FINAL PROJECT – TI 184833

DETERMINATION OF PLASTIC MEMBRANE DEMAND FORECASTING METHOD AND RAW MATERIAL INVENTORY CONTROL POLICY (CASE STUDY: PT. KENCANA TIARA GEMILANG)

MOHAMMAD ALFIAN GHIFFARI
NRP. 02411640000075

SUPERVISOR:
Prof. Dr. Ir. I Nyoman Pujawan, M.Eng., CSCP
NIP. 196901071994121000

DEPARTMENT OF INDUSTRIAL AND SYSTEM ENGINEERING
FACULTY OF INDUSTRIAL TECHNOLOGY AND SYSTEMS ENGINEERING
INSTITUT TEKNOLOGI SEPULUH NOPEMBER
SURABAYA
2020

FINAL PROJECT - TI 184833

DETERMINATION OF PLASTIC MEMBRANE DEMAND FORECASTING METHOD AND RAW MATERIAL INVENTORY CONTROL POLICY (CASE STUDY: PT. KENCANA TIARA GEMILANG)

MOHAMMAD ALFIAN GHIFFARI
NRP. 02411640000075

SUPERVISOR
Prof. Dr. Ir. I Nyoman Pujawan, M.Eng., CSCP
NIP. 196901071994121000

DEPARTMENT OF INDUSTRIAL AND SYSTEM ENGINEERING
FACULTY OF INDUSTRIAL TECHNOLOGY AND SYSTEMS ENGINEERING
INSTITUT TEKNOLOGI SEPULUH NOPEMBER

SURABAYA 2020

APPROVAL SHEET

DETERMINATION OF PLASTIC MEMBRANE DEMAND FORECASTING METHOD AND RAW MATERIAL INVENTORY CONTROL POLICY
(CASE STUDY: PT. KENCANA TIARA GEMILANG)

FINAL PROJECT

Proposed as a Requisite to Graduate in Industrial Engineering Major and to
Achieve a Bachelor Degree in Department of Industrial and System Engineering
Faculty of Industrial Technology and Systems
Institut Teknologi Sepuluh Nopember
Surabaya

Author:

MOHAMMAD ALFIAN GHIFFARI

NRP. 02411640000075

Approved by:

Final Project Supervisor:

Prof. Dr. Ir. I Nyoman Pujawan, M.Eng., CSCP

NIP. 196901071994121000

KEMENTERIAN PENDIDIKAN DAN KEBUDAYAAN
INSTITUT TEKNOLOGI SEPULUH NOPEMBER
FAKULTAS TEKNOLOGI INDUSTRI DAN REKAYASA SISTEM
DEPARTEMEN
TEKNIK SISTEM DAN INDUSTRI

SURABAYA, AUGUST 2020

DETERMINATION OF PLASTIC MEMBRANE DEMAND FORECASTING METHOD AND RAW MATERIAL INVENTORY CONTROL POLICY (CASE STUDY: PT. KENCANA TIARA GEMILANG)

Name : Mohammad Alfian Ghiffari
Department : Industrial and System Engineering
Student ID : 02411640000075
Supervisor : Prof. Dr. Ir. I Nyoman Pujawan, M.Eng., CSCP

ABSTRACT

PT Kencana Tiara Gemilang is a plastic manufacturer which accommodate the needs of agriculture, fisheries, marine, construction, and industrial sectors for plastic membrane. The main products of PT Kencana Tiara Gemilang are Geoprotec Geomembrane, Mulsa (Mulch), and Lembrane. PT Kencana Tiara Gemilang implements make-to-order production system, which means that PT Kencana Tiara Gemilang will start the production planning and production process after customer order receipt is received. The problem faced by PT Kencana Tiara Gemilang is the absence of proper product forecasts and raw material inventory management. Without an accurate forecasting method and a raw material inventory control policy, the company will not be able to estimate the future needs and demand accurately and to prepare the required resource in advance well. This research is focused on determining the proper demand forecasting method to estimate the demand in future period. The forecasting result will be used to compare four inventory control method: (s,Q) system, (s,S) system, (R,S) system, and (R,s,S) system to find the most efficient method. The result is that simple exponential smoothing is chosen as the forecasting method for three products (Mulsa-35-6-440, Mulsa-35-6-220, and PB- 80-3-3), the trend-corrected exponential smoothing is chosen for four products (Geomembrane - 500.6.50, PB-30-99-87, PB-80-7-4, and PB-80-5-4), and the SBA method is chosen for five products (Mulsa-27-6-560, DT - SGP - 30.69, Geomembrane - 300.6.50, Mulsa- 27-5-670, and PB-30-10-11). The selected raw material inventory control policy for Material 1 is the periodic review system (R,s,S) system, for Material 2 is the continuous review system (s,Q) system, for Material 3 is the periodic review system (R,S) system, and for Material 4 and Material 5 is the continuous review system (s,S) system.

Keywords: Continuous review system (s,S), Continuous review system (s,Q), Forecasting, Periodic review system (R,S), Periodic review system (R,s,S)

ACKNOWLEDGEMENT

Alhamdulillahi Robbil Aalamin, praises to Allah SWT, because of His guidance and love, the author was able to finish this Final Project research with the title of “Determination of Plastic Membrane Demand Forecasting Method and Raw Material Inventory Control Policy (Case Study: PT. Kencana Tiara Gemilang)” very well. Within more or less one semester, the author successfully conducted this research as a graduation requirement from Industrial System and Engineering Department of Institut Teknologi Sepuluh Nopember (ITS), Surabaya.

With the completion of this research, the author would like to thank everyone who has provided their support for the author during the process of completing the research. Greatest gratitude for the parties as follows:

1. Author’s beloved parents, Mr. Mohammad Fatir Harijadi and Mrs. Kusnul Khotimah, and siblings, Roisya Nur Farhania and Nabiila Zahra Muthmainnah that provided financial and moral support during the completion of this research.
2. Prof. Dr. Ir. I Nyoman Pujawan, M.Eng., CSCP, as this research supervisor that has given guidance, instructions, evaluation, and motivation during the process of completing this research.
3. Mrs. Eliana as the General Manager of PT. Kencana Tiara Gemilang, that has given the permission to conduct this research on the company.
4. Mrs. Agatha as the Human Resource and General Affair Manager and Mr. Bintoro as the Plant Manager of PT. Kencana Tiara Gemilang, that provided data and guidance during the process of completing this research.
5. Prof. Iwan Vanany, S.T., M.T., Ph.D. and Mrs. Ratna Sari Dewi, S.T., M.T., Ph.D that gave useful insight and evaluation on the research proposal seminar.
6. All lecturers and staffs of Industrial System and Engineering Department of Institut Teknologi Sepuluh Nopermber for the knowledge and guidance during author’s study.

7. All friends and relatives for their support for the author on completing the research.

The author is glad to accept criticism and suggestions from the readers in order to improve the further writings.

