to give priority on failure modes foraction.Itis calculated for each failure mode by multiplying the numerical ratings of the severity,probability of occurrence and the probability of detectability. The formulain calculating RPN is given in following statement :

$$RPN = S \times O \times D$$

Note :

RPN = Rank Priority Number

S= Severity rank

O = Occurence rank

D = Detectability of

In general, the failure modes that have the greatest RPNreceive priority for corrective action.

2.5 Simulation Modeling

Modelingis the process to conceptualize a model which represents a particular system. A model is similar to but simpler than the system it represents (Maria, 1997). The objective of developing model is to let researcher is able to investigate the implicationof system changes without directly applying the changes to the real system. This objective will lead to a need of data or features which aproximately represent the actual system.

A simulation of asystem is theoperationof a model that already conceptualized before. This operation can be studied, whether the process or the result. There are some steps to develop asimulation model. According toAnu Maria in the Journal of Introduction toModeling and Simulation, the steps involved in developing a simulation model,designing a simulation experiment, and performing simulation analysis are:

Step 1. Identify the problem.

Step 2. Formulate the problem.

Step 3. Collect and process real system data.

Step 4. Formulate and develop a model.

Step 5. Validate the model.

Step 6. Document model for future use.

Step 7. Select appropriate experimental design.

Step 8. Establish experimental conditions for runs.

Step 9. Perform simulation runs.

Step 10. Interpret and present results.

Step 11. Recommend further course of action.

Although this is a logical ordering of steps in a simulation study, many iterations at various sub-stages may be required before the objectives of a simulation study are achieved. Not all the steps may be possible and/or required. On the other hand, additional steps may have to be performed.

2.5.1 Validation

Model validity is an important issue in simulation modeling. Validation is the process of determining whether the conceptual model correctly reflects the real system or not. Model can be stated as valid if the results of the comparison that appears between simulated model with real condition indicates that the two alternative models do not differ significantly.

One of validation techniques is Welch method. In this researchwelch confidenceintervalforcomparingtwosystemsisthemethodused inthe validation process. The validation process using such methods as the number of samples in each population and variance between populations 1 and 2 different populations.

Hypothesis:

H_0 : μ1- μ2 = 0

H_1 : μ1- μ2 ≠ 0

The conditions of using Welch confidence interval comparing two systems are as follows:

1. Each population (simulated systems) are free and Gaussian normal both in population and between populations.
2. The number of samples in each population (n1) and (n2) does not always same.
3. The number of variance between population 1 and population 2 does not always same.
4. Calculation of the Welch confidence interval for comparing two systems for a significant level α.

$$df \approx \frac{\left[\frac{S_1^2}{n_1}+\frac{S_2^2}{n_2}\right]^2}{\frac{\left[\frac{S_1^2}{n_1}\right]^2}{(n_1-1)}+\frac{\left[\frac{S_2^2}{n_2}\right]^2}{(n_2-1)}} \cdots$$

$$hw = t_{df,\frac{\alpha}{2}}\sqrt{\frac{S_1^2}{n_1}+\frac{S_2^2}{n_2}}$$

CHAPTER III
RESEARCH METHODOLOGY

Every research basically has steps or structure to get proper sequence for researcher conducts it. It is commonly given in specific methodology of research. In this chapter, the methodology in conducting research and the steps contained will be explained. The steps start from earlier phase (problem identification), observation and data processing, analysis of result, improvement development, simulation of improvement scenarios, and the recommendation are all spoiled. A flowchart of research sequence is also previewed to show the clear steps in form of chart.

3.1 Problem identification and formulation phase

In this step, researcher tries to identify problem from existing condition of PT Petrokimia Gresik's special port. The problem identified will be formulized and found the improvement solution through further process.

3.1.1 Problem Identification Process

The problem faced by PT Petrokimia Gresik's special port is loading rate of Phonska in-bag (bag-packaged) fertilizers has low loading rate. It is still below the standard rate targeted by the company. This low rate leads to some problems in the activity cycle, such as stevedore cost, long berthing duration of vessels, the queuing of vessels in Teluk Jamuang, and it possibly affects on the late of distribution. In this case, the low loading rate is supposed not to be occurred because the facilities that the port has is sufficient to direct the loading operations. The study to find the problems root causes/reasons is needed to improve its performance.

3.1.2 Problem formulation

In this phase the identified problem is used to set research form and its objectives. Based on the previous identification, the form of research is an applied research of Six sigma DMAIC to minimize or even eliminate wastes of loading process in PT Petrokimia Gresik's special port. The factors causing low loading rate will be defined, measured, analyzed, improved, and then control it by using standard operating procedure recommendation. The objectives of this research are to measure existing wastes of Phonska in-bag-fertilizer loading processfor Diswil 2 in PT Petrokimia Gresik's port. In order to let PT Petrokimia Gresik knows the performance of wastes in existing loading process. Then, develop improvement solutions to increase Phonska in-bag-fertilizer loading process and give recommendation of control.

3.1.3 Literature review

Literatures that are used for this research basically follow Six sigma DMAIC. In defining the problem, researcher uses cycle map as theoretical guidance to map the loading process. Seven wastes concept is also involved to see which elements of process in real condition of port will be categorized as wastes. The other literatures such as Root Cause Analysis (RCA), Simulation modeling, and Standard Operating Procedure will give supporting reference to Analyze, improve and control the existing condition of port.

3.1.4 Field Observation

This phase has a purpose to let researcher understand about the real condition in work field. The processes which are conducted in the loading activity will be observed through direct investigation and interview to related workers.

3.2 Data Collection and Processing Phase

Data Collection and processing phase is the stage where data from the company is gathered and computed to get further analysis.Some data that will be required in conducting this research are :

1. Historical data of loading time and loading rate ofPhonska in-bag fertilizer. It is used as the initial statement of existing performance.
2. Data of workers and facilitiesinvolved each loading process.
   - Number of crane, trucks, forklift which are available
   - Crane, truck, forklift capacities

- The workers and their job description.

3. Loading activity operation time. This data used to calculate standard time as the input of simulation model.
4. Demands and vessels arrival data. This data is used for simulation modeling.

3.2.1 Loading process mapping

In order to get the clear sequence of loading process, this step needs to be accomplished. The processes are mapped into one cycle map to see the flow of activity and variables related to it. This will help researcher to track element of work which make the loading rate lower than it is targeted to be. This step will need direct observation to see the flow of process.

3.2.2 Measurement of Loading Process Cycle Time

Since there is no data record of loading cycle time,the data should be measured primarily from the field. Stopwatch time study is chosen as the method. In this phase, the standard time of eachelement of works are determined based on the measurements. This data will be the source of further processing in simulation and measuring cycle time of one truck load.

3.2.3 Identification of wastes

The cycle time measured in previous step will be used to check the unused working hour (the wasted time) in available time. This result will be identified what kind of wastes they are.

3.2.4 Waste measurement

After the wastes are identified and the type of wastes known, the measurement is done using simulation. A simulation model will be developed using the combination of historical data (demand and vessel arrival) and measurement data(standard time of loading process). It uses ARENA software. This simulation is made to build the representation of existing condition, so that the measurement of wastes magnitude in the existing condition can be generated, since the waste appears may have fluctuation and also difficult to measure manually.

3.3 Analysis and data interpretation

In this phase, all of the result from data processing phase will be analyzed. This is aimed to pull out some solutions from the result and this solution can be proposed in improvement phase.

3.3.1 Analysis the root causes

The Root cause analysis is done to find the root reasons of wastes appearance in the loading process. RCA in this research is conducted using 5whys method.

3.3.2 Failure Modes and Effect Analysis (FMEA)

FMEA is conducted as the further analysis from RCA. It is used to give an analysis of effects from the failure implementation of the cause. Severity, Occurence and Detectability rating assesment then are conducted to generate RPN value. The RPN gathered from this FMEA will give priority of which root cause should be improved using control actions.

3.3.3 Improvements Development

This phase is the step when some improvements are developed from the root causes analysis and FMEA. The improvements are based on the capacity and capability of port.The improvement scenarios are analyzed basedon the wastes implication to loading process, costs, and the benefit for company.

3.4 Conclusion and Recommendation

After all steps are done, the conclusions are obtained. These conclusions relate to the research’s objectives. Then, recommendation for the company is also developed based on previous improvements scenario. The recommendation is also given for the next researcher who wanted to do research in the same topic or field.

3.5 Research flowchart

The Flowchart of research will give simple preview of whole research in form of graphic. This represents all research sequence aand steps.

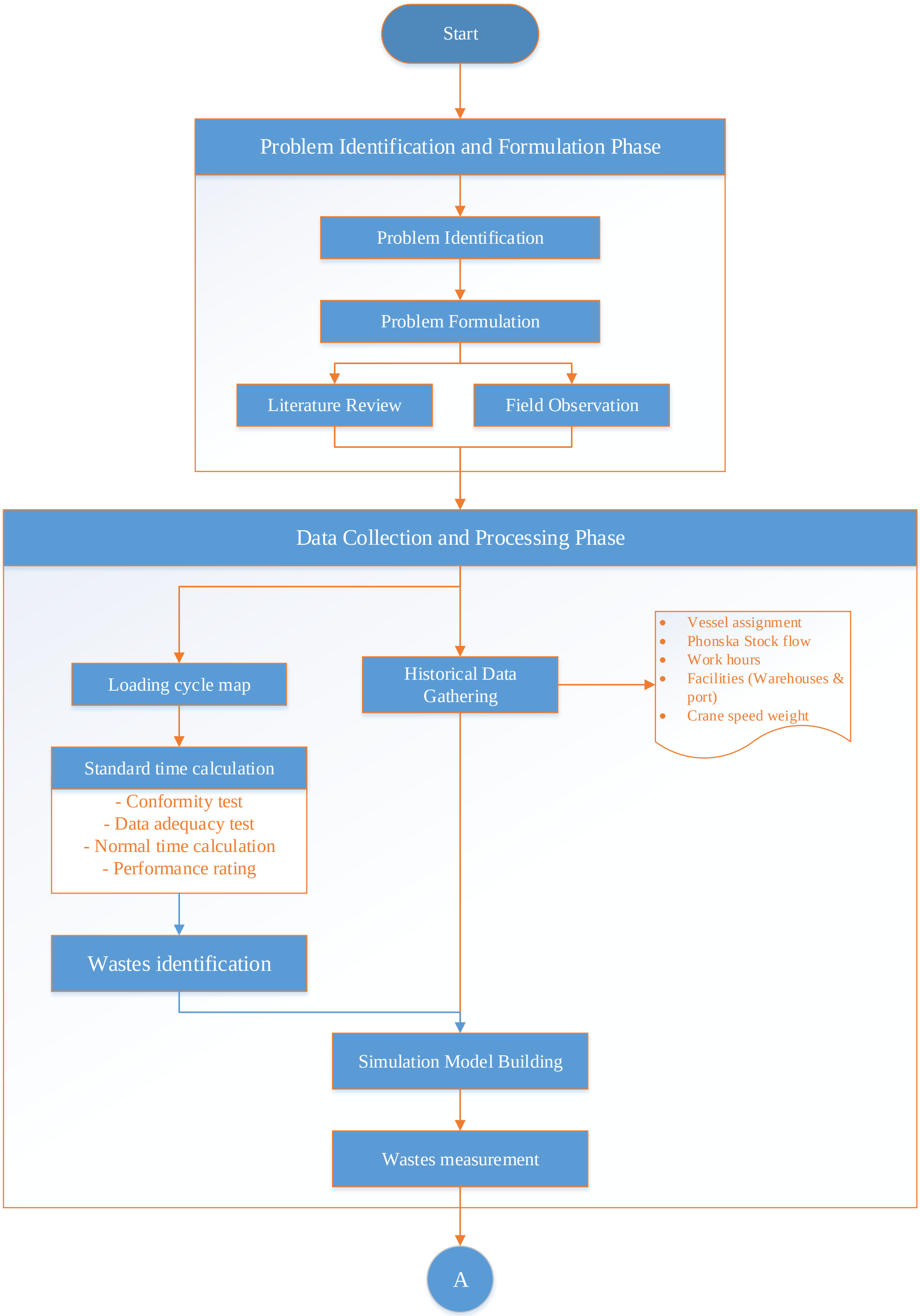


Figure 3.1Research flowchart

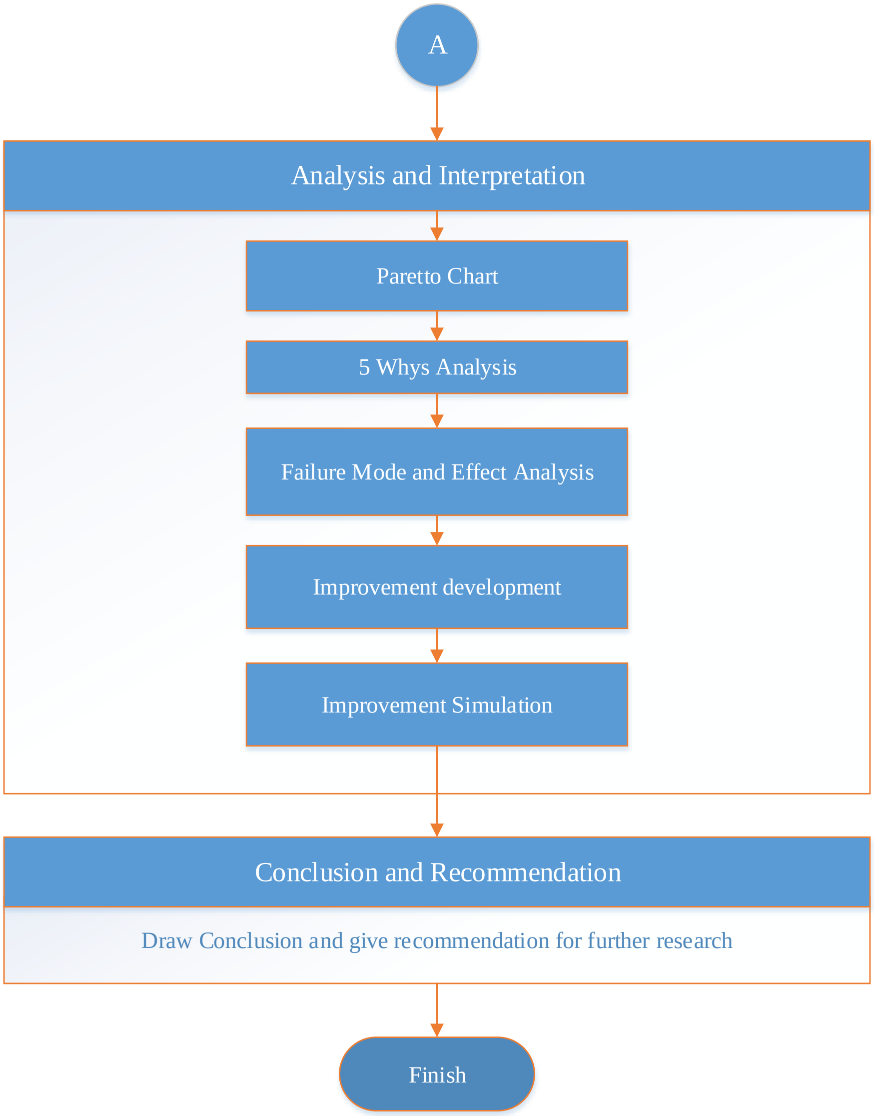


Figure 3.2Research flowchart (cont)

CHAPTER IV
DATA COLLECTION AND PROCESSING

This chapter contains anoverview of loading activities and the data gathering. The data gathered are actual data of existing condition in port. It will later be processed using certain tools to define the wastes and measure them through simulation. The output of this chapter will be used in analysis phase in the next chapter.

4.1 Define Phase

Define is the first step of Six-Sigma DMAIC, where the problem faced by object should be initially known and chosen which one to be investigated. At this phase will be explained the problems that become observation topic. Further work will be given in a cycle mapping, cycle time calculation, waiting time identification.

4.1.1 Diswil 2LoadingProcess Mapping

The fertilizer demands from buffer warehouse in outside java region need to be accomplished accurately in time when they are needed. As already mentioned in the research background, there are 2 types (packaging based) of product produced by PT Petrokimia Gresik. They are bulk and in-bag fertilizers. In this research, the chosen product to be studied is only in-bag Phonska because it has the highest demand among all fertilizer types, and in-bag fertilizer faces longer process than the bulk product. This condition is indicated to be the crucial one in the company.

In order to seekhow the process of loading Phonska in-bag contains of time wasting or other wastes, which giveundesired impacts toPort Department achievement, firstly the sequence of loading process should be mapped based on the existing condition.This will ease the understanding of related activities. The figure below shows the sequence of loading process. It isdivided into 3 parts of process which represent the cycle of loading process in existing PT Petrokimia

Gresik's Port condition. Those three parts are Pre loading activities, Loading activities, and After loading activities.

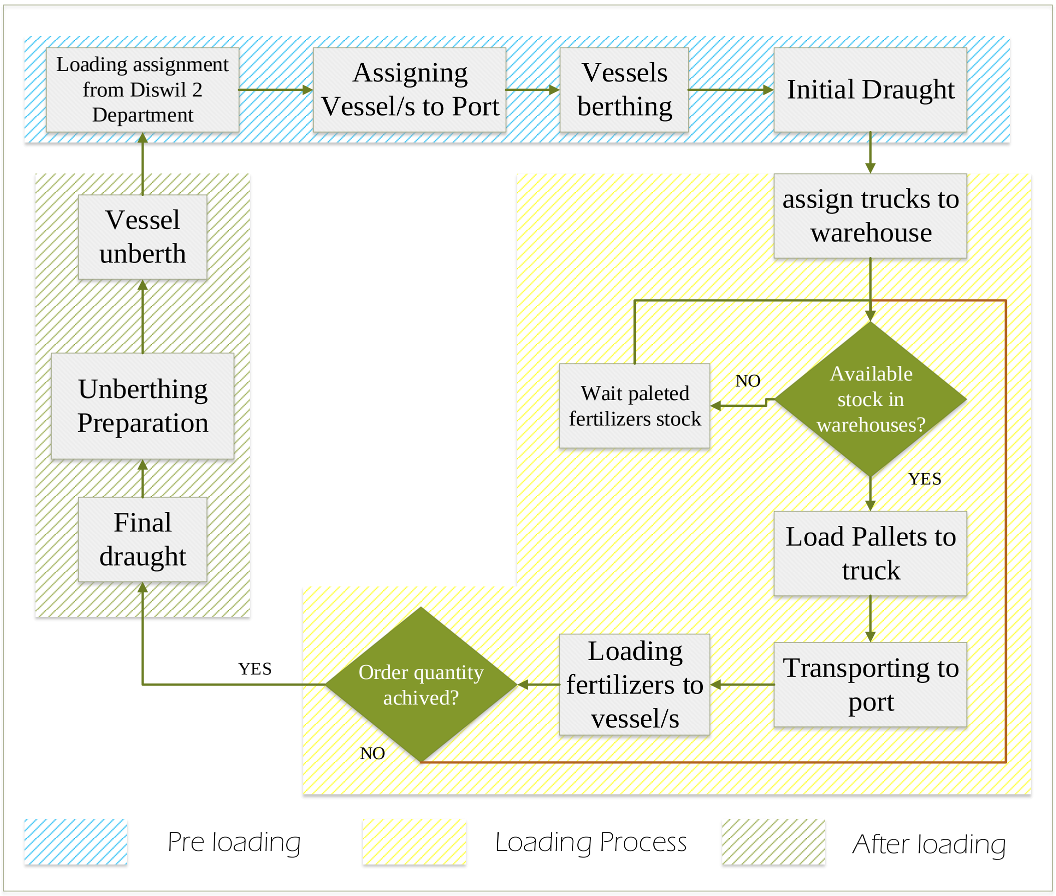


Figure 4.1Loading process cycle map

The map above figures the stages faced by Port department in order to fulfil the assignment. The description of each step is given in these following points:

1. **Pre Loading Activities**

   a. **Order Assignment from Diswil 2 Department**

   Order assignment by Diswil 2 is started when buffer warehouses in outside java demand PT Petrokimia to distribute certain amount of fertilizers. This assignment is then followed up trough Port department to deliver the demand to location of buffer warehouse. The responsibility of Port Department is to prepare all facilities regarding to the delivery, such as vessels, trucks, workers, crane or other equipments.

b. Assigning Vessel/s to Port

After assignments received by Port Department, Port Department will assign a vessel which has enough capacity to carry the demanded fertilizers to go to the port.

c. Vessels berthing

Vessel comes to port, it puts down the anchor to stay. The berthing duration is according to the time needed by Port Department to accomplish all the loading process of demand.

d. Initial Draught

This process is one step of vessel's administrational activity. Initial draught is a survey to check the initial weight of vessel and its container. This process is done by a surveyor from vendor partner of PT Petrokimia Gresik. The aim of vessel draught is to minimize the probability of miss achievement of tonnage loaded to the vessel.