Surabaya, July 2020

Mohammad Alfian Ghiffari

TABLE OF CONTENTS

ABSTRACT i

ACKNOWLEDGEMENT iii

TABLE OF CONTENTS v

TABLE OF FIGURES vii

LIST OF TABLES ix

1 CHAPTER I INTRODUCTION 1

1.1 Background 1

1.2 Problem Formulation 3

1.3 Objective of Research 3

1.4 Benefits of Research 3

1.5 Scope of Research 3

1.5.1 Limitation 3

1.5.2 Assumption 3

1.6 Research Outline 4

2 CHAPTER II LITERATURE REVIEW 7

2.1 Inventory 7

2.2 Inventory Costs 8

2.3 Safety Stock 9

2.4 Inventory Control Model 11

2.4.1 Deterministic models 11

2.4.2 Probabilistic models 13

2.5 Forecasting 18

2.6 Previous research 21

3 CHAPTER III RESEARCH METHODOLOGY 23

3.1 System Study 24
3.2 Data Collection 25
3.3 Data Processing 25
3.3.1 Forecasting 25
3.3.2 Raw material requirement calculation 25
3.3.3 Raw material inventory control 25
4 CHAPTER IV DATA COLLECTION AND PROCESSING 27
4.1 Data Collection 27
4.1.1 Product demand 27
4.1.2 Bill of materials 28
4.1.3 Lead time of raw material 30
4.2 Data Processing 30
4.2.1 Forecasting Method Determination 30
4.2.2 Inventory Control Policy Determination 42
5 CHAPTER V ANALYSIS AND INTERPRETATION 59
5.1 Analysis of Forecast Method Selection 59
5.2 Analysis of Inventory Control Policy Determination 61
6 CHAPTER VI CONCLUSION AND RECOMMENDATION 69
6.1 Conclusion 69
6.2 Recommendation 70
REFERENCES 71
APPENDIX 73

TABLE OF FIGURES

Figure 2.1 Safety stock visualization 10
Figure 2.2 Demand and lead time interaction on determining safety stock.......... 10
Figure 2.3 Classical inventory model... 11
Figure 3.1 Research methodology flowchart 23
Figure 4.1 ADI - CV Classification 31
Figure 4.2 2018 - 2019 Geomembrane - 500.6.50 Demand 31

LIST OF TABLES

Table 4.1 Demand of Each Product in 2018 (Kg) ... 27

Table 4.2 Demand of Each Product in 2019 (Kg) ... 28

Table 4.3 Bill of Materials ... 28

Table 4.4 Lead Time of Raw Material ... 30

Table 4.5 ADI – CV Classification and Recommended Forecasting Method ... 33

Table 4.6 Mulsa-35-6-440 Forecast Result Using Simple Exponential Smoothing Method ... 35

Table 4.7 Mulsa-35-6-440 Forecast Result By Using Trend-Corrected Exponential Smoothing Method ... 36

Table 4.8 Mulsa-35-6-440 Forecast Result By Using Croston's Method ... 37

Table 4.10 Mulsa-35-6-440 Forecast Result By Using SBA Method ... 38

Table 4.11 Comparison Of MAD Of Each Forecasting Method ... 39

Table 4.12 Selected Forecasting Method of Each Product ... 40

Table 4.13 Selected Forecasting Method of Each Product (Cont.) ... 41

Table 4.14 Recapitulation Of Material Requirement Of All Products ... 44

Table 4.15 Cost Of Electricity, Administration, And Telecommunication ... 45

Table 4.16 Cost Of Salary ... 45

Table 4.17 Cost Of Asset ... 46

Table 4.18 Total Ordering Cost Per PO ... 46

Table 4.19 Cost Of Electricity, Administration, And Telecommunication ... 46

Table 4.20 Cost of Asset ... 47

Table 4.21 Cost of Rent and Tax ... 47

Table 4.22 Cost of Salary ... 47

Table 4.23 Cost of Equity Components ... 48

Table 4.24 Cost of Debt (After Tax) ... 49

Table 4.25 Raw Material Holding Cost ... 49

Table 4.26 Inventory Control Parameter Of Continuous Review (s,S) System ... 51

Table 4.27 Inventory Control Parameter Of Continuous Review (s,Q) System ... 53

Table 4.28 Inventory Control Parameter Of Periodic Review (R,S) System ... 54

Table 4.29 Of Inventory Control Parameter Of Periodic Review (R,s,S) System 55
Table 4.30 Total Annual Inventory Costs Of Material 1 Using (s,S) System 56
Table 4.31 Total Annual Inventory Costs Of All Materials Using (s,S) System .. 56
Table 4.32 Total Annual Inventory Costs Of Material 1 Using (s,Q) System 57
Table 4.33 Total Annual Inventory Costs Of All Materials Using (s,Q) System.. 57
Table 4.34 Total Annual Inventory Costs Of Material 1 Using (R,S) System...... 57
Table 4.35 Total Annual Inventory Costs Of All Materials Using (R,S) System . 58
Table 4.36 Total Annual Inventory Costs Of Materials 1 Using (R,s,S) System.. 58
Table 4.37 Total Annual Inventory Costs Of All Materials Using (R,s,S) System 58
Table 5.1 Comparison Of MAD of Each Forecasting Method.............................. 60
Table 5.2 Selected Forecasting Method 61
Table 5.3 Total Annual Inventory Costs of (s,S) System, (s,S) System, (R,S) System, and (R,s,S) System.. 62
Table 5.4 Total Annual Inventory Costs of Material 1.. 63
Table 5.5 Total Annual Inventory Costs of Material 2.. 64
Table 5.6 Total Annual Inventory Costs of Material 3... 64
Table 5.7 Total Annual Inventory Costs of Material 4... 65
Table 5.8 Total Annual Inventory Costs of Material 5... 66

CHAPTER I
INTRODUCTION

This chapter explained the background of the study, problem formulation, objectives, benefits and scope, consisting of boundaries and assumptions used in research, and the research report outline.

1.1 Background

Inventory is needed because supply and demand are difficult to be synchronized correctly and takes a long time to do operations related to raw materials (Tersine, 1994). Product availability can reduce the probability of a stockout resulting in a backorder and lost sales. However, excessive inventory results in overstock occurrence which increase the company total inventory costs. Therefore, inventory control is needed to get the right amount of materials in the right place, at the right time, and low cost.

PT Kencana Tiara Gemilang is a plastic manufacturer which accommodate the needs of agriculture, fisheries, marine, construction, and industrial sectors for plastic membrane. The main products of PT Kencana Tiara Gemilang are Geoprotec Geomembrane, Mulsa (Mulch), and Lembrane. Mulsa is mostly used in agricultural sectors as a membrane covering agricultural soil. Mulsa modify the microenvironmental conditions around the vegetable crops and increase the total yield, quality, and early harvest of the crops (Lamont, 2017). Geoprotec Geomembrane is an impermeable membrane used in fisheries, marine, and construction sectors. For the industrial sectors, PT Kencana Tiara Gemilang accommodate the production of custom plastic membrane according to customer's order, such as plastic packaging.

PT Kencana Tiara Gemilang implements make-to-order production system, which means that PT Kencana Tiara Gemilang will start the production planning and production process after customer order receipt is received. This production system is applied to all of its plastic membrane production process. At the beginning, Sales and Marketing Department receive the order from customer and issue the sales order to PPIC Department. PPIC Department then check the availability of materials, machines, and operators to create the production planning, production / work order letter , and target delivery date for Production Department. Under the condition of the unavailability of material, Purchasing Department will hold a purchasing review with the user and purchase the required materials from supplier. In case of a new material is required, Purchasing Department will do supplier selection process before ordering raw material.

In this research, the products being observed are Mulsa (Mulch), Plastic Packaging, and Geomembrane. The materials used in production process consist of Material 1, Material 2, Material 3, Material 4, and Material 5. Mulsa (Mulch) uses Material 2, Material 4, and Material 5. Plastic Packaging uses Material 2 and Material 3. Geomembrane uses Material 1, Material 2, and Material 4. The lead time of Material 1 and Material 2 is 14 days, Material 3 is 7 days, Material 4 is 90 days, and Material 5 is 45 days.

The problem faced by PT Kencana Tiara Gemilang is the absence of proper product forecasts and no raw material inventory control policy. The production planning and material purchasing is started after receiving customer order. In a case of an order that requires short production lead time, there is a possibility of insufficient material for production to occur. In a condition of the insufficient material in inventory, the production process and customer order fulfilment have to be postponed until the material is available, especially when the material lead time is long. The forecasting method used by PT Kencana Tiara Gemilang produce high forecast error with MAD value range of 1,980 – 162,787 and MAPE value range of 21% - 409% per product. Without an accurate forecasting method, the company will not be able to estimate the future needs and demand accurately to prepare the required resource in advance to reduce the lead time.