2. Loading Activities

Loading Activities are the main activities of the whole sequence. Inside the sequence given in figure 4.1, there is another sequence of trucking system. Figure below is the sequence of trucking derived from the previous cycle mapping.

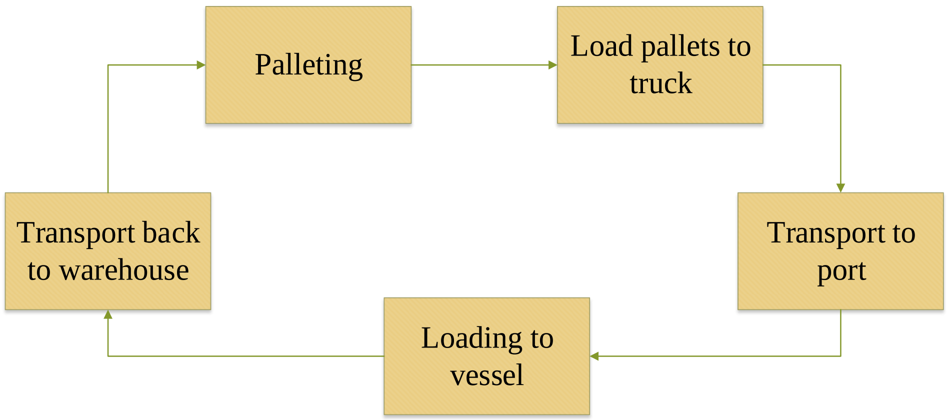


Figure 4. 2 Truck cycle map

The truck cycle is started when a vessel comes to the port and already faces Pre loading activities. This sequence of trucking system contains of some activities, it begins with assigning trucks to warehouse, palletizing process, load pallets to truck, transport to port, loading to vessel, and transport back to warehouse. This cycle ends when the demanded fertilizers are all loaded to the vessel. Descriptions of all activities in the loading activities / trucking system are explained in the paragraphs below.

a. Assign Truck to Warehouses

The main view point of this research is on the trucking system. The trucks assigned to warehouse handlethe crucial aspect of loading achievement. Truck utilization is the factor that can define daily loading rate. The more trucks served either in warehouse or in the port, it will imply on higher loading rate achievement.

The trucking system is vessel-based trucking system. It means that one group of trucks serves one specific vessel. If there are two or more vessels in the port, the Port Department will assign other trucking groups to fulfil the demanded fertilizers to those vessels. One trucking group contains of 5 flat trucks. These trucks do the cycle continuously within 18 hours/day working period.

There are three warehouses of Phonska in the company. These warehouses have different allocation. Warehouse 1 (Gudang Phonska 1)handles the stock for Central Java and DI Yogyakarta regions. Warehouse 2 (Gudang PF 1) take a role on holding the fertilizers for West Java and Banten. The last warehouse, warehouse 3 (Gudang PF 2) has contribution on keeping the stocks for East Java and Bali. All regions mentioned are under responsibility of Diswil 1 (Distribution Region 1) which covers Java-Bali area. The order comes from outside Java will be covered by the combination of those warehouses stocks. Unfortunately, this condition makes the trucks from Diswil 2 have lower priority to be served than trucks from Diswil 1.

Based on historical data in period of January to April 2015, majority of Diswil 2 trucks are assigned to load from warehouse 3. The following figure is the percentage of In-bag Phonska source in April 2015.

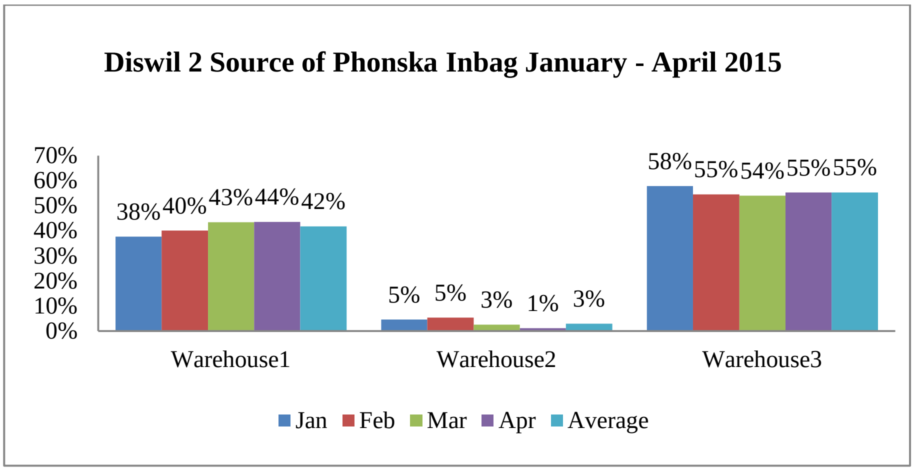


Figure 4.3Fertilizers source percentage (January - April 2015)

55% trucks from Diswil 2 are assigned to warehouse 3 to load the fertilizers. The second most frequent destination to take the fertilizers is Warehouse 1 with 42%, and the rest three percentsis taken from Warehouse 2.

b. Stock checking and Palletizing

The activity of loading begins from warehouse. In here, fertilizers are batched into pallet. This pallet contains of 30 bags with total weight 1.5 tons each. This is the item that will be loaded to truck to be delivered to port. The palletizing process is operated continuously regardless there are trucks to be served or not. The palletized fertilizers will be saved as stocks if there are no trucks, commonly called as stapling process. This is aimed to minimize the trucks queuing due to wait the palletizing process. Oppositely, if there is no stock of palletized fertilizers, the trucks should wait until the palletized fertilizers are ready to load.This stapling process is applied for all warehouses.

c. Load pallets to trucks

Loading pallets to trucks is also executed in warehouse. This activity is about loading the palletized fertilizers from previous activity into flat trucks. This activity is done by two forklifts with the capacity 2 pallets/forklift. The amount that should be loaded is 16 pallets in one truck.

The conflict appears when there are two type of trucks to be served. The first trucks is from Diswil 1 (Distribution region 1), and the second is from Diswil 2 (Distribution region 2) which will bring the fertilizers to port.

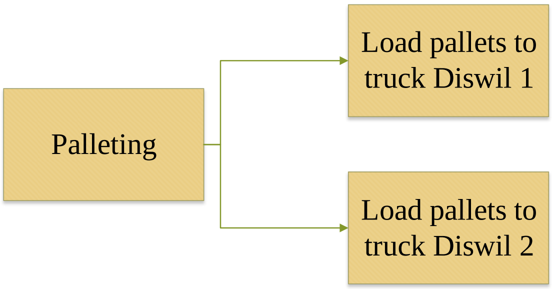


Figure 4.4 Scheme of Diswil 1 & Diswil 2 loading in warehouse

The number of trucks from Diswil one is bigger than Diswil 2. It is because truck from Diswil 1 is assigned to deliver fertilizers through land road, which has higher cycle time of trucking. This condition makes them given higher priority to be served.

While trucks for Diswil 2, there is no regulation to determine when they will be served. Sometimes they have to wait until no trucks from Diswil 1 or if they are permitted to follow the queue of Diswil 1, they will queue. It depends on the warehouse condition.

d. Trucks transporting to port

Truck transportation to warehouse is one activity of delivering the fertilizers from warehouse to the port. This activity will take a relative constant time because there is no such disturbing traffic in the port.This transportation takes different time regarding to the origin warehouse the truck is from. The longer distance will take the longer time of transportation.

e. Loading fertilizers to vessel/s

The loading fertilizers activity is divided into three activities in sequence, which are pinning crane’s hook into pallets, Crane material handling, and unload fertilizers to vessel (unpin the hook).

The first activity in this sequence is pinning crane’s hook to pallet. This is executed by stevedores/workers in the port. They stand on the truck and pin the hook to the bottom of pallets. Each operation will load two pallets.

The second activity is crane handling fertilizers. In this activity, the crane's operator will direct the fertilizers into the empty space of vessel's container.

The last activity is unloading the fertilizers. Stevedores who are on the vessels will unpin the hook and release the pallets. They then put off the fertilizers from the pallets and place it into the empty space.This process is done until the fertilizers on the truck are all loaded.

One fact found in the field is that the stevedores don't work in the same duration with what is assigned by the Port Department. At least one day they work 2 hours less than the workhour stated by the department. Lack of supervising and no regulation of working time may cause this to be happened. This may become an indication one of wastes in loading process.

3. After Loading Activities

The last activity in the cycle map is After loading activity. This activity is executed when the loading activities are all finished or in other words all fertilizers demanded already loaded to the vessel. The activities contain of final draught, coordinate with vessel agent before unberthing, and unberthing.

a. Final draught

Final draught is the activity of measuring the post weight of vessel and its containing. The weight is then subtracted by the initial weight of vessel or the result of initial draught. This will produced the value of fertilizers loaded. It is used to ensure that the tonnage matchs with the quantity ordered.

b. Coordinate with vessel agent before unberthing

This coordination before unberthing is used to check the whether and condition of sea is proper for the vessel to sail.

c. Vessel Unberths

Vessel unberthing is the situation where vessel leaves the port and ready to go to the destination of assignment. The unberth vessel indicates that all loading process is over.

Berthing duration is counted from the time when vessel berths until it unberths. The earlier identification in the research background, the activity that gives longest time in whole sequence is the loading activities. Therefore the further investigation is held in order to find which one to measure. The result of measurement will be aconsideration of improvement.

4.1.2 Loading Activities Processing Time

In order to measure the performance of wastes, first we should know the time needed to process each activity. In the existing condition, activity processing time is not recorded. There is no target time to accomplish each activity related to loading process. This sub chapter will show the data gathered from observation in the field. The observed data is then transformed into standard time in form of a single value of cycle time needed.

4.1.2.1 Palletizing Activity Time

The palletizing Activity is done within four separated lines from the production output. The lines work in parallel to batch in-bag fertilizers into pallet size. It means that every operation time is finished, the output is four pallets. The data observed of palletizing process and the worker allowance time is given in table below.

Table 4. 1 Palletizing activity time

Activity 1: Palletizing process	**Operation Time (seconds)**									
No.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Palletizing	134	159	153	119	105	136	109	107	221	178
Allowance	0	0	1	2	1	5	3	1	0	0
No.	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
Palletizing	154	171	154	197	159	131	128	137	187	174
Allowance	0	3	2	0	0	2	2	1	2	0
No.	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**

Table 4.2 Palletizing activity time (cont)

Activity 1: Palletizing process	Operation Time (seconds)									
Palletizing	126	133	143	142	135	179	228	159	123	155
Allowance	0	0	0	0	2	1	3	2	1	0
No.	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**
Palletizing	194	147	147	188	163	219	183	179	231	150
Allowance	0	1	2	0	0	1	1	1	0	2
No.	**41**	**42**	**43**	**44**	**45**	**46**	**47**	**48**	**49**	**50**
Palletizing	159	138	131	127	173	182	129	119	339	202
Allowance	0	0	3	2	1	1	1	0	0	1
No.	**51**	**52**	**53**	**54**	**55**	**56**	**57**	**58**	**59**	**60**
Palletizing	198	177	189	135	122	180	129	137	199	201
Allowance	2	1	0	0	0	0	0	2	0	2
No.	**61**	**62**	**63**	**64**	**65**	**66**	**67**	**68**	**69**	**70**
Palletizing	205	120	321	300	221	185	157	135	291	191
Allowance	1	0	0	1	2	0	0	2	0	2
No.	**71**	**72**	**73**	**74**	**75**	**76**	**77**	**78**	**79**	**80**
Palletizing	138	151	172	175	181	299	210	120	210	135
Allowance	3	3	1	0	0	0	0	0	1	2
No.	**81**	**82**	**83**	**84**	**85**	**86**	**87**	**88**	**89**	**90**
Palletizing	182	191	120	152	189	222	132	175	151	196
Allowance	0	0	0	0	1	2	1	0	1	0
No.	**91**	**92**	**93**	**94**	**95**	**96**	**97**	**98**	**99**	**100**
Palletizing	142	214	188	136	189	135	210	281	157	182
Allowance	1	0	2	2	1	0	0	0	3	2
No.	**101**	**102**	**103**	**104**	**105**					
Palletizing	192	190	210	301	241					

The data is gathered in only one warehouse, which is warehouse 3 where the diswil 2 trucks majorly assigned. This data is assumed representing the other warehouses. It is also done to reduce the complexity of cycle time calculation.

4.1.2.2 Load to Truck Time

Load to truck is activity which put up the pallets using forklift and then load it to truck. The capacity of forklift in one load is 2 pallets. Therefore this activity sometimes has to wait the predecessor activity which is palletizing. The number of forklift used in the warehouse is two for each warehouse.

This process is repeated for 8 times per truck since truck capacity is 16 pallets per full truck load.

Table 4.3 Loading to truck activity time

Activity 2: Load to Truck	Work Time (seconds)									
No.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
loading to trucks	95	88	79	89	101	105	80	101	77	73
Allowance	1	2	0	2	0	0	3	2	1	1
No.	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
loading to trucks	57	82	64	69	81	72	100	92	86	74
Allowance	5	2	1	1	0	0	0	2	3	1
No.	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**
loading to trucks	81	90	91	84	88	73	84	55	78	80
Allowance	1	1	1	0	0	0	0	2	2	1
No.	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**
loading to trucks	90	91	102	91	87	73	89	56	55	78
Allowance	2	1	1	0	0	1	2	1	1	0
No.	**41**	**42**	**43**	**44**	**45**	**46**	**47**	**48**	**49**	**50**
loading to trucks	100	92	64	49	81	80	91	102	73	86
Allowance	1	1	0	0	0	0	0	2	2	1
No.	**51**	**52**	**53**	**54**	**55**	**56**	**57**	**58**	**59**	**60**
loading to trucks	72	69	91	121	85	79	99	92	85	74
Allowance	1	2	0	0	2	1	1	0	0	0
No.	**61**	**62**	**63**	**64**	**65**	**66**	**67**	**68**	**69**	**70**
loading to trucks	86	62	71	111	101	38	88	76	77	72
Allowance	0	0	1	2	3	5	1	0	0	0
No.	**71**	**72**	**73**	**74**	**75**	**76**	**77**	**78**	**79**	**80**
loading to trucks	83	49	72	91	82	55	70	83	66	74
Allowance	0	0	2	1	0	7	1	0	0	0
No.	**81**	**82**	**83**	**84**	**85**	**86**	**87**	**88**	**89**	**90**
loading to trucks	86	80	57	81	73	75	88	70	90	74
Allowance	1	0	0	0	1	3	1	1	0	1
No.	**91**	**92**	**93**	**94**	**95**	**96**	**97**	**98**	**99**	**100**
loading to trucks	89	91	77	89	89	49	58	73	81	60
Allowance	0	0	0	0	0	0	0	0	1	1
No.	**101**	**102**	**103**	**104**	**105**					
loading to trucks	58	78	100	75	85					
Allowance	1	0	0	0	3					

The same with previous data collection, these data are only collected from one warehouse and assumed to represent all warehouses.

4.1.2.3 Transportation to Port Time

This is the third activity of loading activity. The time used to deliver fertilizers to port is measured through the same measurement with others. The result of measurement is given as in these following tables :

Table 4.4 Transport to Port from Warehouse 1

Activity 3: Transport from warehouse to port	Work Time (seconds)							
No.	1	2	3	4	5	6	7	8
3.1 Transport time from warehouse 1 to port	263	256	278	256	298	302	318	271

Table 4.5 Transport to Port from Warehouse 2

Activity 3: Transport from warehouse to port	Work Time (seconds)				
No.	1	2	3	4	5
3.2 Transport time from warehouse 2 to port	409	369	387	394	362

Table 4.6 Transport to Port from Warehouse 3

Activity 3: Transport from warehouse to port	Work Time (seconds)							
No.	1	2	3	4	5	6	7	8
3.3 Transport time from warehouse 3 to port	397	319	356	354	412	368	403	387

The Velocity of truck is assumed to be the same among all transportation activities to the port which is 20 Km/hour. This velocity setting is made based on the port regulation of truck velocity that should not exceed 30 km/h. The recapitulation of transportation to port time is given below.

In average, the time needed by truck to go from warehouse to port is 336 seconds with the longest time needed is 360 seconds which is from Warehouse 3, and the shortest is from warehouse 1 which is 270 seconds.

4.1.2.4 Load to Vessel Time

In load to vessel activity, this activity is divided into three operations which are: Pinning crane's hook into pallets (4.1), crane-material handling (4.2), and unloading fertilizers to vessel (4.3). The recapitulations of activity time and allowance appear in operating the activity are given in the table 4.7 until 4.10 below.

Table 4.7 Pinning crane's hook to pallets (activity 4.1) time

Activity 4 : Load from truck to vessel	Work Time (seconds)									
No.	1	2	3	4	5	6	7	8	9	10
4.1 Pinning crane's hook to pallets	75	57	59	48	58	49	94	50	51	66
Allowance	1	0	0	2	1	2	0	0	3	2
No.	11	12	13	14	15	16	17	18	19	20
4.1 Pinning crane's hook to pallets	60	62	55	46	49	47	63	54	66	54
Allowance	1	0	2	0	0	0	0	1	1	2
No.	21	22	23	24	25	26	27	28	29	30
4.1 Pinning crane's hook to pallets	71	49	77	73	52	65	59	52	62	57
Allowance	0	0	2	3	0	0	0	1	1	2
No.	31	32	33	34	35	36	37	38	39	40
4.1 Pinning crane's hook to pallets	49	49	60	64	59	50	61	43	43	49
Allowance	1	2	0	1	0	0	0	3	0	1

Table 4. 8 Crane material handling (activity 4.2) time

Activity 4 : Load from truck to vessel	Work Time (seconds)									
No.	1	2	3	4	5	6	7	8	9	10
4.2 Material Handling (Crane)	32	20	36	24	19	27	29	22	30	24
Allowance	0	0	1	0	0	2	0	0	0	0
No.	11	12	13	14	15	16	17	18	19	20
4.2 Material Handling (Crane)	25	27	27	25	29	21	21	22	20	29
Allowance	0	4	0	2	0	0	0	0	0	1

Table 4. 9 Crane material handling (activity 4.2) time (cont)

Activity 4 : Load from truck to vessel	Work Time (seconds)									
No.	21	22	23	24	25	26	27	28	29	30
4.2 Material Handling (Crane)	31	29	35	21	31	26	25	25	22	28
Allowance	2	0	0	0	0	0	0	2	1	0
No.	31	32	33	34	35	36	37	38	39	40
4.2 Material Handling (Crane)	20	18	24	28	21	17	22	25	31	24
Allowance	0	3	0	1	2	0	0	0	0	0

Table 4.10 Unloading fertilizers to vessel (activity 4.3) time

Activity 4 : Load from truck to vessel	Work Time (seconds)									
No.	1	2	3	4	5	6	7	8	9	10
4.3 Unload fertilizers to the vessel	43	32	34	36	33	46	37	57	41	36
Allowance	2	0	1	3	3	1	1	0	0	0
No.	11	12	13	14	15	16	17	18	19	20
4.3 Unload fertilizers to the vessel	41	48	31	30	36	31	44	46	36	40
Allowance	2	3	1	0	0	2	0	0	1	0
No.	21	22	23	24	25	26	27	28	29	30
4.3 Unload fertilizers to the vessel	46	40	35	53	42	46	43	34	47	36
Allowance	0	2	1	1	0	0	0	0	2	0
No.	31	32	33	34	35	36	37	38	39	40
4.3 Unload fertilizers to the vessel	45	60	50	48	36	50	45	43	48	45
Allowance	1	1	0	0	0	0	2	0	0	1

4.1.2.5 Transport Back to Warehouses Time

This activity is basically the same with the previous transportation activity. The difference lays on the velocity of the trucks. In this case, the velocity is assumed to be faster due to no weight carried by the trucks. The velocity is assumed to be 30 Km/h. The velocity can not set higher due to port regulation that already stated before. The recapitulation of time needed bytruck to transport back from port to warehouses is given below.