Current research is focused on determining the proper demand forecasting method to estimate the demand in future period. The forecasting result will be used to compare four inventory control method: (s,Q) system, (s,S) system, (R,S) system, and (R,s,S) system to find the most efficient method.

1.2 Problem Formulation

Based on the background, this research is conducted to find a proper product forecasting method and the most efficient raw material inventory control policy .

1.3 Objective of Research

The objectives to be achieved by this research are:

1. Determining a proper forecasting method for the products.
2. Determining raw material inventory control policy for the company and the total annual inventory cost.

1.4 Benefits of Research

Benefits that would be earned by the end of this research is providing a recommendation for the company on how to improve their business process, especially on their product demand forecasting and raw material inventory management.

1.5 Scope of Research

1.5.1 Limitation

The limitation of this research is as follows:

a. The product of PT Kencana Tiara Gemilang which is used as the research object are Mulsa (Mulch), Plastic Bag, and Geomembrane.
b. The product demand data being used is based on the demand of 2018 to 2019 period.

1.5.2 Assumption

The assumptions of this research is as follows:

a. Sufficient warehouse capacity and funding.
b. Costs related to inventory costs are known and constant.
c. Unit price is constant and not affected by the ordering size.
d. Lead time is constant for every period.
e. Total annual inventory costs calculation did not consider any of capital costs regarding the assets needed to implement the review method.
f. The supplier is reliable and can fulfill all of company's orders.

1.6 Research Outline

CHAPTER I INTRODUCTION

This chapter explained the background of the study, problem formulation, objectives, benefits and scope, consisting of boundaries and assumptions used in research, and the research report outline.

CHAPTER II LITERATURE REVIEW

This chapter explains the theories and concepts that support the research. The theories in this chapter come from various sources literature, namely books, articles, journals, previous research, etc. used as a basis for analyzing and completing the problem in this research.

CHAPTER III RESEARCH METHODOLOGY

This chapter explains about the research methodology that contains steps in conducting research. The steps of this work used as a guide to conduct research systematically.

CHAPTER IV DATA COLLECTION AND PROCESSING

This chapter contains the collection of supporting data and processing data to achieve the desired goals. Data collection is done by direct observation, interviews with parties who stakeholders, and collecting historical data from the company.

CHAPTER V ANALYSIS AND INTERPRETATION OF DATA

This chapter explains the analysis of the collected data and data processing results that has been done in the previous chapter.

CHAPTER VI CONCLUSIONS AND RECOMMENDATIONS

This chapter explains the conclusions and recommendations of this research. Conclusions serve to answer the goals and suggestions for the company as well as for future research.

CHAPTER II
LITERATURE REVIEW

This chapter explains the theories and concepts that support the research. The theories in this chapter come from various sources literature, namely books, articles, journals, previous research, etc. used as a basis for analyzing and completing the problem in this research.

2.1 Inventory

The terms of inventory has several means: the stock of materials on hand at a time, list of all physical assets, used as a verb to determine the on hand item's quantity, and the value of goods on stock at a time (Tersine, 1994). Inventory exists because of the difference of supply and demand which is hard to synchronize. The reasons of supply and demand difference are explained by the following factors:

a. Time factor

   Providing products for customer requires the process of production and distribution. A set amount of time is required to perform those processes, including material procurement, production scheduling, material inspection, production process, and distribution to retailer or customer.

b. Discontinuity factor

   The discontinuity factor allows the parties to treat dependent operations (material purchasing, production, distribution, and retailing) in independent and economical manner by using inventory. The use of inventory permit each of dependent operation operate economically by freeing each operation from the next.

c. Uncertainty factor

   The uncertainty factor includes the error of demand estimates, variable yields of production, equipment breakdowns, and delivery delays which can affect the initial plans of the company. Inventory enables protection from the unanticipated event.

d. Economy factor

Taking advantage of cost-reducing options such as purchasing or producing in economic quantities and stabilize the human resource level.

The types of inventory may consists of supplies, raw materials, in-process goods, and finished goods.

a. Supplies

   Supplies are the items which is not consumed during the production process of finished good but consumed in the normal functioning of the company. Supplies includes paper, pen, ink, and maintenance items.

b. Raw materials

   Raw materials are the items used as an inputs in the production process. Raw materials will be converted into finished goods. Raw materials for a car manufacturing process, for example, includes metal plates, tire, paint, screws, glass, etc.

c. In-process goods

   In-process goods are the partially completed product from raw material conversion that are still need to be processed to be finished goods.

d. Finished goods

   Finished goods are the final product of the entire production process ready to be sold, distributed, or stored.

2.2 Inventory Costs

According to Waters (2003) all kind of stocks will incur costs. There are four types of costs involved.

a. Unit cost

   Unit cost is the price of an item or the cost to acquire one unit of item. Unit cost value is easy to find when the item is purchased from suppliers. On the other hand, unit cost value will be hard to set if the item is produced by the company itself.

b. Reorder cost

Reorder cost is the cost incurred to reorder an item. It means that it is the cost of repeating an order, not a first-time order which may include the cost to select suppliers.

c. Holding cost

Holding cost is the cost of holding an item for a period of time. Holding cost may consist of cost of storage space, cost of capital, loss, handling, administration, and insurance.

d. Shortage cost

Shortage cost may consist of loss of profit from lost sale, cost of shortage counteract, special deliveries, production reschedule, maintenance reschedule, finding alternative suppliers, expensive materials, and finished goods storage.

2.3 Safety Stock

Safety stock is the amount of inventory carried to protect against uncertainty. The uncertainty that may occur can be divided into two ways: quantity and timing uncertainty (Arnold, Chapman, & Clive, 2008). When the amount of demand and supply varies, it is called quantity uncertainty. The timing uncertainty happen when the actual time of supply and demand receipt is different from the planning. Holding additional stocks above the perceived needs is implemented for safety to avoid higher costs of shortage. Safety stock as extra stock for reserve will not normally be used, but it is available when demand higher than company's expectation and deliveries are late (Waters, 2003).

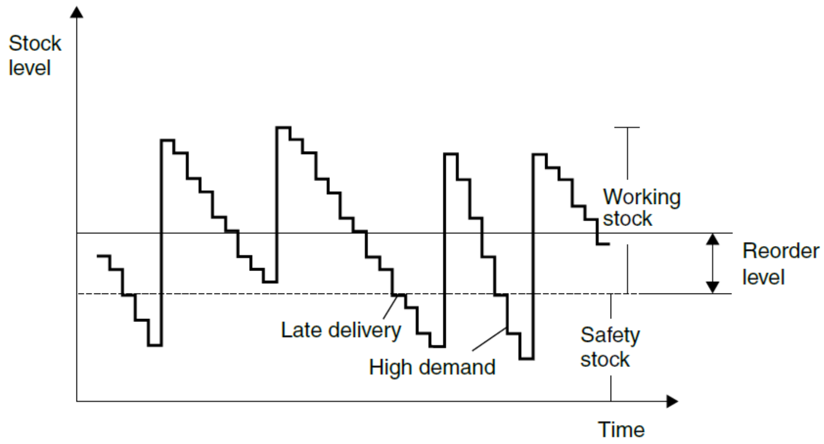

Figure 2.1 Safety stock visualization

(Waters, 2003)

Based on the variability of demand and lead time, there are four condition for determining the quantity of safety stock: constant demand and constant lead time, variable demand and constant lead time, constant demand and variable lead time, and variable demand and variable lead time. The table below will visualize the interaction of demand and lead time variability on determining the safety stock quantity (Pujawan, 2017).