Table 4.11Transport back from port to warehouse 1

Activity 5: Transport back from port to warehouse	Work Time (seconds)											
No.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	9	10	11	12
5.1 Transport time from port to warehouse 1	178	212	200	190	220	177	178	231	180	210	180	173

Table 4. 12Transport back from port to warehouse 2

Activity 5: Transport back from port to warehouse	Work Time (seconds)					
No.	**1**	**2**	**3**	**4**	**5**	**6**
5.2 Transport time from port to warehouse 2	248	268	291	298	253	269

Table 4. 13Transport back from port to warehouse 3

Activity 5: Transport back from port to warehouse	Work Time (seconds)													
No.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
5.3 Transport time from port to warehouse 3	280	226	224	255	273	244	231	213	228	295	252	286	267	291

4.1.2.6 Standard Time calculation

Standard time calculation is done to reduce the effect of outlier data gathered from observation. It is also aimed to involve the allowance and worker performance in the defining cycle time. There are some steps in order to develop the standard time.They are conformity test, data adequacy test, normal time calculation, and the last, standard time calculation itself.

4.1.2.6.1 Conformity Test

Conformity test is used to ensure the data of activity time are within the control limits (UCL and LCL). Control limits are set of limits in normal distribution which has range of 6σ. The unconforming data will be eliminated because it is indicated as an improper data. The determination of the limits is following formulas using the mean value of data and its standard deviation. In this test, only non-transportationtime data will be tested. The formula of UCL & LCL and also recapitulation of all activity limits are given below.

$$UCL = Mean + 3 \times Standard\ Deviation \quad (4.1)$$

$$LCL = Mean - 3 \times Standard\ Deviation \quad (4.2)$$

Table 4.14 Recapitulation of upper and lower control limits

No.	Phase	Activity	mean	standard deviation	UCL	LCL
1	1	Palletizing	174.2667	47.4788	316.703	31.8303
2		Load Pallets to Truck	79.99048	14.4764	123.42	36.5612
3.1		Transportation from Warehouse 1 to Port	280.25	23.230214	349.941	210.559
3.2		Transportation from Warehouse 2 to Port	384.2	18.992104	441.176	327.224
3.3		Transportation from Warehouse 3 to Port	374.5	31.089732	467.769	281.231
4.1		Pinning pallet to the crane's hook	57.675	10.4007	88.877	26.473
4.2		Material Handling (Crane)	25.3	4.59208	39.0762	11.5238
4.3		Unload fertilizers to the vessel	41.75	7.19954	63.3486	20.1514
5.1		Transportation from Port to Warehouse 1	195.545	19.796503	254.935	136.155
5.2		Transportation from Port to Warehouse 2	271.167	19.97415	331.089	211.245
5.3		Transportation from Port to Warehouse 3	254.643	27.664493	337.636	171.65

The data gathered are then plotted into graphs and check the position of data is within the control limits or not. The result of conformity test is given in figure 4.8 until4.12 below which show the first phase data plots.

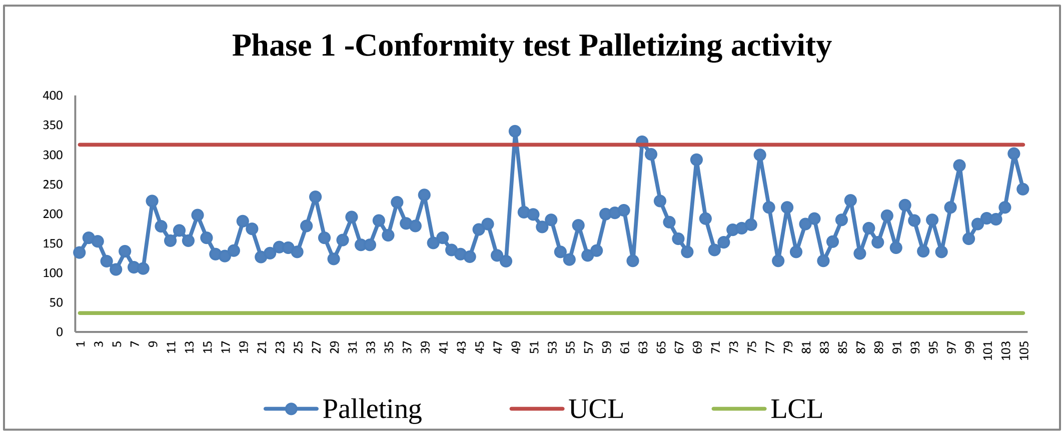


Figure 4. 5Conformity test palletizing activity time - phase 1

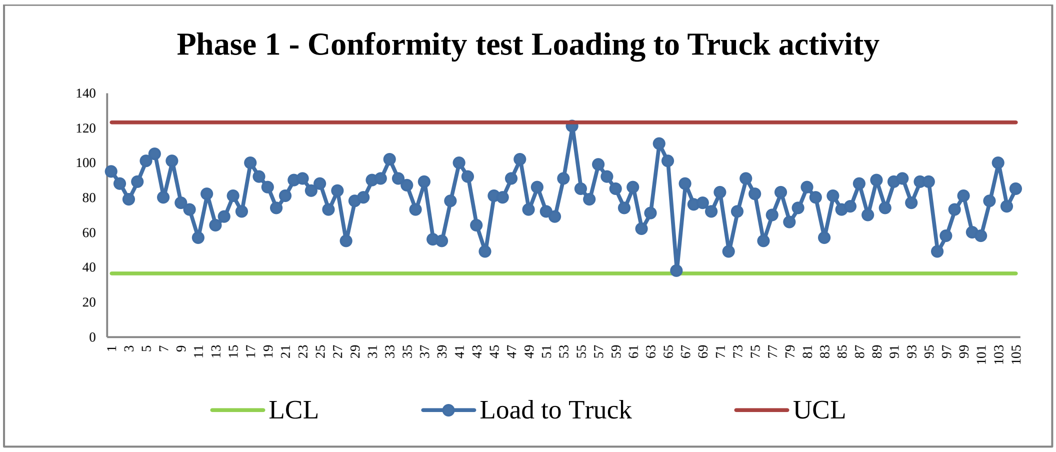


Figure 4. 6 Conformity test Loading to Truck Activity

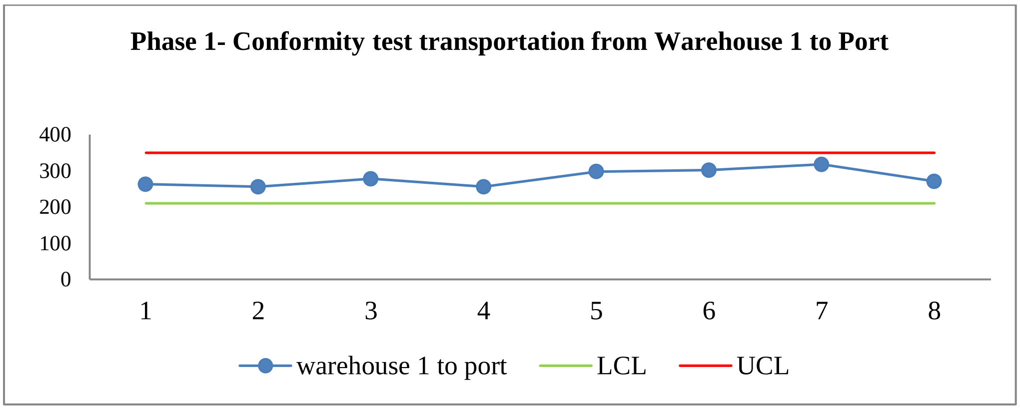


Figure 4. 7 Conformity test transportation from warehouse 1 to port

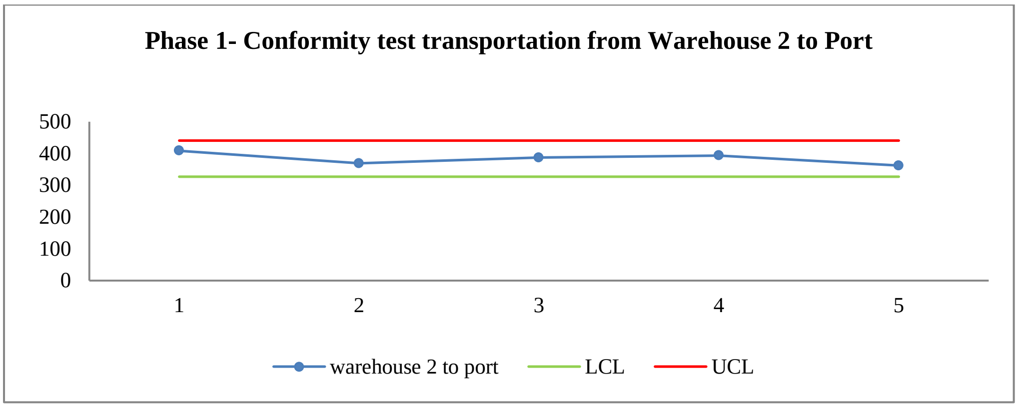


Figure 4. 8 Conformity test transportation from warehouse 2 to port

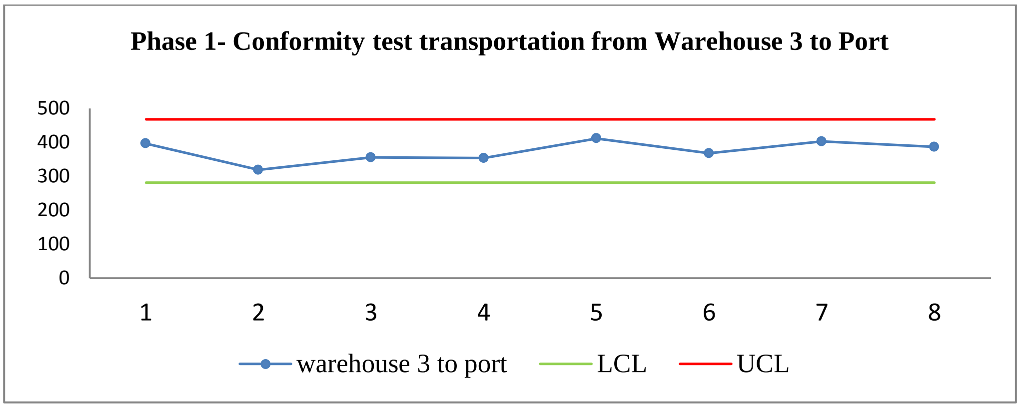


Figure 4. 9Conformity test transportation from Warehouse 3 to Port

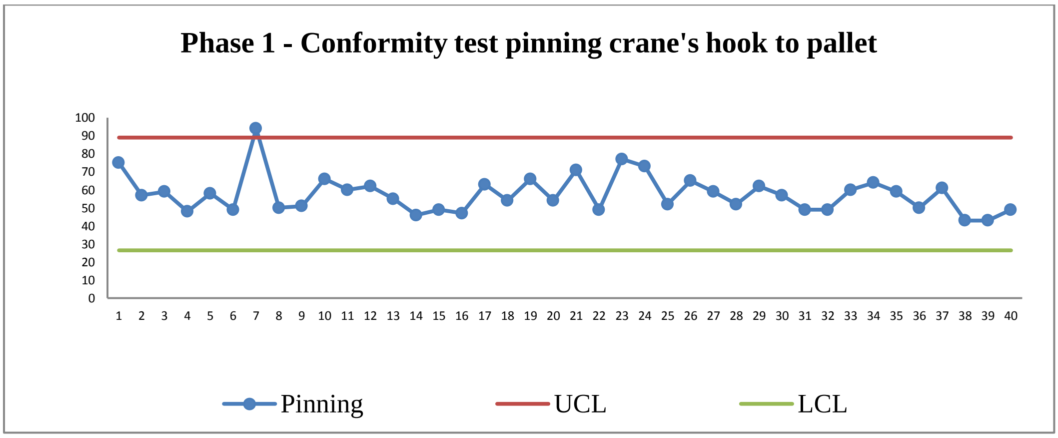


Figure 4.10 Conformity test Pinning crane's hook to pallets

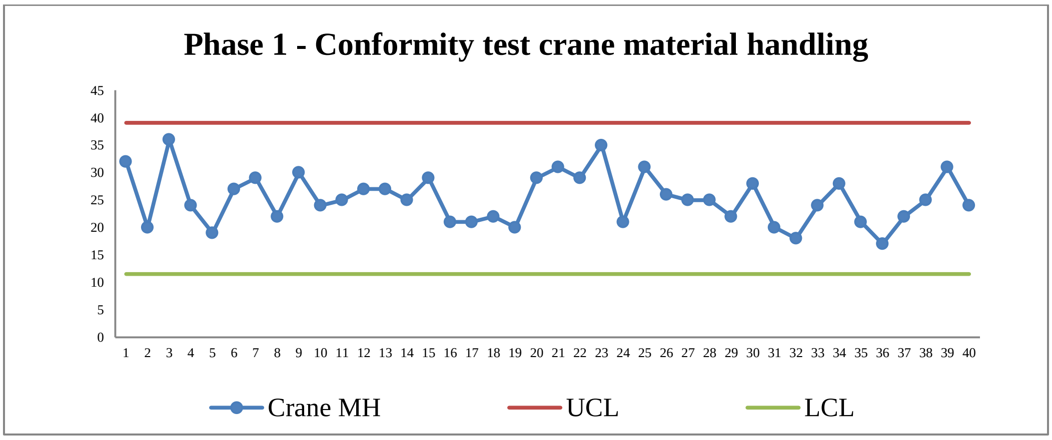


Figure 4.11Conformity test crane material handling

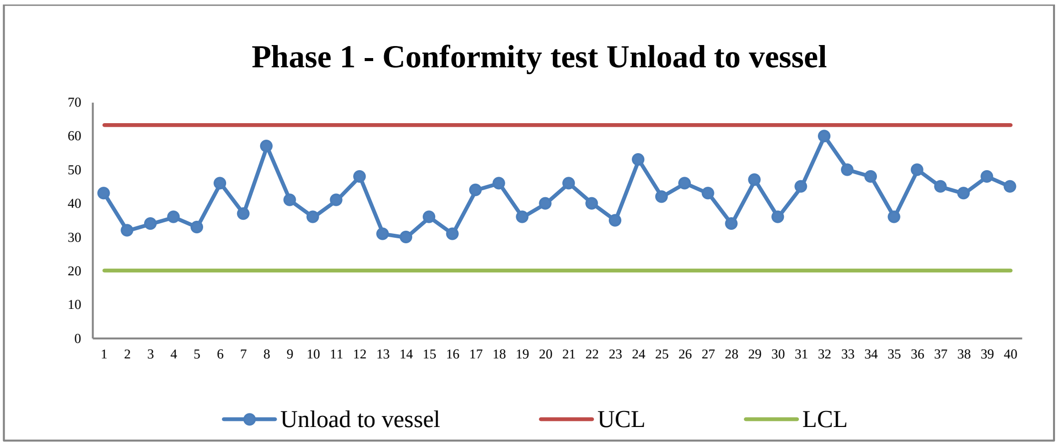


Figure 4.12Conformity test Unload to vessel

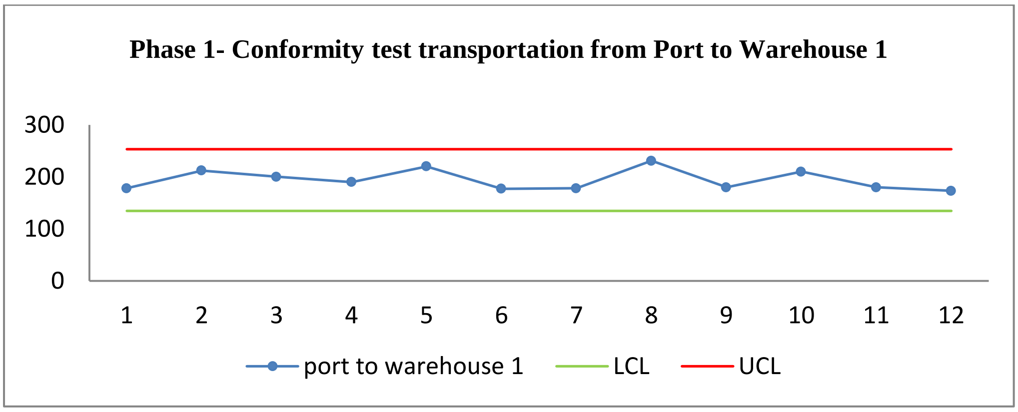


Figure 4.13Conformity test transportation from Port to Warehouse 1

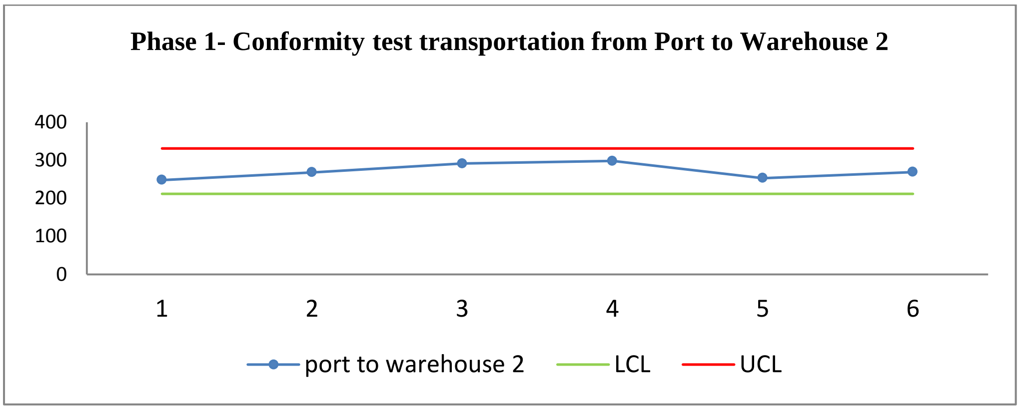


Figure 4. 14Conformity test transportation from Port to Warehouse 2

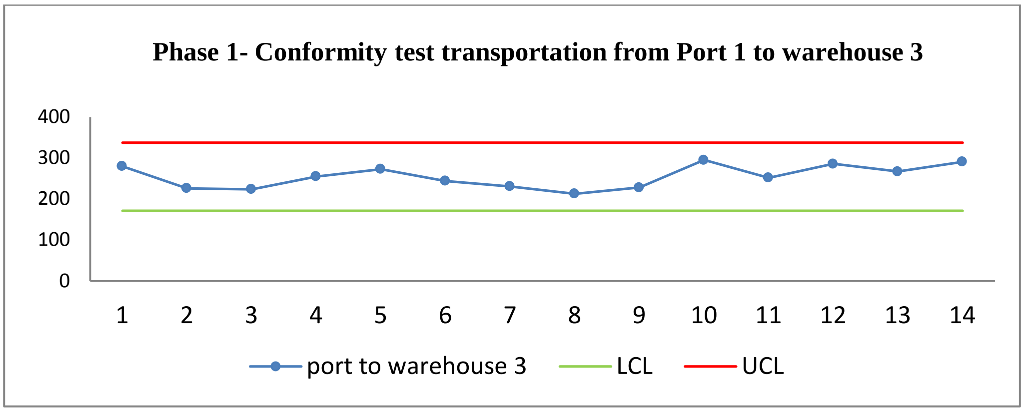


Figure 4. 15Conformity test transportation from Port 1 to warehouse 3

Based on the previous plots of observed data, there are some data that exceed their upper limit. These data will be eliminated and the next phase of conformity will be done. The activities that have some outliers data time are Palletizing activity (activity 1) and pinning crane's hook to pallet (activity 4.1). Graphs given below are the updated plots of further phase from activity 1 and activity 4.1.

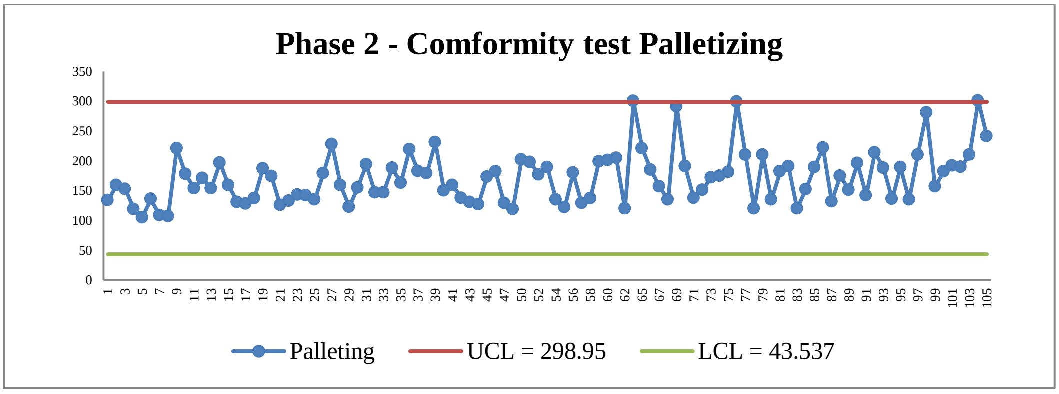


Figure 4.16 Conformity test palletizing - Phase 2

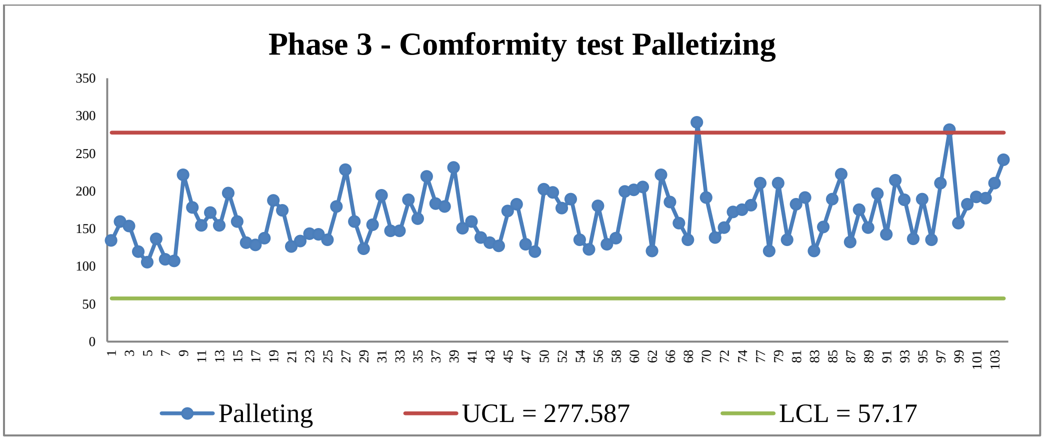


Figure 4.17 Conformity test Palletizing activity - Phase 3

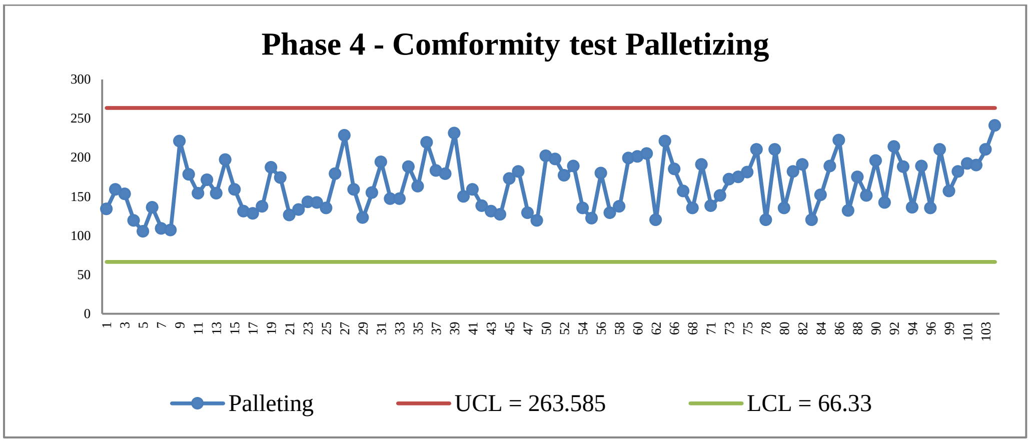


Figure 4. 18 Conformity test Palletizing - Phase 4

The final phase of Palletizing activity shows only 98 data from 105 total data conform within the upper and lower limits. This means 7 data categorized as outliers and eliminated.

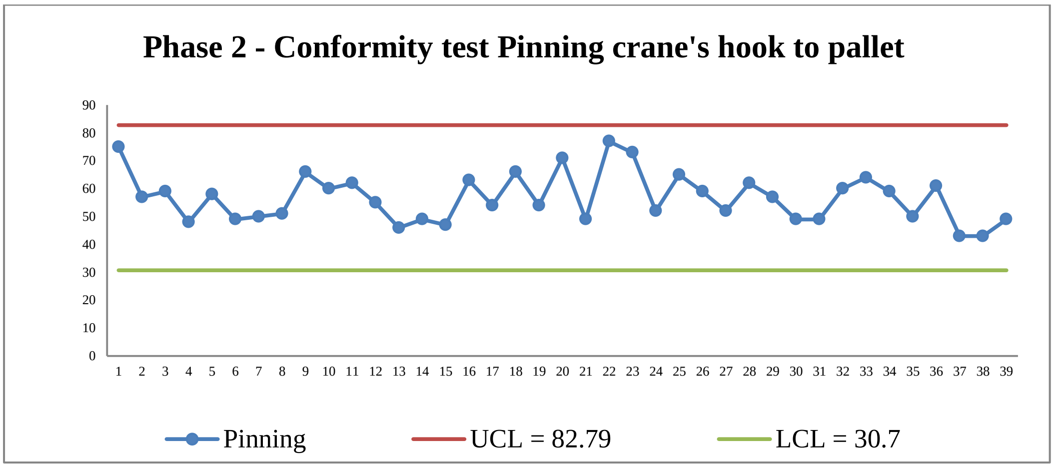


Figure 4. 19 Conformity test Pinning crane's hook to pallet

The second phase of activity 4.1 results all conforming data with one data elimination and the others are conformed.

4.1.2.6.2 Data adequacy test

Data adequacy test is used to measure whether the data gathered is enough or not. In this test, the data used are only data which passed the conformity tests. The decision of enough or not is when the value of N>N'. Where N is the number of collected data, and N' is the number of data that should be gathered.

Table 4. 15Recapitulation of data adequacy test

No.	Activity	Mean	Standard deviation	N	N'	Conclusion
1	Palletizing	165.0	32.88	98	43.0	Sufficient Data
2	Load to Truck	80.0	14.48	105	35.4	Sufficient Data
3.1	Transportation from Warehouse 1 to Port	280.3	23.23	8	7.4	Sufficient Data
3.2	Transportation from Warehouse 2 to Port	384.2	18.99	5	2.6	Sufficient Data
3.3	Transportation from Warehouse 3 to Port	374.5	31.09	8	7.5	Sufficient Data
4.1	Pinning crane's hook to pallet	56.7	8.68	39	25.3	Sufficient Data
4.2	Crane material handling	25.3	4.59	40	35.7	Sufficient Data
4.3	Unload fertilizers to vessel	41.8	7.20	40	32.2	Sufficient Data
5.1	Transportation from Port to Warehouse 1	195.5	19.80	12	11.3	Sufficient Data
5.2	Transportation from Port to Warehouse 2	271.2	19.97	6	5.9	Sufficient Data
5.3	Transportation from Port to Warehouse 3	254.6	27.66	14	12.8	Sufficient Data

All data gathered are enough based on the result of test. This means that the data gathered can be used to calculate the standard time without any additional data.

4.1.2.6.3 Actual Time

Actual time is the average of data that pass the previous tests. This is data that represent existing condition of processing each activity. The recapitulation of actual time is given in the table below.

Table 4. 16 Recapitulation of Actual time

No.	Activity	Actual Time (seconds)
1	Palletizing	164.9591837
2	Load to Truck	79.99047619
3	Transportation from warehouse to port	224
4.1	Pinning crane's hook to pallet	56.74358974
4.2	Crane material handling	25.3
4.3	Unload fertilizers to vessel	41.75
5	Transportation from port to warehouse	134.4

The actual time is not enough, because there is performance rating that given as the evaluation of worker achievement and also allowance time that is done by the workers. Those weights should be involved to determine the valid standard time. Those weighting process is done in the next phases which are calculation of normal time and standard time phase.

4.1.2.6.4 Normal time

Before determining the normal time, the performance rating should be developed first. Performance rating is a weight of performance given as rating achievement by operators in executing the activity.Performance rating determination is done using the Westinghouse Rating System. In this method, there are four factors used to evaluate the performance of the operator, which are skill, effort, conditions, and consistency. The table below shows performance rating calculation.

Table 4. 17 Recapitulation of Westinghouse performance rating

Activity No.	Skill		Effort		Conditions		Consistency		Total	Rating
	Rate	Weight	Rate	Weight	Rate	Weight	Rate	Weight		
1	C1	0.06	C1	0.05	C	0.02	C	0.01	0.14	114%
2	B2	0.08	C1	0.05	C	0.02	D	0	0.15	115%
3	C1	0.06	C2	0.02	C	0.02	C	0.01	0.05	108%
4.1	C2	0.03	D	0	C	0.02	B	0.03	0.08	108%
4.2	A2	0.13	C2	0.02	C	0.02	D	0	0.17	117%
4.3	C2	0.03	C2	0.02	C	0.02	B	0.03	0.1	110%
5	B2	0.08	D	0	C	0.02	C	0.01	0.11	111%

Normal time is the product of multiplying actual time with performance rating. The better worker performance will be given bigger weight of performance rating. It is caused of westinghouse rating system is aimed to find the time needed by the worker in the normal skill, effort, condition and consistency. It weights the data gathered with a defined value and resulting the normal time for normal performance.

Table 4.18 Recapitulation Normal time calculation

No.	Activity	Actual Time	Rating	Normal time (seconds)
1	Palletizing	165	114%	188.0534694
2	Load to Truck	79.99	115%	91.98904762
3.1	Transportation from Warehouse 1 to Port	280.3	108%	302.67
3.2	Transportation from Warehouse 2 to Port	384.2		414.936
3.3	Transportation from Warehouse 3 to Port	374.5		404.46
4.1	Pinning crane's hook to pallet	56.74	108%	61.28307692
4.2	Crane material handling	25.3	117%	29.601
4.3	Unload fertilizers to vessel	41.75	110%	45.925
5.1	Transportation from Port to Warehouse 1	195.5	111%	217.05495
5.2	Transportation from Port to Warehouse 2	271.2		300.99537
5.3	Transportation from Port to Warehouse 3	254.6		282.65373

4.1.2.6.5 Standard time

Standard time is the Normal time with additional weighting of allowance. The total allowancegathered ineach activity is divided by total normal time + allowance itself.The result of calculation is given in the following table.

Table 4. 19Recapitulation of standard time

No.	Normal time	N	Σ Normal time	Σ Allowance	% Allowance	Standard time
1	188.05	98	18429.24	94	1%	189.0126531
2	91.99	105	9658.85	95	1%	92.89380952
3.1	302.67	8	2421.36	-	-	302.67
3.2	414.936	5	2074.68	-	-	414.936
3.3	404.46	8	3235.68	-	-	404.46
4.1	61.28	39	2389.92	35	1%	62.1774359
4.2	29.6	40	1184	21	2%	30.125
4.3	45.93	40	1837.2	31	2%	46.705
5.1	217.05495	12	2604.6594	-	-	217.05495
5.2	300.99537	6	1805.97222	-	-	300.99537
5.3	282.65373	14	3957.15222	-	-	282.65373

Σ Normal time is the value of normal time times by the number ofconforming data. The Σ Allowance is the total time of allowance appeared in the conforming data.

The result above shows the standard time for non-transportation activities (activity 1, 2 & 4) and transportation activities (activity 3 & 5). The transportation activities are assumed to have the standard time the same with calculation result of time needed to transport. It is because the data gathering is not following the measurement method, but through calculation of distance covered and trucks' velocity.

These values of standardtime will be used in the measurement phase of waste. The single value of time is meant to minimize the variance of cycle time. The high variance of cycle time will disturb the value of wastes measurement.

4.1.2.7 Truck Cycle Time

In period of April 2015, there are 17 vessels assigned to the port. As previously stated, the trucking system is vessel based. Each vessel has different crane's speed but the same capacity. Therefore cycle time of truck different one to another depends on which vessel is served. In this section, the calculation of truck cycle time will be generated. The crane material handling time in table 4.2 is the activity time for vessel named Tradisi 7 which berths in May 2015 period. In order to know the the previous vessel material handling time, there are some weights given based on the discussion and historical data with the port supervisor. The weight of crane's speed will then become a multiplier to define the time of crane material handling needed for previous vessels in May 2015.

Table 4. 20 Weight of crane's speed of vessels in April 2015

No	Vessel name	Weight
1	Kamasan	3
2	Niaga 56	4
3	Tradisi 6	2
4	Mutia Ladjoni	2
5	Spirit Sejati	2
6	Permata Sakti	4
7	Caraka Jaya Niaga 3-32	3
8	Karya Perdana 8	2
9	Putri Mulya 2	5
10	Harapan Sejati	1
11	Kairos 2	2
12	Blossom Pescadores	4
13	Tradisi 7	3
14	Shanon	3
15	Indah Surya 8	3
16	Permata Cinta	5
17	Baruna Fortuna 1	4

Based on the weight recapitulated, the cranes standard timesare defined as follows. The graph in figure 4.20 below

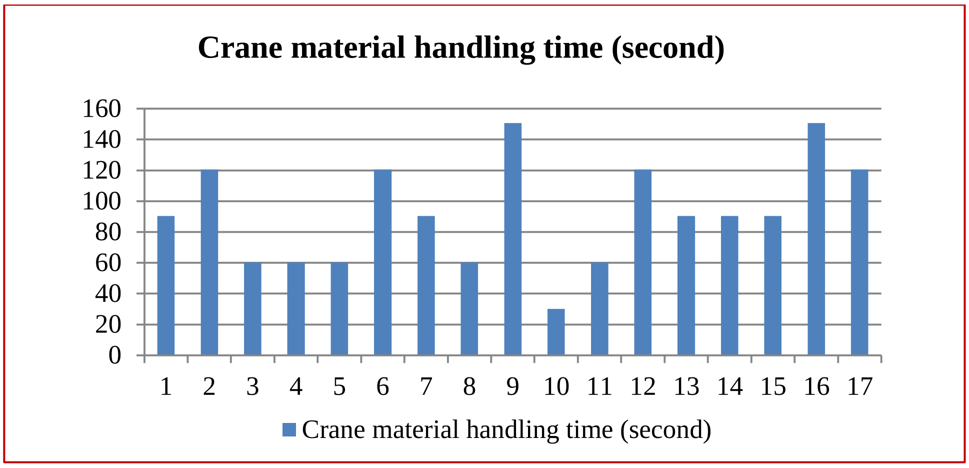


Figure 4.20Vessels material handling time

The x-axis in graph 4.18 above shows the vessel number and the y-axis is the standard time in second. It is very important to not assuming the vessel's speed with only one value. It is one of factor that impacting the cycle time of truck. In the real condition this problem appears as one unsolved problem since the available vessels are not in the same type. Therefore, speeds of cranes are also varied.

Beside the vessel's crane speed, the origin warehouse of fertilizer source also gives impact on the cycle time. The following table tries to give average time of transportation from warehouse based on the source percentage in figure 4.3.

Table 4.21 Transportation time from warehouses to port

Origin point	Destination	Standard time	Allocation percentage	Result
Warehouse 1	Port	302.67	42%	127.1214
Warehouse 2		414.936	3%	12.44808
Warehouse 3		404.46	55%	222.453
Transportation time from warehouse to port				362.02248

Table 4.22 Transportation time from warehouses to port

Origin point	Destination	Standard time	Allocation percentage	Result
Port	Warehouse 1	217.05495	42%	91.163079
	Warehouse 2	300.99537	3%	9.0298611
	Warehouse 3	282.65373	55%	155.45955
Transportation time from warehouse to port				255.65249

The cycle time can be generated since the standard time of each activity already determined. The example of truck cycle time calculation is given in the consecution table using the standard time that already defined before.

Table 4.23Example of truck cycle time calculation

<table>
<tr><th colspan="2">Palletizing</th><th colspan="2">Load to Truck</th><th colspan="2">Transport to port</th><th colspan="2">Load to vessel</th><th colspan="2">Transport to warehouse</th></tr>
<tr><th>Start</th><th>End</th><th>Start</th><th>End</th><th>Start</th><th>End</th><th>Start</th><th>end</th><th>Start</th><th>End</th></tr>
<tr><td rowspan="2">0</td><td rowspan="2">189</td><td rowspan="2">189</td><td rowspan="2">282</td><td rowspan="8">849</td><td rowspan="8">1211</td><td>1211</td><td>1350</td><td rowspan="8">2323</td><td rowspan="8">2579</td></tr>
<tr><td>1350</td><td>1489</td></tr>
<tr><td rowspan="2">189</td><td rowspan="2">378</td><td rowspan="2">378</td><td rowspan="2">471</td><td>1489</td><td>1628</td></tr>
<tr><td>1628</td><td>1767</td></tr>
<tr><td rowspan="2">378</td><td rowspan="2">567</td><td rowspan="2">567</td><td rowspan="2">660</td><td>1767</td><td>1906</td></tr>
<tr><td>1906</td><td>2045</td></tr>
<tr><td rowspan="2">567</td><td rowspan="2">756.1</td><td rowspan="2">756</td><td rowspan="2">849</td><td>2045</td><td>2184</td></tr>
<tr><td>2184</td><td>2323</td></tr>
</table>

The cycle time is measured through sequential form. The Palletizing output per processing time is 4 pallets, since each warehouse has 4Palletizing lines. Therefore in the sequence it is repeated until 4 columns of Palletizing start-end time which represent 16 pallets in total. The second activity is loading to truck.It is started after the Palletizing is done. It uses two forklifts with capacity 2 pallets each, it means 4 pallets resulted from the previous Palletizing process are all loaded by the two forklifts at the same time. Those sequencesare done 4 times since the capacity of truck is 16 pallets.

After that, the transport to port is started and takes time 336 seconds as the standard time result. When the truck arrives in the port, the loading to vessel activity begins. The starting time is the time when the truck was arrived. The crane capacity is 2 pallets per load, so it is repeated 8 times until the pallets are all loaded. The last activity is transporting back to the warehouse which take time 224 seconds. Based on that example sequence form, a cycle time of truck can be determined for all the vessels served in April 2015. The cycle time is different since the activity crane material handlings have different time processing. Figure

4.21 is the recapitulation of cycle time for each truck for its specific vessel in April 2015.

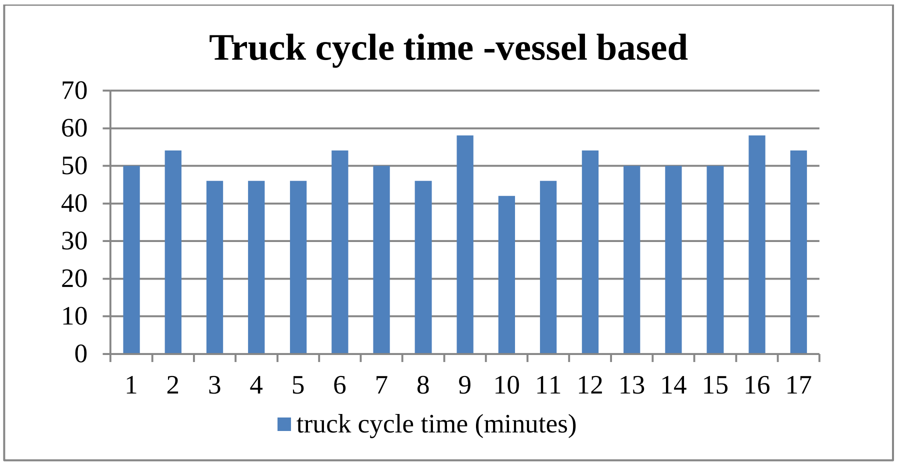


Figure 4.21Truck cycle time - vessel based

The result of cycle is time calculated with assumption that there is no queue of Diswil 1 trucks. It is only representing the time needed by truck from port / diswil 2 in normal condition. It will then be used to check the daily achievement of truck, so that the wastes can be indicated from here. In existing condition, there is possibility the cycle time can be longer but not faster due to the queue of truck for both Diswil 1 & 2.