Demand	*Constant* (**Lead Time**)	*Variable* (**Lead Time**)
Variable	$Sdl = sd\times \sqrt{l}$ Safety stock determined by demand uncertainty	$Sdl=\sqrt{(d2\times Sl2)+(l\times Sd2)}$ Safety stock determined by interaction of demand and lead time uncertainty
Constant	Safety stock is not needed sue to deterministic situation	$Sdl=d\times sl$ stock determined by lead time uncertainty

Figure 2.2 Demand and lead time interaction on determining safety stock

2.4 Inventory Control Model

One reason of having inventory is to produce or buy product in economic lot size. This means to find the balance between availability to meet customer demand and so that costs incurred is not excessive. Inventory control models according to Albright, et al (2009) have several categories, namely deterministic models and probabilistic models.

2.4.1 Deterministic models

In deterministic models, especially in fixed order size systems, the demand is assumed to be known and continuous. The quantity of demand and the time between order (lead time) is expected to be constant. Company doesn't need product safety stock since the lead time and demand is constant.

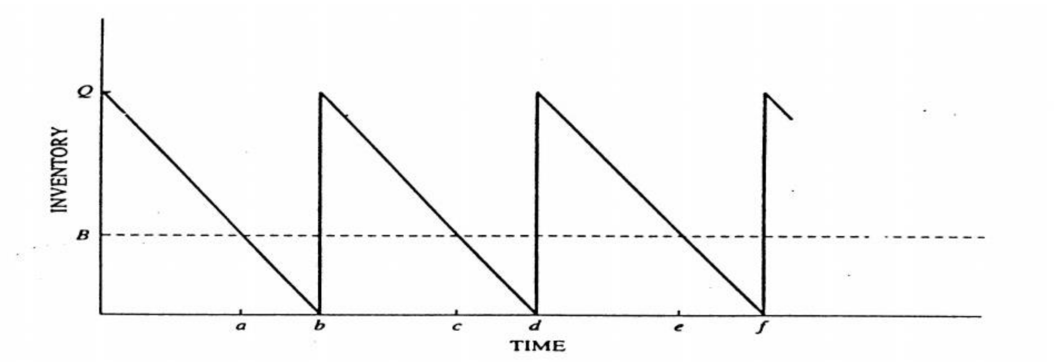

Figure 2.3 Classical inventory model
(Tersine, 1994)

The figure above represents the classical inventory model which assumes the ideal situation where Q is the order size and B is the reorder point. The negative slope represents the unit withdrawal from the inventory. Whenever the inventory reaches reorder point B, an order is placed with the amount of Q units the vertical lines represents the receipt of goods into inventory.

In this model, there are several costs component of the total inventory costs, those are purchase cost, order cost, and holding cost. Below is the formula assuming the time frame of 1 year or annual purchase.

Total cost = purchase cost + order cost + holding cost

$$TC(Q) = PR + \frac{CR}{Q} + \frac{HQ}{2} \tag{2.1}$$

Where:

R = annual demand in units

P = purchase cost of an item

C = ordering cost of an item

H = *PF* = holding cost per unit per year

Q = lot size or order quantity in units

F = annual holding cost as a fraction of unit cost

To obtain the minimum cost of a lot size quantity / economic order quantity (EOQ), take the first derivative of total annual cost with respect of lot size or order quantity and set it equal to zero.

$$\frac{dTC(Q)}{dQ} = \frac{H}{2} - \frac{CR}{Q^2} = 0$$

$$\frac{H}{2} - \frac{CR}{Q^2} = 0$$

$$\frac{H}{2} = \frac{CR}{Q^2}$$

$$Q^* = \sqrt{\frac{2CR}{H}} = \sqrt{\frac{2CR}{PF}} \tag{2.2}$$

The equation above is the formula to find the EOQ known the holding cost per unit per year, demand, and ordering cost.

2.4.2 Probabilistic models

A probabilistic or stochastic control model, is a method that considers all variables to have an uncertain value and one or more of these variables are random numbers. The uncertainty is related to the uncertainty of demand and lead time. Both of these can result in a shortage of inventory (stockout) which has an impact on the service level offered by the company has decreased. To anticipate the lead time, it is necessary to determine the reorder point or reorder point before the item experiences a stockout. As for demand uncertainty, it is necessary to have a safety stock to reduce the possibility of shortage that occurs when the actual demand is greater than the demand during lead time. Probabilistic inventory control model is divided into two parts, continuous review and periodic review

2.4.2.1 Continuous review

In the continuous inventory review policy, inventory control monitoring is carried out continuously. Replenishment process is carried out when the inventory reaches the reorder level or below so that a review of this control policy is based on the quantity of the reorder point (ROP). In addition, in this continuous review policy the value of the maximum inventory level is not determined. The advantage of a continuous review policy is that there is little possibility of a shortage or excess stock because the stock position is always reviewed at any time. However, continuous review can lead to greater employee workloads and less predictable workloads. Therefore, this policy requires technology that can monitor inventory conditions that can reduce costs and review errors. The following methods are used in continuous review:

a. Method (s,Q)

In method (s,Q), if the inventory is below or equal to the reorder point s, an order of Q will be made. This method is often called a two-bin system because there are two storage areas consisting of demand during lead time and safety stock. As long as the unit of inventory remains in the first bin, requests will be fulfilled from that bin. For the amount of inventory in the second bin according to the reorder point. When the second bin is open, replenishment must be done by placing an order. When replenishment comes, the second bin will be full again and the rest is stored in the first bin. This method is simple and easily understood. However, the weakness of this method is that it cannot be modified and is less effective in dealing with large demand transactions because replenishment by Q cannot raise inventory positions above the reorder point. So it is necessary to have a large amount of replenishment to increase the inventory position. The following are formulas for calculating inventory control parameters of method (s,Q) (Smith, 1989).

Step 1. Calculate

$$q = q_w = \sqrt{\frac{2kr}{h}} \tag{2.3}$$

Step 2. Calculate

$$F(K) = \frac{\pi r - hq}{\pi r} \tag{2.4}$$

Step 3. Determine the K value from the safety factor table

Step 4. Calculate

$$N_k = \sigma_L \times E(K) \text{Type equation here.} \tag{2.5}$$

Step 5. Calculate

$$q = \sqrt{\frac{2r(k + \pi N_k)}{h}} \tag{2.6}$$

Step 6. If $|q_{new} - q_{old}| < \varepsilon$, calculate

$$s = \mu + K_{\sigma_L} \tag{2.7}$$

and stop. If not, back to step 2.

Where:

q = order quantity

r = number of demand

k = ordering cost

h = holding cost

π = shortage cost

K = safety factor

σ = demand standard deviation

π = demand average

L = lead time

b. Method (s,S)

Method (s, S) is also known as the min-max, because the inventory position is always between the minimum value of s and the maximum value of S. method (s,S) replenishment time is the same as the method (s, Q), which is done when inventory is below or equal with reorder points s. But what distinguishes from the method (s, Q) comes in terms of quantity replenishment. The quantity of replenishment from this method varies so that the order is sufficient to raise the inventory position to reach level S. If there is demand as much as unit-sized, the order request is made when the inventory position is right at point s with the terms S = s + Q. If the transaction is greater than unit-sized then the number of replenishment varies. This often makes suppliers make mistakes because suppliers prefer to send in fixed and predictable quantities. The following are formulas for calculating inventory control parameters of method (s,S) (Smith, 1989).

$$q = \sqrt{\frac{2kr}{h}} \tag{2.8}$$

$$F_L(K) = \frac{\pi r - hq}{\pi r} \tag{2.9}$$

$$SS = K \times \sigma_L \tag{2.10}$$

$$s = \pi + SS \tag{2.11}$$

$$S = q + s \tag{2.12}$$

Where:

q = order quantity

r = number of demand

k = ordering cost

h = holding cost

π = shortage cost

K = safety factor

σ = demand standard deviation

π = demand average

L = lead time

2.4.2.2 Periodic review

The periodic review inventory policy has the same time interval (T) to carry out the replenishment process for the inventory, however the size of the order varies depending on the condition of the inventory at the end of the period. If there is a shortage of stock before replenishment, then no action can be taken so as to result in shortage. Therefore, to avoid the existence of stockout, a large amount of safety stock is needed. The following are the methods used in the periodic review:

a. Periodic Review, Order-Up-to-Level (R,S) System

This periodic review method can also be called the replenishment cycle system which is commonly used in companies that do not use computer control. The control procedure is carried out every R unit time. The R value has been predetermined so that when an order is made, the inventory position rises to reach level S. This method also provides an opportunity for the company to set the desired order-up-to S level if the demand pattern changes over time. However, one disadvantage of this method is the greater holding cost compared to the continuous review method. The following are formulas for calculating inventory control parameters of method (R,S) (Smith, 1989).