4.1.3` Wastes Identification

The contribution of berthing duration is dominated by the duration of loading activities.The loading achievement can be seen from loading rate or how many cycles a truck did in one day. Historical dataof April 2015 show that it is very low number of cycles achieved by one truck.

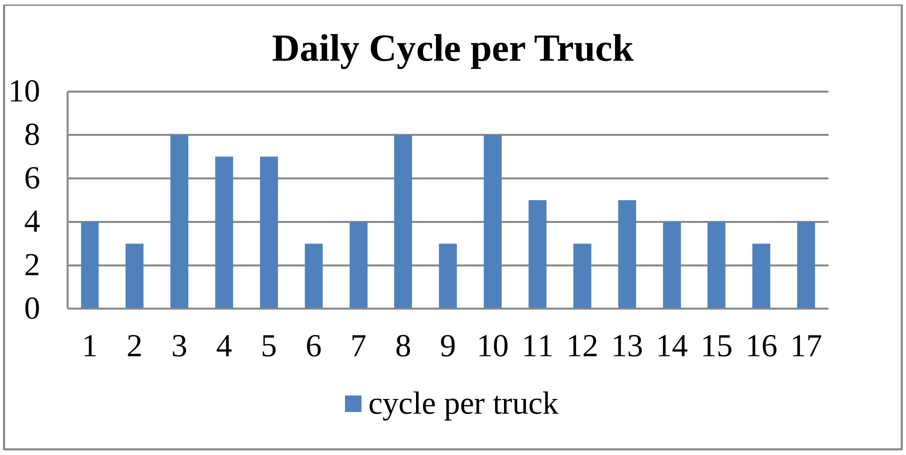


Figure 4. 22Daily cycles per truck (vessel based)

Using the data of Truck cycle time and the number of daily cycle per truck, the daily utilization of truck can be generated. The daily utilization means the time that truck spends in a day to do the cycles.

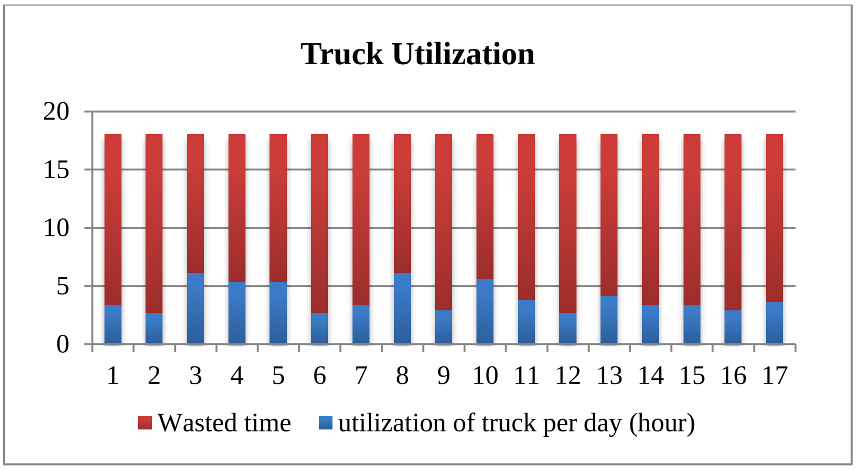


Figure 4.23 Daily truck Utilization

Figure 4.23indicates that in one day working (18 hours), the utilization is very low. This also emphasizes that some activities may contain wastes of time that impacts on low truck utilization. Further investigation of factors causing the wastes should be developed to seek which waste is giving biggest contribution.

4.1.3.1 Wastes in service

The value of time wasted in a day has identified in the previous section. This chapter tries to break down what kind of wastesappear in the unutilized time by trucks. Identification is done through certain brainstorming with Port employees and warehouses employees.

Types of wastes in service are different with wastes in manufacturing. Given an example, stocks or inventory are categorized as a waste in manufacturing, but in service it is not. Low level inventory will give impact on delay of service process. In this research type of waste that will be measured is only delay or waiting time since the most critical and measurable according to discussion is this waste. Another reason this waste is chose is because indicator of achievement is loading rate or number of truck cycle per day. The rate is related to achievement in certain time. The more time wasted by a truck will give lower loading rate to the truck. The wastes that contain of time in truck cycle is the waiting.

4.2 Measure Phase

Measure phase is the second stage in the Six Sigma DMAIC method. This phase addresses and calculatesthe magnitude of waste in related problem.

4.2.1 Simulation Model Development

The performance of wastes are difficult to measure by manual measurement because the uncertainty of factors / variables causing them. The variables that influencing these waiting are fertilizers stock, Queue of Trucks fromDiswil 1, Weather, port employees / stevedores performance, and so on. This condition makes the variables that causing wastes are complex. The scheme put below will explain the variable levels which are causing the wastes.

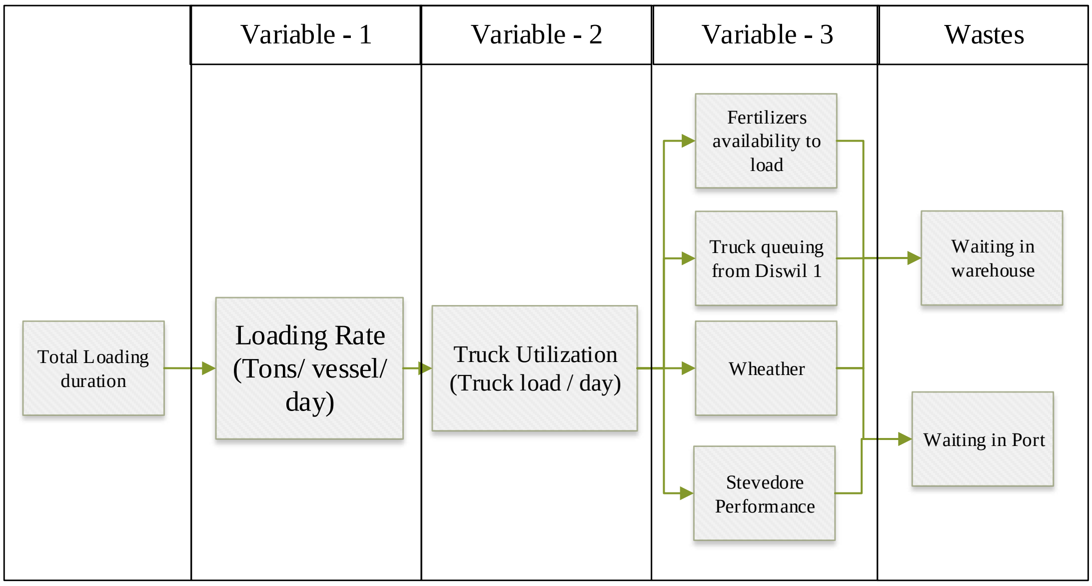


Figure 4.24 Variables / Factors that impact on waiting

It needs one tool to put those variables into one system, so that the performance of wastes can be measured.Based on the initial identification, the waiting time lays on warehouses (before loading to truck) and in the port (before loading to vessel). Direct measurement will take long time and it also does not represent the port condition in longterm perspective. That's why simulation is needed.

4.2.1.1 Simulation Data Collection

The simulation is made to virtually run the loading process of Phonska in-bag fertilizers in certain period. In this case, the period of simulation is April 2015. In order to develop the model, data of April 2015 variables should be collected.It will be used as inputs of simulation model later on.

The data collection contains of historical loading assignments, stock flow of Phonska in-bag in each warehouse (input from production and output to both Diswil 1 & 2), and stevedores workhour. Each data will be explained and given in following points.

4.2.1.1.1 Historical Loading Assignments

The authority of order assignment for outside java region is under the responsibility of Diswil 2 Department. Every assignment given to Port Department contains oforder quantity, destination and other details. This is the basic information of Port Department loading activity. Once order comes, Port

Department will prepare vessel and other equipment. The data given below is the Historical assignment of Phonska in-bag loading activities in period of April 2015.

Table 4.24 Recapitulation of Historical loading assignment April 2015

No	Vessel name	Quantity	Berthing date	Start loading	End Loading	Unberth
1	Kamasan	1,000	3/31/2015 22:05	4/3/2015 21:30	4/5/2015 21:00	4/6/2015 18:40
2	Niaga 56	3,400	4/2/2015 18:15	4/3/2015 9:45	4/11/2015 21:15	4/12/2015 6:10
3	Tradisi 6	800	4/3/2015 16:25	4/5/2015 14:05	4/6/2015 11:00	4/6/2015 22:10
4	Mutia Ladjoni	1,800	4/4/2015 12:25	4/4/2015 19:00	4/6/2015 23:30	4/8/2015 0:05
5	Spirit Sejati	6,800	4/5/2015 14:10	4/5/2015 20:30	4/13/2015 12:00	4/13/2015 19:10
6	Permata Sakti	1,602	4/7/2015 15:10	4/7/2015 19:00	4/12/2015 1:30	4/12/2015 13:00
7	Caraka Jaya Niaga 3-32	2,000	4/10/2015 3:00	4/10/2015 13:00	4/14/2015 15:00	4/18/2015 17:40
8	Karya Perdana 8	300	4/13/2015 22:00	4/15/2015 8:00	4/15/2015 15:30	4/20/2015 6:30

Table 4. 25Recapitulation of Historical loading assignment April 2015 (cont)

No	Vessel name	Quantity	Berthing date	Start loading	End Loading	Unberth
9	Putri Mulya 2	1,350	4/14/2015 13:20	4/14/2015 20:15	4/18/2015 23:00	4/21/2015 15:20
10	Harapan Sejati	3,030	4/18/2015 13:50	4/18/2015 16:00	4/21/2015 16:00	4/23/2015 2:50
11	Kairos 2	2,150	4/18/2015 13:50	4/20/2015 15:00	4/24/2015 0:20	4/24/2015 10:20
12	Blossom Pescadores	3,800	4/18/2015 17:10	4/19/2015 10:00	4/30/2015 0:00	5/1/2015 17:30
13	Tradisi 8	730	4/20/2015 18:05	4/22/2015 10:00	4/23/2015 17:00	4/24/2015 12:40
14	Shanon	1,800	4/23/2015 12:50	4/23/2015 15:15	4/26/2015 23:30	4/27/2015 2:55
15	Indah Surya 8	1,640	4/27/2015 13:10	4/27/2015 15:00	5/1/2015 10:00	5/1/2015 15:05
16	Permata Cinta	1,368	4/27/2015 15:30	4/27/2015 19:00	5/1/2015 23:30	5/2/2015 7:00
17	Baruna Fortuna 1	1,500	4/27/2015 22:40	4/30/2015 9:45	5/3/2015 22:00	5/4/2015 6:50

The yellow-marked vessels are the work in process that not yet finished in period of April 2015. These vessels are included to the simulation model, in order to give the fair traffic as the existing condition has.

4.2.1.1.2 Phonska Stock Flow

As already mentioned before, the loading activities are started from warehouses.PT Petrokimia Gresik has 3 warehouses located near the port. Eachwarehouse has specific region to handle. Warehouse 1 (Gudang Phonska 1) is responsible to handle Central Java and Yogyakarta region. Warehouse 2 (Gudang PF 1) takes a role on holding stock of East Java and Bali. The last, warehouse 3 is responsible to hold the fertilizers stock for West Java. All of regions that mentioned are Diswil 1 regions. Those regions are the first priority of each related warehouses, while for outside java region (Diswil 2) is fulfilled by combination of stocks available from those warehouses. A clearer preview of all warehouses responsibilities is given in figure below (unit = ton)

Table 4.26Recapitulation daily phonska input to warehouses

Date	Warehouse 1	Warehouse 2	Warehouse 3	Date	Warehouse 1	Warehouse 2	Warehouse 3
1	3294	1809	3297	16	2565	465	2758.5
2	3322	1150.5	3366	17	2974	1165.5	2686.5
3	3322	1044	3154.5	18	3183	1206	3303
4	3144	1260	3580.5	19	3321	1492.5	3537
5	3294	1519.5	3546	20	3201	1399.5	3559.5

Table 4.27Recapitulation daily phonska input to warehouse (cont)

Date	Warehouse 1	Warehouse 2	Warehouse 3	Date	Warehouse 1	Warehouse 2	Warehouse 3
6	3321	1578	2004	21	3310	1197	3268.5
7	2512	1057	2899.5	22	2860	28.5	2760
8	3060	1105.5	3208	23	2314	0	3094.5
9	2956	865.5	3417	24	3313	1311	3337.5
10	3262	1153	3237	25	3259	2082	3679.5
11	3220	1252	3510	26	1980	1839	3418.5
12	3042	2095.5	3513	27	1740	10.5	2173.5
13	3318	1822.5	3357	28	1740	0	2034
14	3318	700.5	3145.5	29	1740	870	1468.5
15	3280	943.5	2965.5	30	2220.5	1093.5	0

Table 4.28 Phonska Stock inflow April 2015

Warehouse	Initial Stock	From production	Stock shifted from warehouse			Stock shifted to warehouse			Total stock
			1	2	3	1	2	3	
1	1923.35	87385.5		11086.5	19863		21190.65	36918.05	62149.65
2	97.35	33516	21190.65		14034.5	11086.5		10733.3	47018.7
3	90.95	91120.5	36918.05	10733.3		19863	14034.5		104965.3

Table 4.29 Phonska Stock Outflow

Warehouse	Diswil 1	Diswil 2	DO	Reprod	Final stock	Total stock
1	27426.5	29443	3250.5	419.8	1609.85	62149.65
2	45594.15	1317		36	71.55	47018.7
3	67416.85	37311		84.95	152.5	104965.3

4.2.1.1.3 Stevedores Work Hour

Stevedoresare the rough workers who involved in the loading process from trucks to vessels. In this report their jobs are named as activity 4.1, 4.2, 4.3 which are pinning crane's hook to pallet, operating crane, and unload fertilizers to vessel. They work in group for specified vessel. It means the stevedore workers only responsible for one specific vessel, while the other vessels are handled by other stevedore groups.

The port is open 24/7 with 18 hours working time, but stevedores sometimes don't available in the working time. They averagely work only 16 hours/day.

4.2.1.2 Existing Model

The existing model is made as a duplication of existing condition of the loading activity. This model is completed by readwrite module which connects ARENA with Ms. Excel spreadsheet.

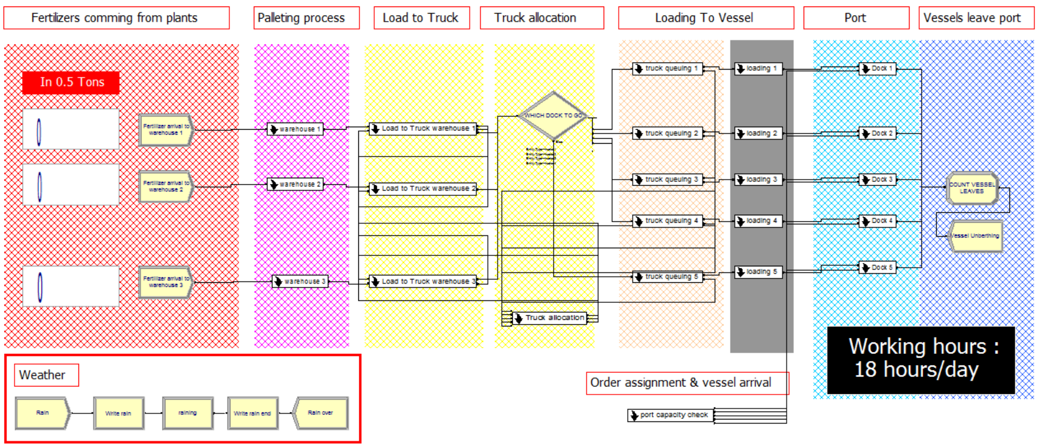


Figure 4. 25 Existing arena model

The figure above is the whole simulation model that already made to represent the existing condition of Phonska loading activity. This model contains of several submodels which represent each activity in the warehouses and port. Those submodels will be explained in these following lists.

Submodel 1 -Order assignment and vessel arrival

The sequence of loading activities for diswil 2 is started when the vessel berths in the port. The inter-arrival time of vessel is set to be coming to the system the same like the historical data of berthing date. .

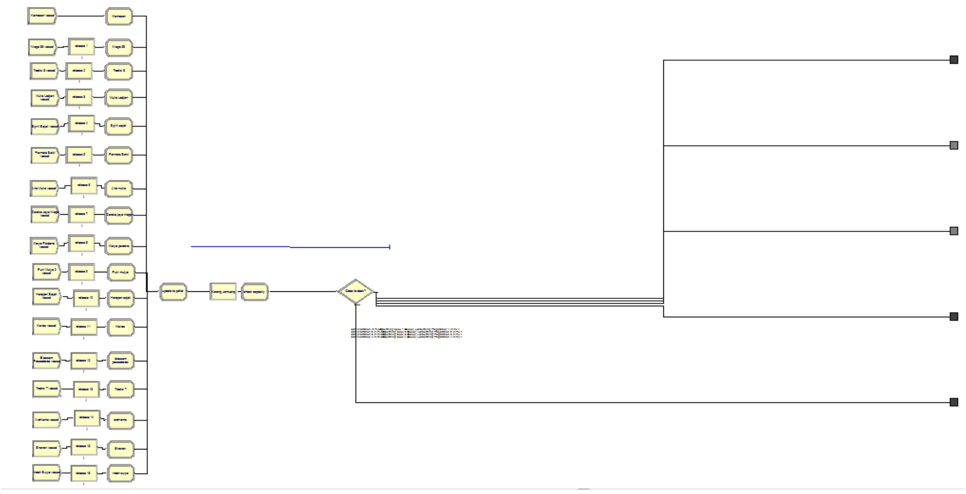


Figure 4.26 Vessels assigned to berth

The vessel that entering simulation will then go to the dock to follow the pre loading activity. Before it berths, there is order quantity submodel and decisional capacity checking to be passed. The explanation is given in the following list of steps.

Step 1. Order assignment

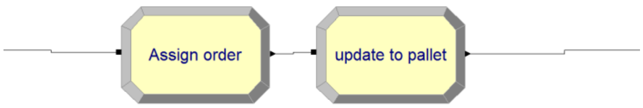


Figure 4.27Order assignment module

The vessel will be attached with order attribute& vessel identity through the assign order module. This order is in unit of ton, this will update into pallet size quantity. So that can be known the number of pallet that should be loaded.

Step 2. Port capacity check

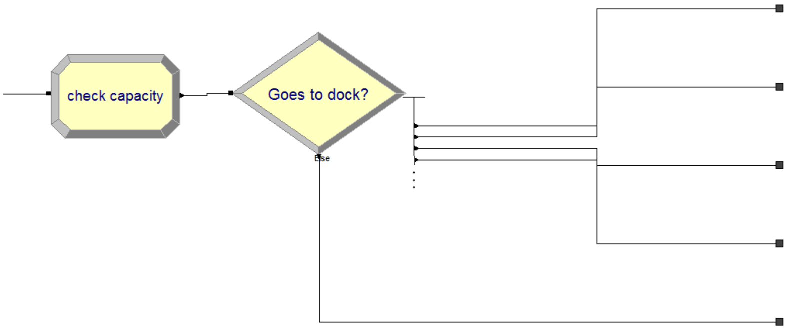


Figure 4.28 Port capacity checking

Port capacity submodel will check the number of vessels in the docks and allocate the incoming vesselto the empty dock.

Submodel 2 - The docks

Submodel dock is the place where the vessel waiting for the loading process. In this submodel, vessel will pass pre loading activity and also the after loading activity.

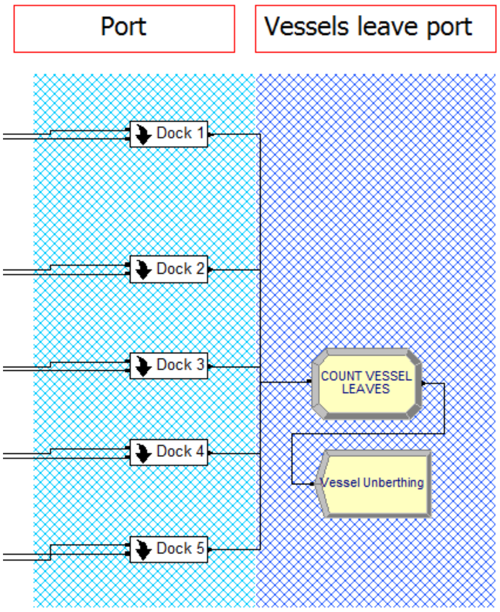


Figure 4.29 Docks sub models

There are five docks / berthing places made to be available in the model. It is made due to the historical data said that there is possibility 5 vessels served in the same time. Inside this submodel there are sequence that will be explained through the figure and steps below.

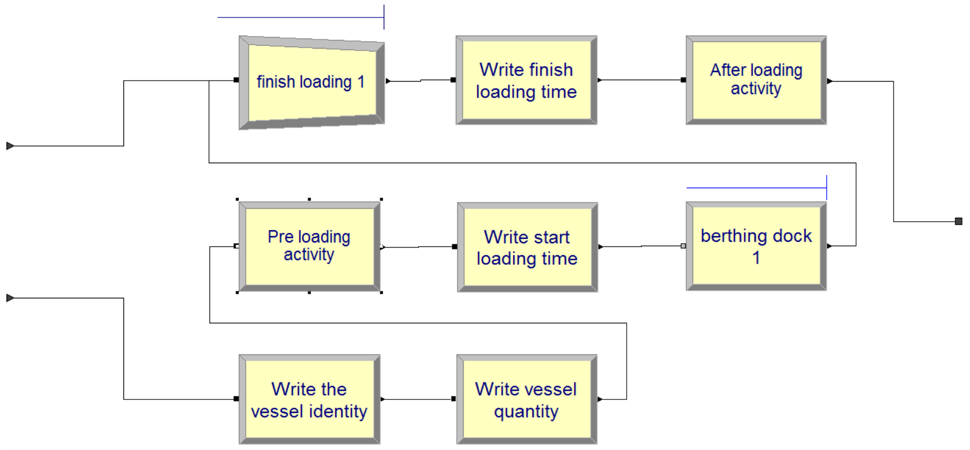


Figure 4.30 Preview inside dock sub model

Step 1. Write identity & quantity

The identity and quantity that already attached before are recorded into spreadsheet. This identity contains of vessel number and time when it comes to the port, while the quantity is in form of the size of order as the quantity in the historical condition.

Step 2. Pre loading activity

The pre loading activity is a delay that represents the initial draught and other process faced by the vessel before the loading process is done.

Submodel 3 - Truck allocation

Truck allocation submodel is the submodel that has function to regulate destination of Diswil 2 trucks. This submodel will assign the group of trucks to warehouses with certain priority of which warehouse to go. It also regulate the trucks only work when there is vessel in the port and ensure the truck stop assigned to port when the loading quantity of vessel is totally achieved.

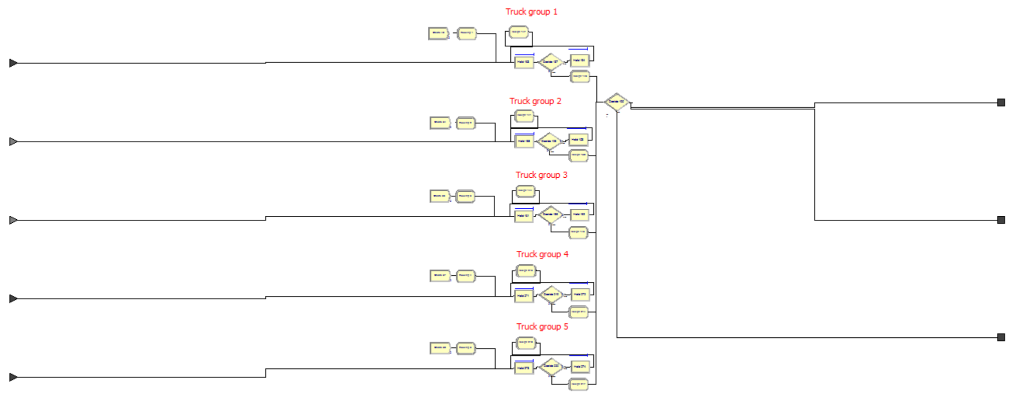


Figure 4.31 Truck assignment to warehouses

The explanation of this submodel is explained in these steps:

Step 1. Trucking group

The trucking group will released from its hold module when the vessel is already in the dock and had faced the pre loading activity.

Step 2. Truck load count

Every truck released will be count as one truck load with attaching number to them. If the number of truck left is already achieving the number truck load that should be done, it will later be go back in its hold and stop the loading activity.

Step 3. Warehouse destination

The priority of which warehouse to be the destination of the truck is following the historical data of the warehouse output for diswil 2. These percentages will be used to assign the truck to which warehouse.

Table 4.30Percentage of truck destinatin

Warehouse	Percentage
1	42%
2	3%
3	55%
Total	100%

The percentage shows 42% of trucks passing the decision module in truck allocation submodels will go to the warehouse 1, only three percents will go to warehouse 2, and the rest 55% are allocated to warehouse 3. This value comes from earlier calculation in table 4.7.

Submodel 4 - Palletizing process

Palletizing process is the submodel which executes the Palletizing activity (Activity 1). There are three sub models that represent three warehouses of phonska in-bag warehouses.

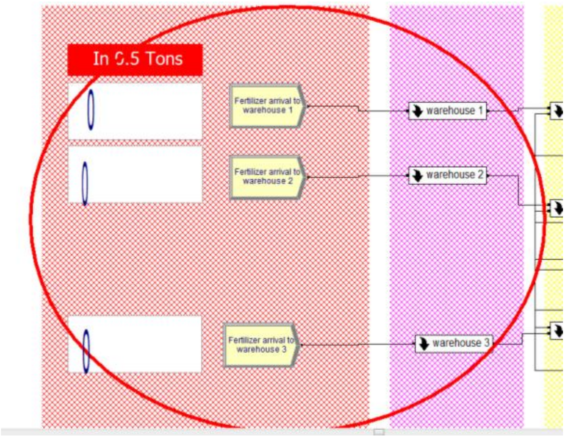


Figure 4. 32 Palletizing process

The Palletizing activities from three warehouses are assumed to have the same time operation. This Palletizing process submodule batchs the fertilizers input from production plant into pallet size. The input is different based on the production plant output to each warehouse.

The daily in-bag fertilizers input for warehouses are set to be in unit of 0.5 ton, not in the unit of bag (50kg). This is aimed to ease the batching process, and reduce the number of entities involved in the system. The batching process/Palletizing process needs 30 entities (in bag fertlizer) with each 50kg in weight. It means in a single day with average of 3300 tons input the entity entering the system will be 66000 entities/day from only one warehouse. This will not affect the simulation result.

The input is also assumed to be coming in every day and having integer value, so the daily input is rounded up to the nearest integer. Using those assumptions, the fitting distribution test of warehouses inputs are then built.

Warehouse 1:

Expression: TRIA(3.48e+003, 6.33e+003, 6.64e+003)

Square Error: 0.199753

Used Expression : ANINT(TRIA(3.48e+003, 6.33e+003, 6.64e+003))

Warehouse 2:

Expression: NORM(2.24e+003, 1.16e+003)

Square Error: 0.041244

Used Expression : ANINT(NORM(2.24e+003, 1.16e+003)

Warehouse 3:

Expression: -0.001 + 7.36e+003 * BETA(2, 0.472)

Square Error: 0.025310

Used Expression : ANINT(0.001 + 7.36e+003 * BETA(2, 0.472)

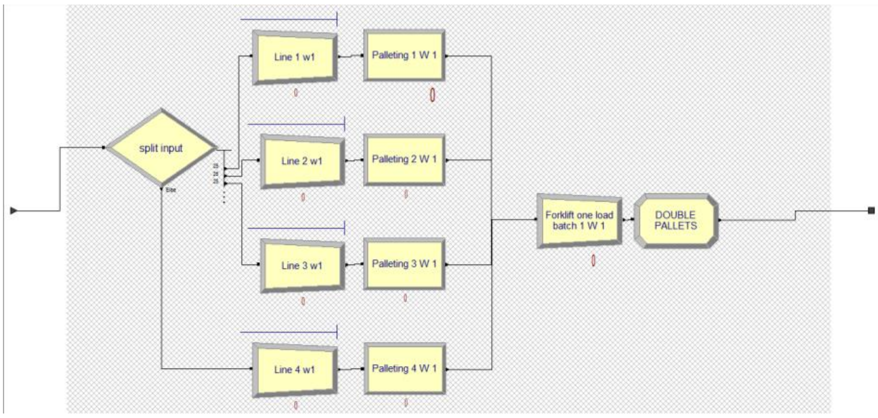


Figure 4.33 Inside sub model Palletizing process

The process of Palletizing is shown in the figure above. The explanation will be given in these following steps.

Step 1. Four lines of Palletizing

Each warehouse has four active Palletizing lines with different resources. The decision module will split the input with the same weight (25%) to all of those lines.

Step 2. Palletizing process

The Palletizing process module will delay the batched fertilizers with the Palletizing time as already generated in the standard time result

Submodel 5 - Load to Truck

Load to truck submodels are made to represent all warehouses of Phonska fertilizers in the company. There are three submodels of loading to truck,. The process inside these submodels are the same, the thing that differentiate is the input from each Palletizing activity as the predecessor activity before loading and also the frequency of truck arrivals both for Diswil 1 and Diswil 2. The figure below show the submodels of loading processes of three warehouses.

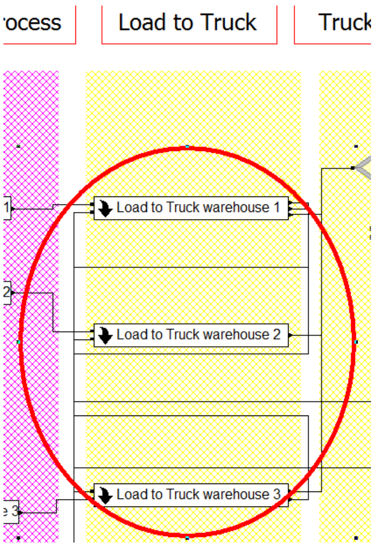


Figure 4.34 Loading to truck sub model

Inside the submodel, the re are some activities related to the loading to truck activity, which will be explained in the following figure and steps.

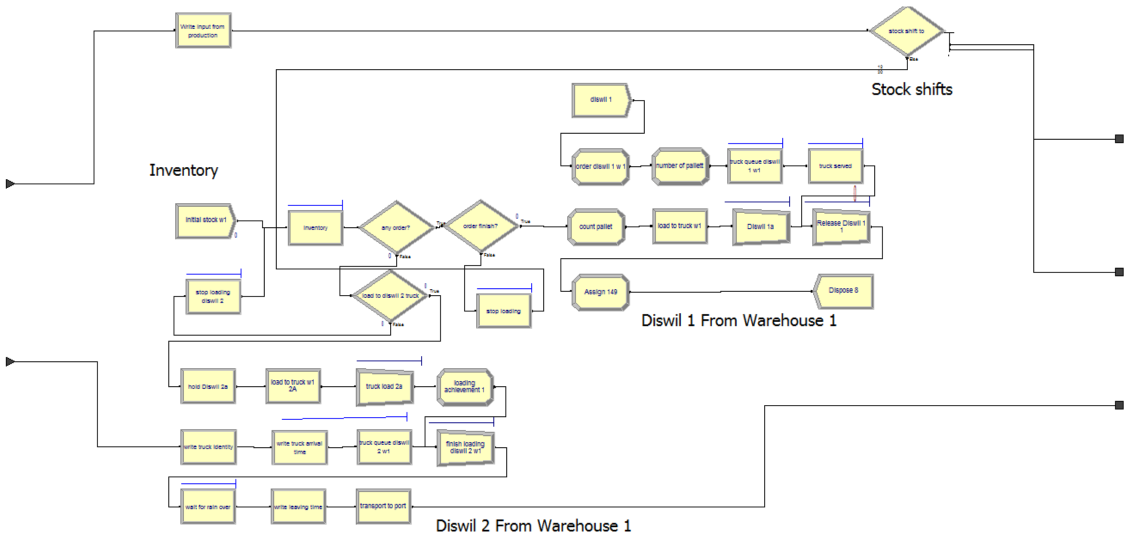


Figure 4.35Sequence of loaing process

Step 1. Stock shifting

Stock of Palletized fertilizers will be assigned to go out from warehouse to other warehouses, the quantityis the same as the historical stock shifting data said.

Step 2. Inventory

The rest Palletized fertilizers (unshifted) will be hold in the inventory. This inventory will be released when there are trucks from diswil 1 or diswil 2. The priority is the diswil 1 truck will be served first, the diswil 2 trucks have to wait until the loading process for truck from diswil 1 finish.

Step 3. Diswil 1 loading process

The loading process is assumed to come every hour with the quantity as already defined in the Phonska stock flow. The monthly quantity is divided by 30 days in April, so it results the daily quantity of loading for diswil 1. This daily quantity is divided by 18 hours since the truck is assumed to come every hour. The processing time is the same with the diswil 2 which is already determined in the standard time calculation since in the existing condition it is not different.

Step 4. Diswil 2 loading process

This process wait until truck from diswil 2 is arrived in the warehouse. The process is not directly executed, it wait for the process from Diswil 1 trucks finished like already stated before. It will leave the warehouse when the loading process is over and there is no rain. The time truck coming and leaving warehousewill be recorded to see the service time of each truck.

Step 5. Transport to port / dock

The transportation of truck to go to the port is then done by the truck with the time needed as same as the result of transportation standard time calculated in the previous section.

Submodel 6 - Loading to vessel

Inside the sub model loading to vessel, the palletized fertilizers will be loaded into vessel with crane capacity 2 pallets per load. The time operation is using the standard time of activity 4 in development of standard time sub chapter.

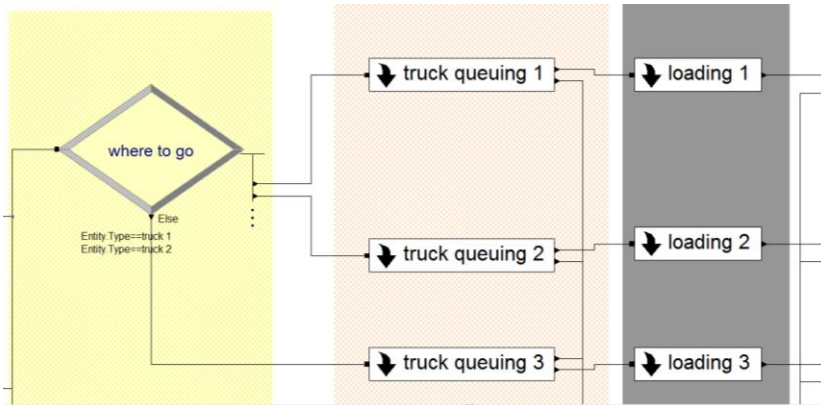


Figure 4.36 Loading to vessel

Submodel 7 – Weather

The weather will assumed to come into the system exponentially with means 30hours per arrival and the duration is random also.

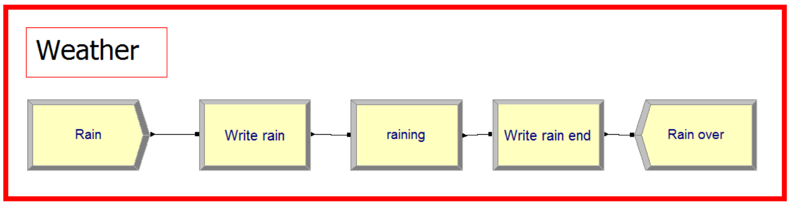


Figure 4.37 Weather regulator

4.2.1.3 Model Verification and Validation

Verification is a step to check the model logic works as the desired purpose, while validation is aimed to see the result is representing the real condition or not. Both verification and validation are developed through several method. The verification is using the trace debug facility in the ARENA software, proportion of output test, and proportion of input test. The validation will be using loading rate per vessel as the component. The method of validation depends on the result of simulation. If the variance between real loading rate and the simulation model result is the same, the chosen method is welch confidence interval test. If there is unequal variance, the test will use t-paired confidence interval with α = 0.05 for both tests.

4.2.1.3.1 Verification with Trace Debug and Logic Error ARENA

The first verification is using trace debug and logic error in ARENA to find whether there is module which doesn't work as the logic stated. This can be generated with pressing F4 button in ARENA preview mode.

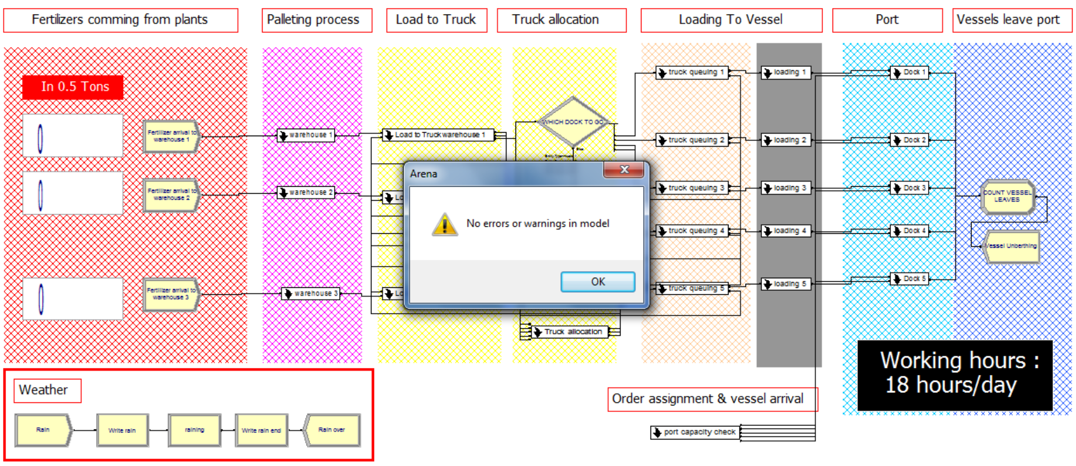


Figure 4.38 Trace Debug and Logic error verification

4.2.1.3.2 Verification Input Output of Fertilizers

Input of fertilizers are also going to be checked the proportion as the verification that the logic works. The verification is given below.

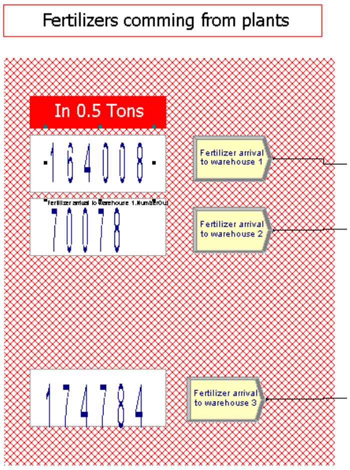


Figure 4.39 Number of input fertilizers to warehouse

The verification will be using comparison with the existing condition. Table below shows the comparison result.

Table 4.31Fertilizers input verification

Warehouse	Real input from production (Tons)		Simulation result (Tons)		Deviation	Average Absolute Deviation
	Value	Percentage	Value	percentage		
1	87385.5	41%	82004	40%	-1%	0.89%
2	33516	16%	35039	17%	1%	
3	91120.5	43%	87392	43%	0%	
Total	212022	100%	204435	100%		

The result of simulation still has deviation with the real input from production in the historical condition. This deviation comes from random value of daily input using the distribution in the simulation fit data test. The absolute average of deviation shows only 0.89 percent of the input is error. This small percentage indicates that the input has small error and the model can be stated working as the desired logic. This condition is also verified that the input of phonska inbag in the warehouse submodels.