$$t^* = \sqrt{\frac{rk}{rh}} \quad (2.13)$$

$$F_{L+tp} = \frac{\pi - ht_p}{\pi} \quad (2.14)$$

$$S^* = \pi_{L+t_p} + K^*_{\sigma_L+t_p} \quad (2.15)$$

Where:

t^* = order cycle

r = number of demand

k = ordering cost

h = holding cost

π = shortage cost

K = safety factor

σ = demand standard deviation

π = demand average

L = lead time

b. Periodic Review (R, s, S) System

This method is a combination of method (s, S) and method (R, S). For this method, checking the inventory position is done every R units of time. If the stock position is right or below the reorder point, a number of orders are made to raise the inventory position up to level S. However, if the stock position is still above the reorder point, no order is made until the next review. According to Silver (1998), the method (s, S) is a special case for R = 0, and the method (R, S) is a special case for s = S - 1. So this method requires deeper calculations to obtain the best value for the three parameters include the amount of replenishment, carrying cost and shortage cost that are lower than other methods. The following are formulas for calculating inventory control parameters of method (R,s,S) (Smith, 1989).

$$q_w = \sqrt{\frac{2kr}{h}} \quad (2.16)$$

$$F_{L+w}(K) = \frac{\pi r - hq}{\pi r} \quad (2.17)$$

$$SS = K \times \sigma_{L+w} \quad (2.18)$$

$$s = \mu_{L+w} + SS + \frac{rw}{2} \quad (2.19)$$

$$S = q_w + s - \frac{rw}{2} \quad (2.20)$$

Where:

q = order quantity

r = number of demand

k = ordering cost

h = holding cost

π = shortage cost

K = safety factor

σ_L = demand standard deviation during lead time

π = demand average

L = lead time

w = review period

2.5 Forecasting

Forecast is an estimate of conditions in future period and a prelude to planning (Arnold, Chapman, & Clive, 2008). Forecast is used in developing plans to satisfy the future demand. Company need to prepare for resources and equipment to meet customer demand before customer places an order to reduce the lead time.

Forecasting techniques are divided into four types (Chopra & Meindl, 2016).

1. Qualitative

   Qualitative methods rely on human judgement which can be used when only little historical data is available.

2. Time series

   Time series method rely on historical data to do the forecast. This method is under assumption that the historical data is an indicator of future demand / condition.

3. Causal

   Causal method assume that the forecast is highly correlated to certain environmental factor. Finding the environmental factor correlation to demand and estimate which factor will be used to do the forecast.

4. Simulation

   Simulation method can imitate the behavior or pattern of customer demand to estimate customer demand pattern in the future.

   Below are several the forecasting methods:

   1. Simple exponential smoothing

      Simple Exponential Smoothing forecasting method is appropriate to forecast a time series which demand has no observable trend or seasonality (Chopra, 2007). Simple exponential smoothing forecast calculation is started by calculating the initial estimate of level L_0 by using the following formula:

$$L_0 = \frac{1}{n}\sum_{i=1}^{n} D_i \qquad (2.21)$$

After the calculation of initial estimate of level, the calculation of estimate of level is revised to the following formula:

$$L_{t+1} = \alpha D_{t+1} + (1 - \alpha)L_t \qquad (2.22)$$

The forecast for all future period is equal to the current estimate of level which is expressed by the following formula

$$F_{t+1} = L_t \qquad (2.23)$$

and

$$F_{t+n} = L_t \qquad (2.24)$$

2. Trend-corrected exponential smoothing

   The trend-corrected exponential smoothing forecasting method is appropriate to forecast time series which demand is assumed to have a level and trend components in its systematic components (Chopra, 2007). Trend-corrected Exponential Smoothing Forecast is started by determining the value of initial estimate of level L_0 and initial estimate of trend T_0 by running a linear regression of the demand data. Initial estimate of level L_0 can be identified by the value of intercept and initial estimate of trend T_0 can be identified by using the value of slope. After the calculation of initial estimate of level and initial estimate of trend, the calculation of estimate of level L_t and trend T_t is revised to the following formula:

$$L_{t+1} = \alpha D_{t+1} + (1-\alpha)(L_t + T_t) \quad (2.25)$$

$$T_{t+1} = \beta(L_{t+1} - L_t) + (1-\beta)T_t \quad (2.26)$$

   The forecast for all future period is expressed by the following formula:

$$F_{t+1} = L_t + T_t \quad (2.27)$$

and

$$F_{t+n} = L_t + nT_t \quad (2.28)$$

3. Croston’s method

   Croston's method can be useful with intermittent, erratic, an slow-moving demand and its use is significantly superior to exponential smoothing (Pham, 2006). Croston’s method for forecasting started by inputting the demand value as Z_t and demand inter-arrival time as P_t which will be used to calculate the value of demand approximation Z'_t and demand inter-arrival time P'_t according to the rules below.

   If $D_t > 0$, then:

$$Z'_t = \alpha Z_t + (1-\alpha)Z'_{t-1} \quad (2.29)$$

$$P'_t = P'_{t-1} \quad (2.30)$$

If $D_t = 0$, then:

$$Z'_t = Z'_{t-1} \quad (2.31)$$

$$P'_t = \alpha P_t + (1-\alpha)P'_{t-1} \quad (2.32)$$

Then calculate the demand approximation D'_t by using the following formula.

$$D'_t = \frac{Z'_t}{P'_t} \quad (2.33)$$

4. Synthetos-Boylan approximation method

   Synthetos-Boylan approximation method is the development of Croston's method. The forecasting is started by inputting the demand value as Z_t and demand inter-arrival time as P_t which will be used to calculate the value of demand approximation Z'_t and demand inter-arrival time P'_t with the same formula as the Croston's method calculation. Then calculate the demand approximation D'_t by using the following formula.

$$D'_t = (1 - \frac{\alpha}{2})\frac{Z'_t}{P'_t} \quad (2.34)$$

2.6 Previous research

There are several researches conducted under the topic of inventory management or inventory control. A research by Qurrotul Ayuni Aini (2016) under the title *"Pengendalian Persediaan Bahan Baku Pupuk Bersubsidi Di Pt Petrokimia Gresik"* compared four inventory control method of (s,Q) method, (s,S) method, (R,S) method, and (R,s,S) method to find the most efficient method to be implemented on the raw material inventory control policy of PT Petrokimia Gresik.

A research by Made Gilang Sedayu B. S. (2019) under the title "*Inventory Management Analysis of Fast-Moving Consumer Goods at Stockpoint: Case Study* *on Distribution Company"* built an improvement method on inventory control using continuous review (s,S) method to increase the service level as well as maintaining low total cost of the distribution company.

A research by Imro'atun Nurul Azizah (2017) under the title *"Kebijakan Pengendalian Persediaan Bahan Baku Obat Nyamuk Bakar Berupa Tepung Dan Material Packaging (Studi Kasus: Pt X)"* compared four inventory control method of (s,Q) method, (s,S) method, (R,S) method, and (R,s,S) method to find an inventory control method with the lowest inventory costs to be implemented on the anti-mosquito powder and packaging material.