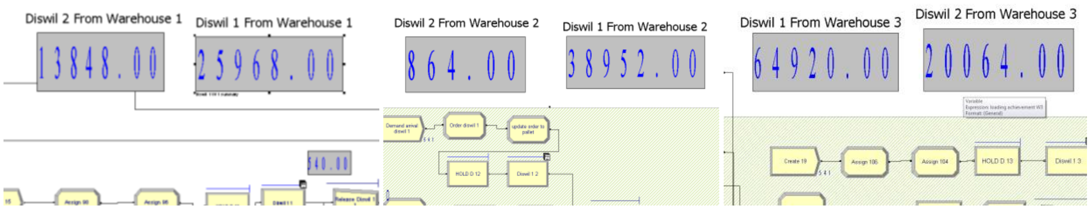


Figure 4.40 The output from each warehous

The value of three warehouses should lay between the total finished assignment and total quantity assignment in April 2015 in the table 4.18 of simulation data collection subchapter. Clearer expression is given as follow :

$$\sum_{i=1}^{14} Qi \leq \sum_{j}^{n} RWj \leq \sum_{i=1}^{17} Qi \quad (4.3)$$

Where :

$\sum_{i=1}^{14} Qi$ = Total Quantity of finished assignment (n = 14 vessels)

$\sum_{j}^{n} RWj$ = Total Warehouses release (j = 1,2,3)

$\sum_{i=1}^{17} Qi$ = Total Quantity of assignment in April 2015 (n = 17 vessels)

Table 4. 32Total output verified

Total release				
Region	Warehouse			Total (Tons)
	1	2	3	
Diswil 2	13848	864	20064	34776

The result of verification by output shows that the value of relesed fertilizers by warehouses lay on the defined range.

$$30562 \leq 34476 \leq 35070$$

It means the output logic of loading simulation is verified since the quantity had released by the warehouses are laid on the appropriate value.

4.2.1.3.3 Non-Terminating Scheme and the Warming Up Period

Recalling the purpose of simulation, it is originally aimed to find the wastes magnitude of Truck waiting time in the warehouses and in the port. These wastes will then be identified through several analyses in the next chapter.

The real system of port works in non-terminating condition. In other word, it runs in non stop situation. It means that model made to represent the system can not be directly used as the representation of real condition because it needs to be warmed up to reach the steady state. Therefore not all of wastes magnitude recorded from the system can be used as the data of wastes measurement. Firstly we have to state the warming up period of the model.

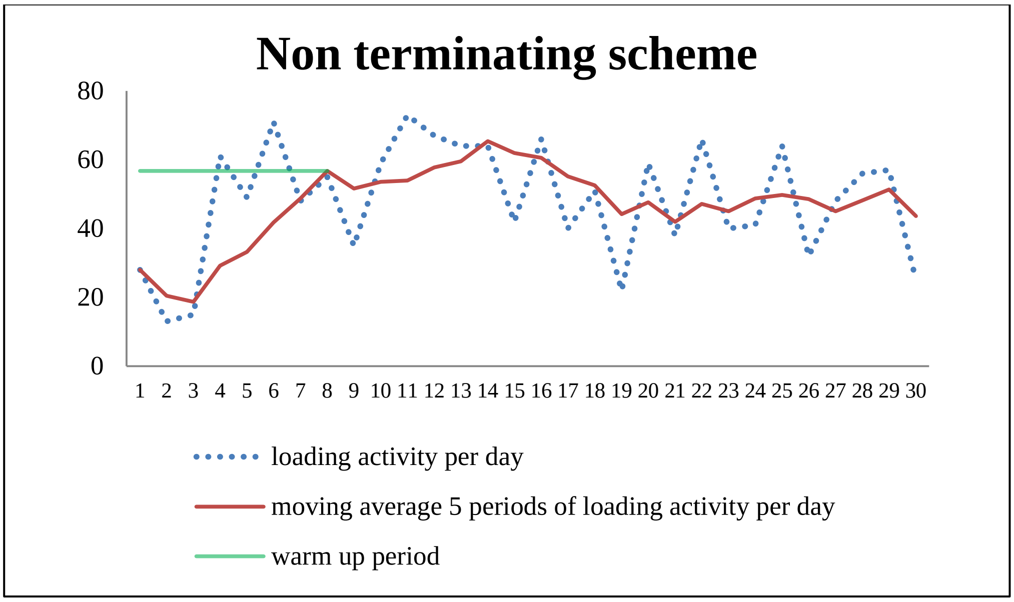


Figure 4.41 Non-terminating condition scheme of simulation

The component that used to see the warming up period is the number of loading cycles per day. This component is chosen as representative output per day. The number of loading activity in simulation result is shown with dotted line (colored blue). In order to determine the warming up period, the moving average is developed to see the transient state. The number of period window in the moving average is 5 days since the recommendation of previous research from Law and Kelton (2000) stated that the number of moving average period window should not exceed 25% of total period. Thered line in the figure 4.38 is the moving average of 5 periods (5 days) result.

The value of moving average daily truck cycle shows that the simulation started entering the steady state situation in the 8th day. The period after 8th day (9th -30th) shows quiet constant achievement. This condition also states that only the period of 9th – 30th day is valid to be used as the component of wastes measurement.

4.2.1.3.4 Steady State Simulation Result

The steady state simulation is done through rerunning the same model with eight periods of warming up duration. The result of steady state condition of system made to represent existing condition is given in the table 4.27. inside the table also given the real data from port performance in April 2015 to be used as comparison and basic data for validation in next step.

Table 4. 33 Existing condition simulation steady state result

Period	Total truck load per day						Average
	Real condition	R1	R2	R3	R4	R5	
1	17	22	0	18	24	43	21.4
2	17	41	34	53	31	45	40.8
3	37	26	39	60	45	61	46.2
4	62	37	68	62	12	71	50
5	130	68	41	49	13	97	53.6
6	109	70	71	50	16	82	57.8
7	65	74	78	84	11	48	59
8	78	53	61	77	16	25	46.4
9	78	37	20	69	44	17	37.4
10	81	46	55	54	64	18	47.4
11	81	53	61	90	75	30	61.8
12	65	30	38	80	68	47	52.6
13	52	42	26	34	102	29	46.6
14	28	57	22	54	69	58	52
15	24	55	29	35	45	102	53.2
16	11	22	34	35	30	85	41.2
17	11	47	30	52	50	57	47.2
18	53	42	27	87	50	74	56
19	42	20	3	35	62	28	29.6
20	64	17	28	32	32	25	26.8
21	74	19	29	27	29	27	26.2
22	71	30	35	20	58	78	44.2

Period	Total truck load per day						Average
	Real condition	R1	R2	R3	R4	R5	
23	89	66	38	20	42	24	38
24	74	76	26	21	28	50	40.2
25	52	45	46	50	6	53	40
26	52	77	54	42	32	84	57.8
27	61	102	62	52	39	94	69.8
28	61	68	39	13	62	90	54.4
29	38	44	49	1	79	47	44
30	53	43	31	12	81	47	42.8
Variance	777.2644	Variance					122.502
Mean	57.66667	Mean					46.1467

4.2.1.3.5 Validation of Simulation Model

Validation of model is the step to see the result of simulation represents the real condition of the system or not. The result of simulation has to be confirmed as a valid representation of the real system. This validation method uses welch confidence interval since the variance of simulation and real condition is different (Unequal variances). This method compares the real system with simulation result using two hypothetical statements, which are :

$$H_0 : \mu 1 - \mu 2 = 0$$

$$H_1 : \mu 1 - \mu 2 \neq 0$$

When H_0 is accepted, the value of simulation can be said as representation of the real condition, but when the hypothesis 1(H_1)is accepted, it means the simulation can not be used to represent the real condition.

The hypothesis will be checked using formula below to see which one is accepted.

$$P\,[(\bar{x}_1-\bar{x}_2) - hw \leq \mu 1 - \mu 2 \leq (\bar{x}_1-\bar{x}_2) + hw] = 1 - \alpha \qquad (4.4)$$

Where :

$$hw = t\,df, \alpha/2 \sqrt{\frac{S_1^2}{n_1} + \frac{S_2^2}{n_2}} \qquad (4.5)$$

and,

$$df = \frac{\left[\frac{s_1^2}{n_1}+\frac{s_2^2}{n_2}\right]^2}{\frac{[s_1^2]^2}{(n_1-1)}+\frac{[s_2^2]^2}{(n_2-1)}} \tag{4.6}$$

The result of calculation shows df = 37.91961, the hw (halfwidth) is calculated below

$$\text{hw} = t_{37.91961\,,0.05/2}\sqrt{\frac{777.2644}{30}+\frac{122.502}{30}}$$

$$\text{hw} = 2.398\sqrt{\frac{777.2644}{30}+\frac{122.502}{30}}$$

$$\text{hw} = 13.3649$$

The interval of $\bar{x}_1$-$\bar{x}_2$ ±hw is then developed using the value of hw that already generated before.

$$11.52 - 13.3649 \le \mu1 - \mu2 \le 11.52 + 13.3649$$

$$-1.8365 \le \mu1 - \mu2 \le 24.8765$$

Since the interval shows the value of µ1 - µ2 lies between negative and positive value, it can be concluded that the value of µ1 - µ2 = 0 is possible. This result is also one indication that hypothesis 0 or H_0 is accepted and the simulation result can be used as representation of the real system.

4.2.1.3.6 Number of Replication

Number of replication will define the sensitivity of simulation result to the real condition. In order to determine the number of replication, there should be defined an error rate as the rate of simulation result acceptance. In this result, the error rate is defined as 15%. This value came up from earlier discussion with port department employee. The value is considered to be relatively high because the data in real condition has quite high variance and easily lead to error measurement.

$$N' = N \times \frac{\text{hw}^2}{(\text{error rate} \times \text{simulation mean})^2} \tag{4.7}$$

$$N' = 5 \times \frac{13.3649^2}{(15\% \times 46.1467)^2}$$

$N' = 18.6162$

$N' \approx 19$

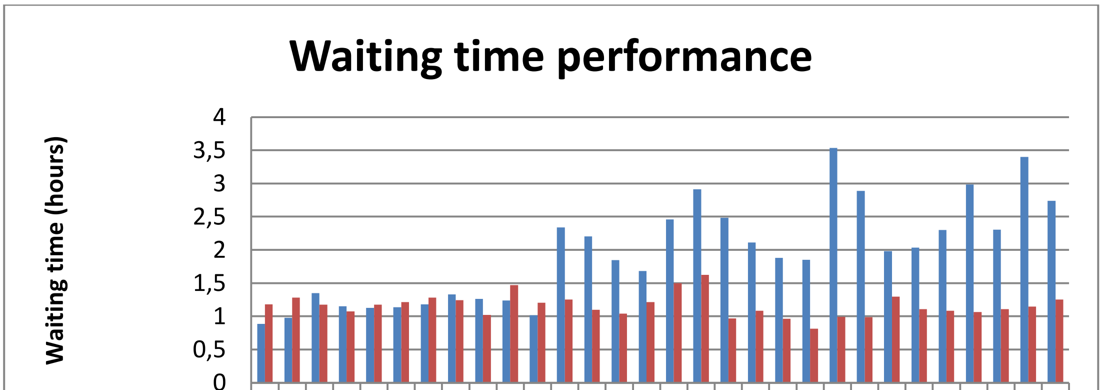
The number of replication should be 19 to get the appropriate result of simulation based on 15% error rate.

4.2.2 Waiting Time Result

Simulation result contains of wastes performance and magnitude that already measured in previous simulation. In this sub chapter, the result of wastes will only taken from the steady state period of simulation which

4.2.2.1 Waiting time in Steady State Period

The period of wastes measurement in steady state period is already gathered. The values of waiting time in warehouses are given in the appendix A to C.In this section is only given the average of value from all warehouses and the port. The simulation result of average time that one truck spends to wait before it is loaded in the warehouseand before it is unloaded in the port is given in the following graph.



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Waiting in warehouses	0,9	1	1,4	1,1	1,1	1,1	1,2	1,3	1,3	1,2	1	2,3	2,2	1,8	1,7	2,5	2,9	2,5	2,1	1,9	1,8	3,5	2,9	2	2	2,3	3	2,3	3,4	2,7
Waiting in port	1,2	1,3	1,2	1,1	1,2	1,2	1,3	1,2	1	1,5	1,2	1,3	1,1	1	1,2	1,5	1,6	1	1,1	1	0,8	1	1	1,3	1,1	1,1	1,1	1,1	1,1	1,3

Figure 4. 42 waiting time resulted from simulation

The average of truck waiting time in warehouses has high fluctuation. Its performance of wasteis contradictory with waiting time in port. The higher waiting in warehouse will imply in low waiting time in the port, and so does the opposite. This means there is bottle neck of truck to be processed. If the number trucks queuing in warehouses are high, it will imply on the waiting or delay time to be processed (Bottlenecking), and contrarily in the port, the truck doesn’t have to wait or may have only low waiting time.

The graph above shows there is pattern of waiting time fluctuation. This happens because in the period when waiting in warehouse (blue bars) has high value, the number of vessels served are also high. This makes the trucks assigned to warehouses are frequent.

In average, the truck has to wait 1.9527 hours before served in the warehouse and 1.636 hours in the port to get served. This waiting time is quiet high and give a bad implication to the loading rate achievement.

CHAPTER V
ANALYSIS AND DATA INTERPRETATION

This chapter contains the next steps of DMAIC which are analyze and improvement steps. The output of data processing in the previous chapter will be analyzed to find the root cause of wastes identified and then the improvement is developed.

5.1 Analyze Phase

The performance of waiting time that makes longer loading duration might be caused by several factors. In this subchapter these factors will be investigated so that it can be improved. Before the analysis is done, the contribution of wastes will be tracked down from its origin to see which one that has the biggest contribution on the loading activity. Paretto chart will be used as the tools to find which waste is the critical one.

5.1.1 Root Cause Analysis

The value of waiting time in warehouses given in the Paretto chart in figure 5.1is the average of waiting in the three warehouses in each day. The waiting time for a truck to be served in each warehouse inside the steady state periodis given in this graph.

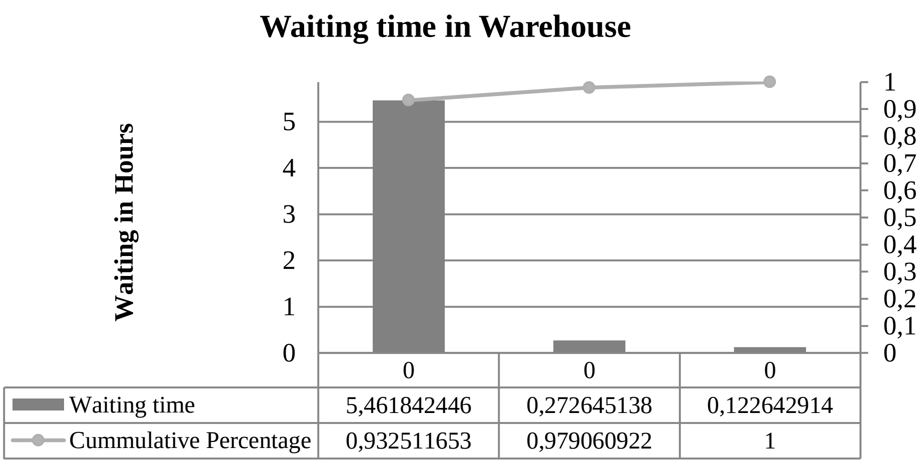


Figure 5.1 Chart of waiting time in warehouses

Warehouse 3 has the biggest contribution on the waiting time before loading to truck. It is caused of warehouse 3 is the biggest Phonska warehouse that the company has. It makes the allocation of truck majorly assigned here, both for Diswil 1 and Diswil 2. In order to know the reasons why it happens, an analysis of root case should be developed.

5.1.1.1 Five Whys Analysis- Waiting in warehouse

Waiting in warehouse 3 as the result of paretto chart should be generate the root cause so that it can be improved later. 5 whys analysis for waste (waiting time) in warehouse 3 is given as follow.

Table 5.1 Five whys analysis for waiting in warehouse 3

Wastes	Why – 1	Why – 2	Why – 3	Why – 4	Why – 5
Waiting in warehouse 3 for truck from diswil 2	Cummulative Truck queue	Run out fertilizer stock	Inconstant daily output from production	Too frequent plant shutdown	Plant failure
			Majorly allocated for trucks from Diswil 1	Diswil 1 has the priority to be served first	Miss-allocation stock for both diswil 1 & 2
		Too many trucks to be served	Queue involving trucks from Diswil 1	To keep flexibility of loading to both diswil 1& 2	Demand majority from Diswil 1
			Slow loading to truck	Only served in one line loading	Lack of facility to do the loading process (Forklift)
	Waiting before go to port	Raining (Bad Weather)	Transportation using truck in open condition & fertilizer bags are not waterproof material		

The last why that appear in the analysis is the root cause of problem. This will later become the input of FMEA.

5.1.1.2 Five Whys -Waiting in port

The same root cause analysis is also developed for the wastes appear in the port. This process is done because researcher believe even the waiting time in port is lower than the waiting in the warehouse, but the root cause should be generated for both of them. It is aimed to see the cause of the port inefficiency time used, so both of up and down stream can be improved. The analysis of 5 whys is done in following table.

Table 5.2 Five whys analysis for Waiting in port

Wastes	Why – 1	Why - 2	Why – 3	Why – 4	Why – 5
Waiting in Port for truck from diswil 2	Truck diswil 2 queue	Slow crane material handling process	Old crane	Machine component decreasing performance	No maintenance by vessel owner
			One line serving	only one shore crane available	Majority of vessel has only one crane
	Stevedore low utilization	fewer working hour than the duration stated by port department	Too often break time	Lack of supervising	No team leader to control the work of stevedore
		Work slower than the standard time	Tired	No working shift regulation	Handled by vendor
	Weather / Rain	Loading to vessel has to be stopped	Dangerous condition because of storm and wind		

5.1.2 FMEA

Failure mode and effect analysis is the steps to analyze the root cause gathered from 5 whys analysis. The causes will be given certain rate of severity, occurrence and its detection. It will later producing Risk priority number which of the causes. This priority defines which cause becomes the focus to improve. The FMEA is developed in Table 5.3 below.

Table 5.3 Failure Modes and Effect Analysis for waiting wastes

Waste	Potential Failure Mode	Potential Effect	Severity	Causes	Occurences	Current control	Detectability	RPN
Waiting in warehouse	Run out of Fertilizer stock for diswil 2	Palletizing process is stopped	7	Plant failure	3	Field inspection	2	42
		Truck diswil 2 queuing	5	Miss-allocation of stocks for both diswil 1 &2	7	Cummulative stock checking	4	140
				Demand majority from Diswil 1	5	Cummulative stock checking	5	75
	Truck queue is high	Longer loading process in warehouse	5	Lack of facility to do the loading process (Forklift)	5	Field inspection	5	125
Waiting in port	Low crane speed	Longer loading to vessel	5	lack of maintenance by vessel owner	2	Field inspection	5	50
	Truck queue in port	Low utilization of truck	3	Majority of vessel has only one crane	5	Field inspection	5	75
	Unnecessary break	Stevedore less workhour	5	No team leader to control the work of stevedore	7	Field inspection by PBM (Vendor)	5	175
	Uncontrolled stevedore performance	Stevedore low utilization	5	Stevedore is handled by vendor	5	Field inspection by PBM (Vendor)	3	75

The yellowed mark cells of RPN are the highest among others with value greater than 100. These causes with high RPN are critical factors which have highest responsibility for the existing low loading rate achievement. The chosen causes are “Proportion of stock for both diswil 1 & 2 is not properly implemented”, “Lack of facility to do the loading process (Forklift)”, and “No team leader to control the work of stevedore”. These critical causes are going to be improved, so the loading rate can increase as the implementation of solution.

5.2 Improve Phase

5.2.1 Improvement ScenariosDevelopment

Improvement scenarios are the alternatives of improvement that will be applied to the generated causes. Table 5.4 is recapitulation of FMEA result and its improvement solution which already confirmed to company.

Table 5.4 Recapitulation of Improvement scenarios

No	Root Cause	Improvement
1	Miss-allocation of stock for both diswil 1 & 2	Adding warehouse staffs to control allocation of Phonska stocks
2	Lack of facility to do the loading process (Forklift)	Adding forklift/service line
4	No team leader to control the work of stevedore	Empower stevedore team leader

The improvement scenarios developed are the solutions to critical causes which lead to waiting. These improvements are clarified to company’s expert the possibility to be implemented. The results for improvements developed are:

1. Adding warehouse staffs to control allocation of Phonska stocks
   This improvement is aimed to give fair allocation for both Diswil 1 and Diswil 2 trucks. The company already sets the proportion of stocks 54% for Diswil 1, and 46% for Diswil 2 but it is not practically achieved since there is no control action to maintain the allocation of stock. It becomes one of critical factor since the trucks from Diswil 1 (Java) is dominantly served than the trucks from Diswil 2 (Outside Java). The trucks of Diswil 2 sometimes should wait due to stockout.
2. Adding Service line
   The initial service line in existing condition is only one line using two forklifts. The processing time is properly skilled and time result in stopwatch time study results also indicates there is no significance variance. The output from its predecessor activity (Palletizing) also

shows relative stable output. The lack of service line is the reason why the trucks should wait for some moments in the warehouses before they are served.