CHAPTER III
RESEARCH METHODOLOGY

This chapter explains about the research methodology that contains steps in conducting research. The steps of this work used as a guide to conduct research systematically. This research consists of several stages including system study stage, data collection and data processing stage, analysis and interpretation of data phase, and conclusion and recommendation. The following figure is the flowchart of the research methodology.

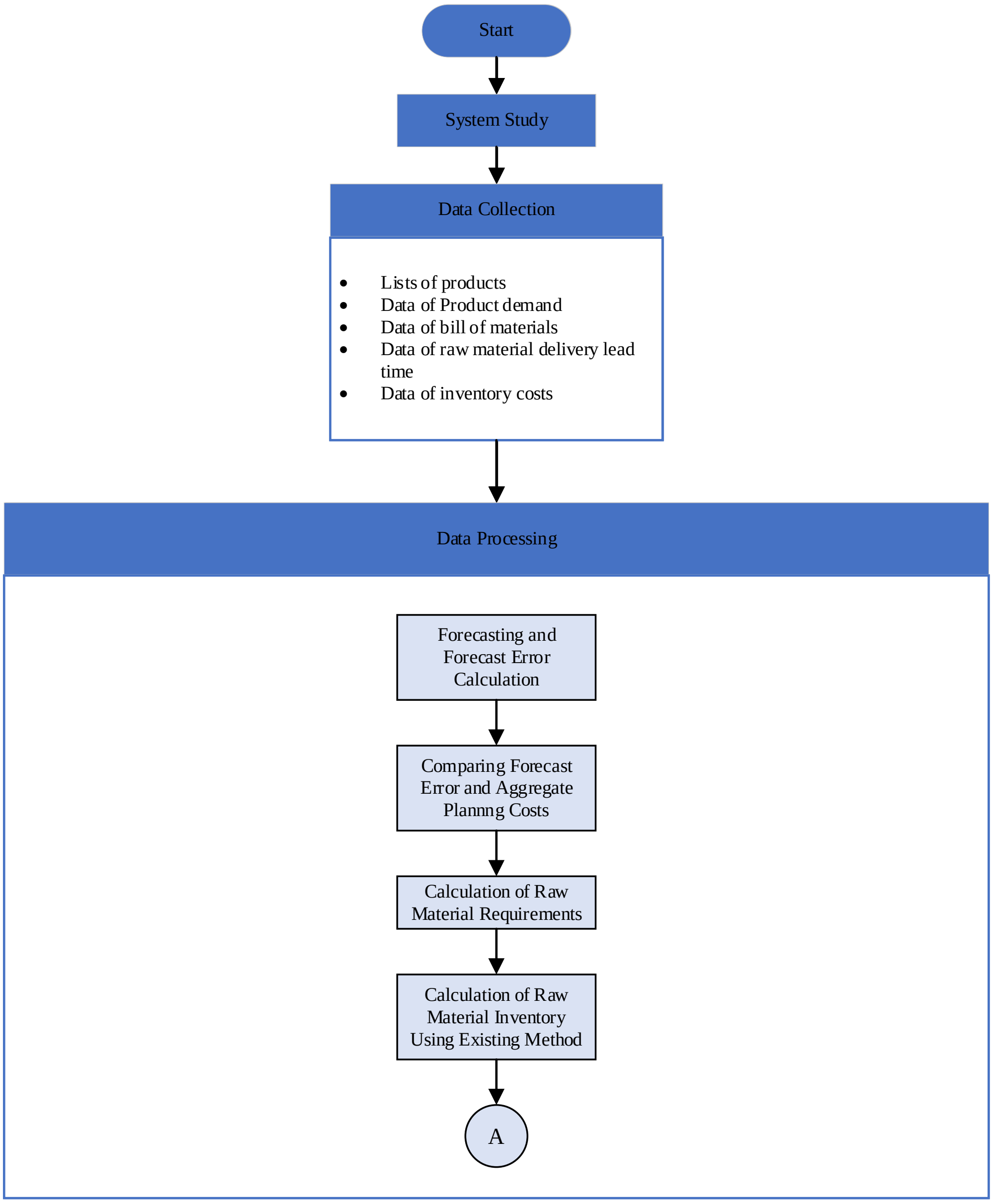

Figure 3.1 Research methodology flowchart

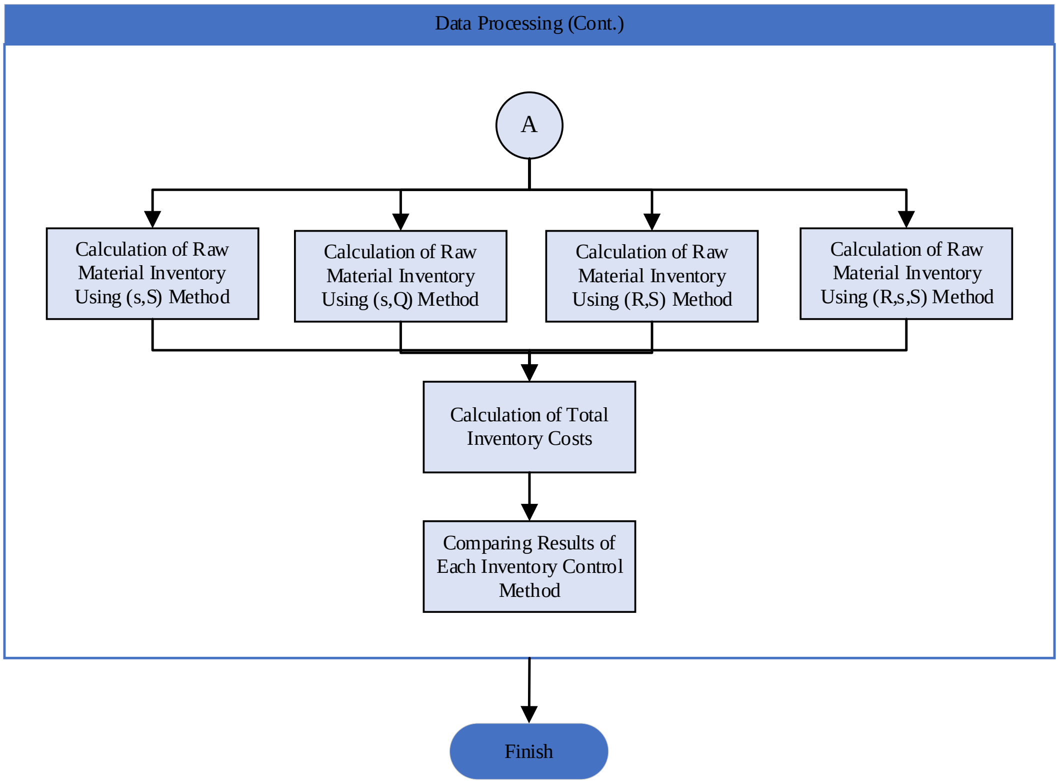

Figure 3.1 Research methodology flowchart (cont.)

3.1 System Study

The system study stage include literature study, field studies, identification and formulation of the problem, setting research objectives and setting scope research. Literature studies are used to understand concepts, theories and methods related to the problem and research objectives. In this literature study too see research before the same type that can also be used reference in research. While the field study is done by taking data from PT Kencana Tiara Gemilang, Malang.

Problem identification is done by direct observation on research object office by looking at related data and interviews with the employees. The objective of the research are finding a better inventory policy for the products, comparing the inventory cost that earned between current company method and improvement method, and finding a proper forecasts for the products to develop material requirement planning and cost estimation of the next production period.

3.2 Data Collection

In this stage, the data required to complete the research is collected. The following are the data needed to complete the research.

a. Lists of product of PT Kencana Tiara Gemilang
b. Data of product demand
c. Data of bill of material
d. Data of raw material delivery lead time
e. Data of inventory costs

3.3 Data Processing

Data processing stage consists of raw material requirement calculation, raw material inventory control, forecasting, and total inventory costs calculation.