3. Empower stevedore team leader

   Stevedoring is the most uncontrolled part of port activity. The stevedores work in less wok hour than the company stated. The charge of responsibility is given to vendor which has low supervising. The Port Department should contribute to the stevedoring supervising. One of the improvements is with hiring team leaders to watch and control them.

5.2.1.1 Improvement Scenarios

All of the improvement scenarios will not certainly proposed to the company. It needs to be analyzed the costs of one improvement to another. The possibility of combining them is also considered to develop.

Table 5.5 Combinations of improvement scenarios

Combination	Improvement scenarios
0	Existing condition
1	Adding warehouse staffs to control separation of stock
2	Adding Service line
3	Empower stevedore team leader
1,2	Adding warehouse staffs to control separation of stock
	Adding Service line
1,3	Adding warehouse staffs to control separation of stock
	Empower stevedore team leader
2,3	Adding Service line
	Empower stevedore team leader
1,2,3	Adding warehouse staffs to control separation of stock
	Adding Service line
	Empower stevedore team leader

Based on the combination result there are 8 alternatives including the existing condition. The existing condition is involved as the basic cost needed to do the loading process in the Port. So, the costs allocation can be developed as additional cost of improvement to the basic cost of existing condition.

5.2.1.1.1 Improvement Scenarios Cost

The costs related to existing are the stevedore cost and trucking cost. Stevedores are paid daily with nominal of IDR 7,400,000/vessel/day. They work in vessel-based system which means one stevedores group (includes crane's operator) only served one vessel until it is finished. Other vessels will be served by other stevedores.So does the trucking group, it works based on vessel with payment IDR 80,000,000/truck load. Based on historical condition in April 2015, there are 17 vessels with vary loading durations. The stevedores and trucking costs are estimated as follows :

Table 5.6 Existing condition cost (Scenario 0)

Cost type	Unit	Cost/unit	Quantity	Total cost
Stevedore cost (PBM)	Day	IDR 7,400,000.00	76	IDR 562,400,000.00
Trucking cost (EMKL)	Truck load	IDR 80,000.00	1461	IDR 116,880,000.00
Grand total				IDR 679,280,000.00

Quantity of stevedore working days in total is more than 30 days in normal month. It happens because it is the total durations of vessels' loading durations, where there is possibility of more than one vessel served in the same day. The total existing condition costs are estimated as big as IDR 679,280,000.00. It contains of IDR 562,400,000.00 Stevedore cost (Perusahaan Bongkar Muat) and IDR 116,880,000.00 Trucking cost (Ekspedisi muatan kapal laut).

Scenario 1 Improvement Costing

This section contains of cost estimation for implementing scenario 1. There is additional cost burdened to the company. The costs are used to recruit staffs to control the stock proportion for Diswil 2. The nominal of costs are given in this following table.

Table 5. 7 Scenario 1 additional cost

Cost type	Unit	Cost / unit	Quantity	Total cost
Supervisor	Person	IDR 5,000,000.00	3	IDR 15,000,000.00
Team member	Person	IDR 3,000,000.00	3	IDR 9,000,000.00
Grand total				IDR 24,000,000.00

The additional cost is summarized with the existing condition (scenario 0) to see the total cost in one month period of time. The summary of scenario 1 improvement costing is previewed in Table 5.8 below.

Table 5.8 Grand total scenario 1 cost

Cost type	Total
Existing condition cost	IDR 679,280,000.00
scenario 1	IDR 24,000,000.00
Grand total	IDR 703,280,000.00

Scenario 2 Improvement Costing

The second scenario costing is about adding service line in warehouse 3 to reduce the waiting time. This improvement needs higher investment than scenario 1, since it needs to afford two more forklifts as supporting facilities. Theestimation of cost is given in Table 5.9 and the summary of total cost in Table 5.10

Table 5.9 Scenario 2 additional cost

Cost type	Unit	Cost / unit	Quantity	Total cost
Forklifts purchasing	Unit	IDR 150,000,000.00	2	IDR 300,000,000.00
Operator costs	Person	IDR 3,000,000.00	6	IDR 18,000,000.00
Grand total				IDR 318,000,000.00

Table 5. 10 Grand total scenario 2 cost

Cost type	Total
Existing condition cost	IDR 679,280,000.00
scenario 2	IDR 318,000,000.00
Grand Total	IDR 997,280,000.00

Scenario 3 Improvement Costing

Third improvement is about adding the supervisor or team leader of stevedore. The team leaders specified as 5 persons to have ability of shifting within 18 hours working time and able to adapt in the vessels traffic in the port.

Table 5.11 Scenario 3 additional cost

Cost type	Unit	Cost / unit	Quantity	Total cost
Stevedore team leader	person	IDR 3,000,000.00	5	IDR 15,000,000.00
Grand total				IDR 15,000,000.00

The cost in previous table will also included in total cost calculation, he same treatment like previous calculation. Table 5.12 is the total cost as the implementation of scenario 3 in existing condition.

Table 5. 12 Grand total scenario 3 cost

Cost type	Total
Existing condition cost	IDR 679,280,000.00
scenario 2	IDR 15,000,000.00
Grand Total	IDR 694,280,000.00

Combination Scenario 1 & 2 Improvement Costing

Combination scenario 1 & 2 will mix the costs from scenario 1, 2 and existing condition. The grand total cost represents overall costs to implement both scenario 1 and 2 in existing condition.

Table 5. 13 Grand total combination scenario 1& 2 costs

Cost type	Total
Existing condition cost	IDR 679,280,000.00
scenario 1	IDR 24,000,000.00
scenario 2	IDR 318,000,000.00
Grand total	IDR 1,021,280,000.00

The total cost is IDR 1,021,280,000.00. It is higher than previous improvement because the costs are accumulated.

Combination Scenario 1 & 3 Improvement Costing

The same with previous combination, this scenario will summarize 2 improvements in one. In this combination, the scenarios that will be combined are scenario 1 and 3. Total cost is given in the consecutive table.

Table 5. 14 Grand total combination scenario 1 & 3 costs

Cost type	Total
Existing condition cost	IDR 679,280,000.00
scenario 1	IDR 24,000,000.00
scenario 3	IDR 15,000,000.00
Grand total	IDR 718,280,000.00

Total cost is IDR 718,280,000.00 for recruiting the staffs in the warehouses and team leaders for the stevedores.

Combination Scenario 2 & 3 Improvement Costing

This section consists of additional costs for implementing scenario 2 & 3. It will then be summarized with cost in existing condition (scenario)

Table 5. 15 Grand total combination scenario 2 & 3 costs

Cost type	Total	
Existing condition cost	IDR	679,280,000.00
scenario 2	IDR	318,000,000.00
scenario 3	IDR	15,000,000.00
Grand total	IDR	1,012,280,000.00

The total cost to implement combination improvement scenario 2 & 3 in existing condition is IDR 1,012,280,000.00.

Combination Scenario 1, 2 & 3 Improvement Costing

This section will emphasize the costs needed when all the improvement solutions are implemented in the existing condition. The value of cost will be the highest among others since the variables which become inputs are the highest too.

Table 5. 16 Grand total combination scenario 1,2 & 3 costs

Cost type	Total	
Existing condition cost	IDR	679,280,000.00
scenario 1	IDR	24,000,000.00
scenario 2	IDR	306,000,000.00
scenario 3	IDR	15,000,000.00
Grand total	IDR	1,036,280,000.00

In total, the costs needed to apply all improvements are IDR 1,036,280,000.00.

5.2.1.2 Improvement Scenario Selection

After all improvements costs are generated. The selection of chosen scenario that will be proposed as solution is executed. In this section, the defining method use is value engineering. All scenarios will be given certain weight of criteria related to critical factors / causes. The criteria that will be used in improvement selection are:

1. Cycle time

2. Efficiency

The defined criteria are chosen based on indicators of targeted loading rate achievement. Critical indicator will be given higher weight value. This is aimed to give expert consideration in the improvements scenario. The weights givenrepresent how significant the improvement will change either cycle time or efficiency of loading process. The result of weights are given in following points :

1. Cycle time 0.6
2. Efficiency 0.4

The given weight will be used in calculation of value engineering with cost variables that already defined before. Based on the value of weight, expert thinks that the improvements will change cycle time in major. So that it is given higher weigh with 0.6 rating. Theefficiencycriterion is given 0.4 of weightfrom maximum scale of 1.

After all data of improvement costing and expert weight on critical criteria is gathered. The next steps are gathering the preference of workers in the port department. The purpose is to involve the voice of stakeholders for the proposed solutions. The questionnaires given to 4 workers who are considered to be skilled and having good understanding of port activity scope. The score in questionnaire lies on range 1 to 9. The higher value means higher priority for improvement to be implemented. Recapitulation of workers scoring is given in the table 5.17 below.

Table 5. 17 Recapitulation of workers s' scores for improvement scenarios

Scenario	Cycle time				Total	Efficiency				Total
	Weight = 0,6					Weight = 0,4				
	1	2	3	4		1	2	3	4	
0	5	4	6	7	22	6	4	5	6	21
1	8	6	7	6	27	7	6	5	7	25
2	7	7	6	7	27	7	6	5	7	25
3	8	5	5	6	24	5	3	6	8	22
1,2	9	8	6	7	30	8	7	7	8	30
1,3	8	7	7	5	27	7	9	6	5	27
2,3	7	9	4	9	29	9	7	7	8	31
1,2,3	8	7	9	9	33	8	8	7	6	29

The total scores will be used in calculation of value engineering. The formula and example of generating value engineering is given in the formula 5.1 – 5.4. The

Table 5. 18 Value engineering development for each scenario

Scenario (i)	Scenario Content	Weight		Total Weighted Score	Scenario cost (i)	Value (i)
		Cycle time	Efficiency			
		0.6	0.4	Ratio = 31448148.15		
0	0	22	21	21.6	IDR 679,280,000.00	1.0000
1	1	27	25	26.2	IDR 703,280,000.00	1.1716
2	2	27	25	26.2	IDR 997,280,000.00	0.8262
3	3	24	22	23.2	IDR 694,280,000.00	1.0509
4	1,2	30	30	30	IDR 1,021,280,000.00	0.9238
5	1,3	27	27	27	IDR 718,280,000.00	1.1821
6	2,3	29	31	29.8	IDR 1,012,280,000.00	0.9258
7	1,2,3	33	29	31.4	IDR 1,036,280,000.00	0.9529

The calculation of ratio and the value engineering are done using formulas in these following lists:

$$\text{Ratio} = \frac{\text{Cost Scenario (0)}}{\text{Total score Scenario(0)}} \tag{5.1}$$

$$\text{Ratio} = \frac{679280000}{21.6} = 31448148.15 \tag{5.2}$$

$$\text{Value (i)} = \frac{\text{Total score scenario (i)} \times \text{Ratio}}{\text{Cost scenario (i)}} \tag{5.3}$$

Where i = 1,2,3,4,5,6,7

$$\text{Value (5)} = \frac{27 \times 31448148.15}{718{,}280{,}000.0} = 1.1821 \tag{5.4}$$

Scenario 0 is the existing condition that will be the reference to apply the improvement scenarios. The ratio is the product of dividing scenario 0 costs with the total weighted score. Total weighted score itself is the result of multiplying weight of criteria by expert and the score of stakeholders' preference.

The result of ratio will then be used to define value engineering of each scenario. The value is developed by dividing total weighted score of scenario (Total score (i)) with the estimation of scenario cost (scenario cost (i)).

Value engineering developed shows the highest is for implementing combination scenario 1& 3 (Scenario 5) with the value of 1.1821. It means this scenario is the chosen one to be proposed to the company.

The value engineering between scenario 1 and combination scenario 1& 3 (Scenario 5) have very small difference. This is caused by the Port Department have one perspective that commonly the low loading rate is caused by the improper stock allocation between Diswil 1 & Diswil 2 in warehouse 3. This makes the weight for all scenario combination containing scenario 1 also have high total weighted score. In the end the consideration of costs reflect on the resulted value engineering and produced combination scenario 1 & 3 as the selected solution.

5.2.1.3 Selected Improvement Scenario Analysis

Value engineering in previous section is resulting combination scenario 1 & 3 as the selected improvement scenario. This part of research will give an analysis of implementation of scenario in existing condition. It will be checked the impact on cost and berthing duration reduction as the improvement implemented.

The selected scenario will be simulated using previous model with some additional modules related to the improvements. The comparison can be generated to see how the improvements can make the existing condition achievement becomes better.The result of loading duration in existing condition simulation and improvement simulation is given in this following table.

Table 5.19 Result of improvement simulation comparison

Loading rate improvement	586.229
Loading rate existing	518.8621
increasing	13%

Estimation of cost reduction can be gathered by calculating the stevedore cost per unit multiply by the number of loading duration reduced in one month.

The only changing variable is stevedore cost since the trucking cost is based on truck load (quantity) of phonska which achievement per day. So that, whatever the achievement the cost will be the same. The recapitulation of monthly cost is given below.

Table 5.21 Cost scenario 0 when the improvement implemented

Cost type	Unit	Cost/unit	Quantity	Total cost
Stevedore cost	day	IDR 7,400,000.00	66	IDR 488,40,000.00
Truck driver cost	Truck load	IDR 80,000.00	1461	IDR 116,880,000.00
Grand total				IDR 605,280,000.00

As the loading duration is decreasing, the stevedore costs are also reduced. The reduction of stevedore cost is estimated to be subtracted until 10 days from 76. The calculation of cost reduction is given as follow :

Reduction cost = 10days × IDR 7,400,000.000 - improvement cost

= IDR 74.000,000- IDR 39,000,000.00

= IDR 35,000,000.00

Assuming the the number of vessels served per month is the same. the annual cost reduction can reach the amount of IDR 35,000,000.00 x 12 = IDR 420,000,000.00

The loading duration is decreasing due to the increasing of loading rate, the berthing duration also becomes quicker than the existing condition like shown in graph below.

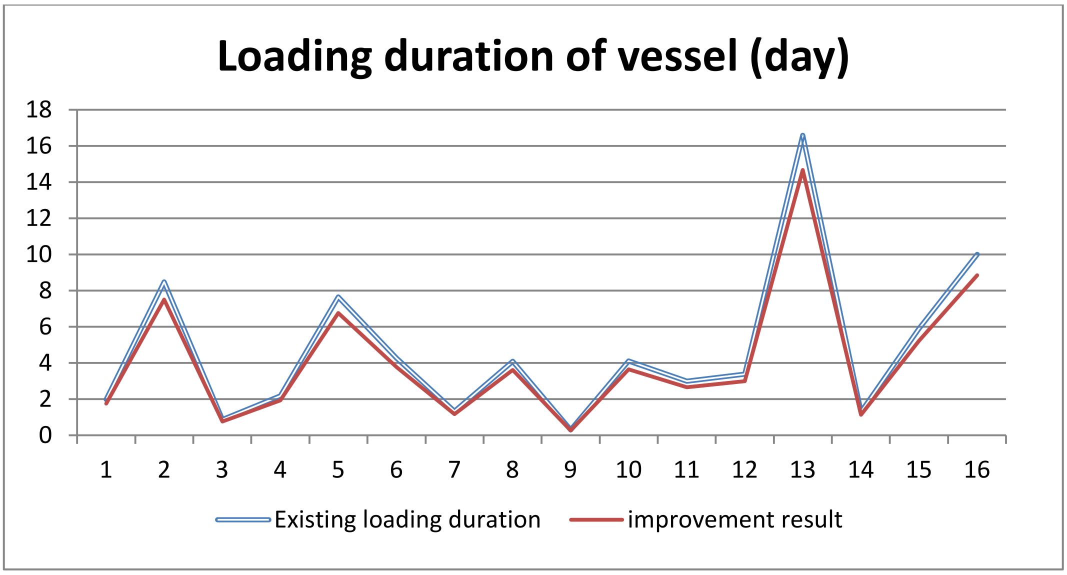


Figure 5.2Loading duration comparison (before - after the improvement is implemented)

5.3 Control Phase

The last phase on DMAIC concept is control phase. In this phase the proposed improvements will be given certain control actions to maintain the performance of improvement itself.

5.3.1 Proposed Control Actionsfor Scenario 1& 3

Control actions in this chapter are only in form of recommendation or proposal. The developed improvements are new aspects that estimated to be appearing in the existing condition. Thus, the control actions are also new for the company.

Table 5. 22 Initial control actionsrecommendation for Supervising Diswil 2 stock in warehouse 3

No	Phase	Activity	Attribute	Related unit
1	Preparation	Check the latest stock quantity	Tonnage of Phonska in-bag stock	Warehouse
		Check the latest status of Diswil 2 vessels in process	Cumulative tonnage loaded	Port department | Surveyor
		Check new arrival of vessels in the port	Number of vessels	Port department | vessel agents
		Make allocation of latest stock	Number of Truck loads	Warehouse
		Check the number of daily input to warehouse	Tonnage of Phonska in bag	Warehouse
2	Execution	Arrange loading assignment for Diswil 2 truck	Truck load	Warehouse | Port Department | surveyor
		Ensure the fertilizers already palletized	Palletized Phonska	Warehouse
		Control the incoming fertilizers from plant is in right proportion for diswil 2 (46%)	Tonnage of Phonska in-bag stock	Warehouse
		Stock shifting from Diswil 2 to Diswil 1 is allowed when the number of vessels in port less than 3	Tonnage of Phonska in-bag stock	Warehouse
3	Pre execution	Write the latest stock of Phonska in bag	Tonnage of Phonska in-bag stock	Warehouse

The second improvement(scenario 3) is for the port to supervise the work of stevedores with additional team leader. The control actions for team leader are given in following table.

Table 5. 23 Initial control actions recommendation for stevedore team leader

No	Phase	Activity	Attribute	Related unit
1	Preparation	Check the latest tonnage loaded	Tonnage of Phonska in-bag loaded	Port department | Surveyor
		Coordination with Port department about loading target	Loading rate	Port department | Surveyor
		Prepare the stevedores	available stevedores assign by PBM	Port department | PBM
		Briefing and allocate stevedore in the each specified job		Stevedores
2	Execution	supervise the work of stevedore		
		Maintain stevedore to be available in effective workhour		
		Keep coordination with port department		Port department
		keep the stevedores work in standard time		
3	Pre execution	Evaluation of stevedore work		Port department | stevedores | PBM

CHAPTER VI
CONCLUSION AND RECOMMENDATION

This chapter contains conclusions that generated as the research result and also recommendation for the next research in the same field. The conclusions are generated to answer the research's objectives that already sated before.

6.1 Conclusion

Conclusions are made as the final statements of research results. The statements are aimed to emphasize what become the purposes of research. After conducting the research, some conclusions resulted to present are :

1. The performance of wastes of loading process for Diswil 2 in PT Petrokimia Gresik's port is dominated by the waiting in warehouse. The simulation result shows a truck has to wait 1.9527 hours before it is served. Another wasted time lies in the port with contribution 1.636 hours waiting time before it is served. Wastes which are appeared both in warehouse and port impact on the daily truck load. This makes loading rate of Diswil 2 has low achievement.
2. Root Cause Analysis for the wastes measured resulting the first cause lies on the warehouse doesn't properly implement proportion of Phonska fertilizers stock as the company stated. The proportion should be 54% for Diswil 1 (land road trucking) and 46% for Diswil 2 (Truck to port). The second root cause is lack of truck service line. Each warehouse only has 1 line service with 2 forklifts to serve the trucks. This condition leads to delay or waiting. The third cause is stevedore has low utilization / low working hour because lack of supervising.
3. Improvements are developed based on the root causes analysis and FMEA results. These improvements are analyzed with value engineering method and resulting the improved sectors are by adding staffs to control the proportion of stocks for Diswil 2, and also by hiring the stevedore team leaders to supervise the work of stevedores.

6.2 Recommendation

The recommendations for other researchers based on the result of research are given as follows:

1. Researcher suggests the possibility of making a feasibility study to build special warehouse for Diswil 2 with consideration of service level, safety stock, ect.
2. Extend the type of fertilizers. This research is only limited for Phonska in-bag. Various types will give broader perspective on the overall loading achievement.

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