3.3.1 Forecasting

Forecasting section is done by estimating demand for the next period using several forecasting period. The selection of forecasting method recommended to be used by the company to estimate future demand for each product is done by comparing the forecasting error value and the effect of forecasting result to the costs related to aggregate planning of the respective product.

3.3.2 Raw material requirement calculation

The calculation of raw material requirement requires the data of product types, demand, and bill of materials. The amount of raw material required to produce the product for a period of time is calculated based on the material composition of the product.

3.3.3 Raw material inventory control

This raw material inventory control section contains the calculation of inventory control parameters including order quantity, order period, minimum inventory, and maximum inventory for current inventory control method implemented by company and four inventory control method: (s,Q) method, (s,S) method, (R,S) method, and (R,s,S) method. The result of calculation is used as the input of material requirement planning for each method and each material that will be used to calculate the total inventory cost for each method. The most efficient inventory control method in term of total inventory cost will be chosen as recommended method for the company.

CHAPTER IV
DATA COLLECTION AND PROCESSING

This chapter will explain about the data collection and data processing stage. The data collected consists of demand data of twelve observed products for the past two years, bill of materials, and inventory cost components. The results of data processing will be explained in the next chapter, namely the analysis and interpretation chapter.

4.1 Data Collection

The data collection sub-chapter contains the collection of data required for this research. The data required consists of data of product demand for the past 2 years, data of bill of material, and data of raw material delivery lead time.

4.1.1 Product demand

PT Kencana Tiara Gemilang is a plastic manufacturer which accommodate the needs of agriculture, fisheries, marine, construction, and industrial sectors for plastic membrane. The main products are Mulsa which is used in agriculture sector, geomembrane which is used in fisheries and construction sector, and plastic bag which is needed by several industries as product packaging. Below are the demand of each product for the past two years, 2018 - 2019:

Table 4.1 Demand of Each Product in 2018 (Kg)

No	Product	2018				
		Jan	Feb	...	Nov	Dec
1	DT - SGP - 30.69	24,211.00	62,924.00	…	6,750.80	9,197.10
2	Geomembrane - 300.6.50	16,204.00	36,005.60	…	20,265.00	20,265.00
3	Geomembrane - 500.6.50	13,844.00	57,870.50	…	12,409.00	7,907.00
4	Mulsa- 27-5-670	1,719.00	1,290.20	…	11,237.00	9,792.80
5	Mulsa-27-6-560	3,117.70	6,302.20	…	6,897.60	6,967.40
6	Mulsa-35-6-220	980.00	1,175.60	…	3,790.50	4,016.10
7	Mulsa-35-6-440	3,725.60	66,993.60	…	1,794.60	18,601.00
8	PB- 80-3-3	4,196.20	0.00	…	0.00	0.00
9	PB-80-5-4	0.00	0.00	…	0.00	0.00
10	PB-80-7-4	5,598.90	0.00	…	0.00	0.00
11	PB-30-10-11	3,976.40	3,922.10	…	1,970.75	1,970.75

Table 4.1 Demand of Each Product in 2018 (Kg) (Cont.)

No	Product	2018				
		Jan	Feb	...	Nov	Dec
12	PB-30-99-87	4,148.20	4,278.00	…	7,099.60	1,455.60

Table 4.2 Demand of Each Product in 2019 (Kg)

No	Product	2019				
		Jan	Feb	...	Nov	Dec
1	DT - SGP - 30.69	4,870.40	14,182.60	…	8,625.00	1,875.00
2	Geomembrane - 300.6.50	15,943.00	0.00	…	12,125.70	13,842.70
3	Geomembrane - 500.6.50	3,345.00	0.00	…	21,327.10	0.00
4	Mulsa- 27-5-670	5,281.20	7,961.60	…	5,944.40	5,096.60
5	Mulsa-27-6-560	5,601.00	48,301.80	…	12,204.40	4,859.00
6	Mulsa-35-6-220	3,613.60	5,219.60	…	3,511.80	3,172.60
7	Mulsa-35-6-440	10,031.00	21,228.00	…	9,132.60	3,632.00
8	PB- 80-3-3	2,092.70	2,165.00	…	1,671.50	1,622.10
9	PB-80-5-4	2,060.20	3,286.10	…	2,705.20	2,507.70
10	PB-80-7-4	4,240.90	0.00	…	0.00	2,084.20
11	PB-30-10-11	989.50	726.40	…	1,147.40	4,222.40
12	PB-30-99-87	1,452.20	6,342.10	…	2,448.10	5,491.90

4.1.2 Bill of materials

There are five materials that is used in the process of manufacturing all of twelve products of PT Kencana Tiara Gemilang. Those materials are named Material 1, Material 2, Material 3, Material 4, and Material 5. This section contains the bill of material for each of the twelve product.

Table 4.3 Bill of Materials

No	Product	Mass / SKU (Kg)	Composition Percentage (%)
1	DT - SGP - 30.69	14.96	
1.1	*Material 2*		90%
1.2	*Material 3*		5%
2	Geomembrane - 300.6.50	84.6	
2.1	*Material 1*		50%

Table 4.3 Bill of Materials (Cont.)

No	**Product**	**Mass / SKU (Kg)**	**Composition Percentage (%)**
2.2	*Material 2*		44%
2.3	*Material 4*		6%
3	Geomembrane - 500.6.50	141	
3.1	*Material 1*		50%
3.2	*Material 2*		44%
3.3	*Material 4*		6%
4	Mulsa- 27-5-670	17	
4.1	*Material 2*		90%
4.2	*Material 4*		6.50%
4.3	*Material 5*		3.50%
5	Mulsa-27-6-560	17	
5.1	*Material 2*		90%
5.2	*Material 4*		6.50%
5.3	*Material 5*		3.50%
6	Mulsa-35-6-220	8.50	
6.1	*Material 2*		90%
6.2	*Material 4*		6.50%
6.3	*Material 5*		3.50%
7	Mulsa-35-6-440	17.00	
7.1	*Material 2*		90%
7.2	*Material 4*		6.50%
7.3	*Material 5*		3.50%
8	PB- 80-3-3	21.2	
8.1	*Material 2*		90%
8.2	*Material 3*		5%
9	PB-80-5-4	20.61	
9.1	*Material 2*		90%
9.2	*Material 3*		5%
10	PB-80-7-4	20.61	
10.1	*Material 2*		90%
10.2	*Material 3*		5%
11	PB-30-10-11	14.93	
11.1	*Material 2*		90%
11.2	*Material 3*		5%
12	PB-30-99-87	14.91	
12.1	*Material 2*		90%
12.2	*Material 3*		5%

It can be seen from the bill of material table above, the product from the geomembrane product family composed of three materials, Material 1, Material 2, and Material 4, the product from Mulsa product family composed of three materials, Material 2, Material 4, and Material 5, while the product from B2B family such as PB and DT composed of two materials, Material 2 and Material 3.

4.1.3 Lead time of raw material

Raw material lead time data is collected from Purchasing and PPIC Department of PT Kencana Tiara Gemilang. Below are the lead time of each material of plastic membrane.

Table 4.4 Lead Time of Raw Material

No	Material	Lead Time (Days)
1	Material 1	14
2	Material 2	14
3	Material 3	7
4	Material 4	90
5	Material 5	45

4.2 Data Processing

This sub-chapter contains the data processing of the data from previous sub-chapter. The data processing process consists of product classification, determination of forecasting method, and determination of raw material inventory control policy.

4.2.1 Forecasting Method Determination

This section will provide the calculation and determination of forecasting method for each product. The forecasting method will be chosen based on the forecast accuracy.

4.2.1.1 Selection of forecasting method

Product classification is done to all twelve observed product of PT Kencana Tiara Gemilang. ADI – CV method is chosen as the product classification method to determine the demand characteristics and which forecasting method to be used. Each demand will be classified into four classification, smooth, lumpy, erratic, and intermittent. Each product classification has its own recommended forecasting method which suited the demand characteristics (Pham, 2006). ADI – CV classification process start with the calculation of Average inter-Demand Interval (ADI) by using the corresponding formula. After the calculation of ADI is done, the Coefficient of Variation (CV) is then calculated. By using the calculated value of ADI and CV of each product, the product will be classified based on the ADI – CV criteria range into the four classification. Below is the criteria range of each classification (Pham, 2006).

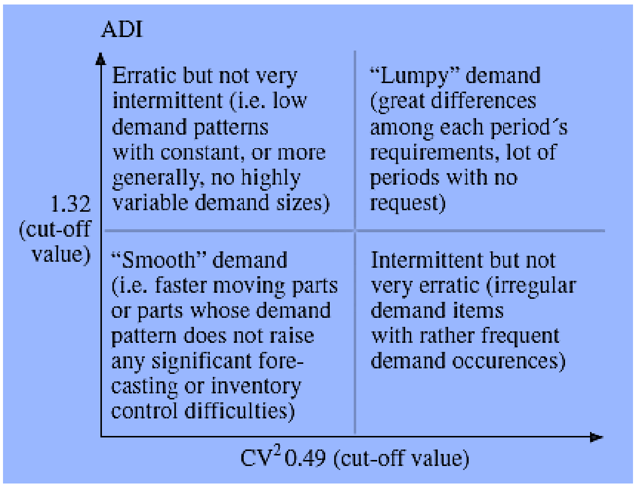

Figure 4.1 ADI - CV Classification

One example of product demand which classified into erratic demand is *Geomembrane - 500.6.50.* Below is the 2018 – 2019 demand graph of *Geomembrane - 500.6.50*:

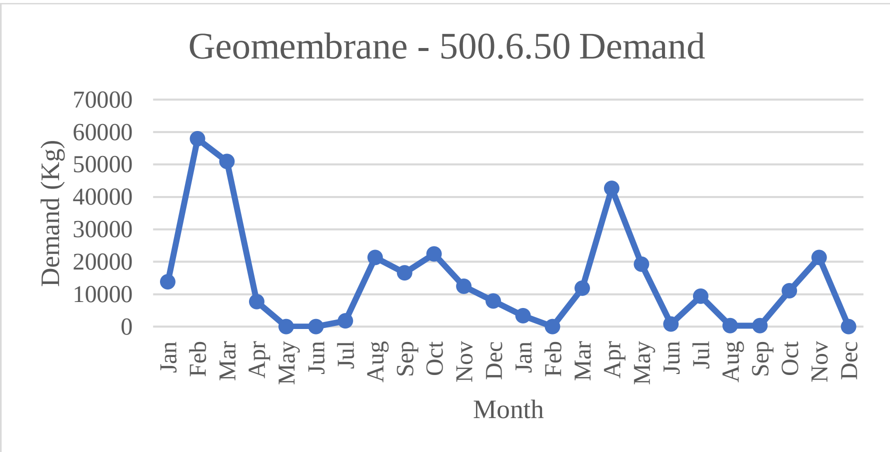

Figure 4.2 2018 - 2019 Geomembrane - 500.6.50 Demand

Based on the demand data of *Geomembrane - 500.6.50* for the past two years, below is the calculation of ADI and CV value of *Geomembrane - 500.6.50.*

$$ADI = \frac{Summation\ of\ the\ intervals\ between\ non-zero\ demand\ periods}{Number\ of\ non-zero\ demand\ periods} \tag{4.1}$$

$$ADI = \frac{22}{19}$$

$$ADI = 1.16$$

$$CV = \frac{Standard\ deviation\ of\ demand}{Average\ value\ of\ demand} \tag{4.2}$$

$$CV = \frac{15860.678}{13868.50}$$

$$CV = 1.14$$

$$CV^2 = 1.31$$

Based on the ADI, CV, and CV^2 of *Geomembrane - 500.6.50*, the product demand is classified as erratic demand. According to (Pham, 2006), the recommended forecasting method to forecast this type of demand is exponential smoothing and Croston forecasting method. Below are the ADI – CV classification and recommended forecasting method of the other product.

Table 4.5 ADI – CV Classification and Recommended Forecasting Method

No	Product	ADI	CV	CV^2	ADI CV Classification	Forecasting Method (Pham, 2006)
1	Mulsa-35-6-440	1.05	1.17	1.37	Erratic	Exponential Smoothing, Croston
2	Mulsa-27-6-560	1.00	1.25	1.57	Erratic	Exponential Smoothing, Croston
3	Geomembrane - 500.6.50	1.16	1.35	1.81	Erratic	Exponential Smoothing, Croston
4	DT - SGP - 30.69	1.00	1.38	1.90	Erratic	Exponential Smoothing, Croston
5	Geomembrane - 300.6.50	1.35	1.13	1.28	Lumpy	Exponential Smoothing, Croston
6	Mulsa- 27-5-670	1.00	1.27	1.60	Erratic	Exponential Smoothing, Croston
7	Mulsa-35-6-220	1.05	1.20	1.44	Erratic	Exponential Smoothing, Croston
8	PB-30-99-87	1.00	1.26	1.58	Erratic	Exponential Smoothing, Croston
9	PB-80-7-4	1.53	1.27	1.62	Lumpy	Exponential Smoothing, Croston
10	PB-80-5-4	1.50	1.10	1.21	Lumpy	Exponential Smoothing, Croston
11	PB-30-10-11	1.10	1.21	1.45	Erratic	Exponential Smoothing, Croston
12	PB- 80-3-3	1.53	1.21	1.46	Lumpy	Exponential Smoothing, Croston

According to the table above, there are eight products which have erratic demand pattern and four products with lumpy demand pattern. Both of the demand pattern can be forecasted by using the exponential smoothing and Croston forecasting method.

4.2.1.2 Simple Exponential Smoothing Forecast

Simple exponential smoothing forecast calculation is started by calculating the initial estimate of level L_0. After the calculation of initial estimate of level, the calculation of estimate of level is revised. The forecast for all future period is equal to the current estimate of level. Below is an example of forecast calculation for product *Mulsa-35-6-440:*

1. Calculation of initial estimate of level.

$$L_0 = \frac{1}{n}\sum_{i=1}^{n} D_i$$

$$L_0 = \frac{1}{24}\sum_{i=1}^{24} D_i$$

$$L_0 = 24{,}989.76$$

2. Calculation of estimate of level for the first period with the assumption of $\alpha = 0.1$.

$$L_{t+1} = \alpha D_{t+1} + (1-\alpha)L_t$$

$$L_{0+1} = \alpha D_{0+1} + (1-\alpha)L_0$$

$$L_1 = 0.1 \times 3{,}725.60 + (1-0.1) \times 24{,}989.76$$

$$L_1 = 22{,}863.35$$

3. Calculation of future period demand of first period

$$F_{t+1} = L_t$$

$$F_{0+1} = L_1$$

$$F_1 = 22{,}863.35$$

After the calculation is done for all of the demand period, the forecast error is calculated as the input for calculating the MAD. In product *Mulsa-35-6-440* forecast case with of $\alpha = 0.1$., the calculated MAD value is 19,401.38. Below is the product *Mulsa-35-6-440* forecast result by using simple exponential smoothing method with $\alpha = 0.1$.

Table 4.6 Mulsa-35-6-440 Forecast Result Using Simple Exponential Smoothing Method

Month	**Actual (Kg)**	**Level**	**Forecast (Kg)**	**Error**	**Absolute Error**
		24,989.76			
1	3,725.60	22,863.35	24,989.76	(21,264.16)	21,264.16
2	66,993.60	27,276.37	22,863.35	44,130.25	44,130.25
3	76,460.60	32,194.79	27,276.37	49,184.23	49,184.23
…	…	…	…	…	…
23	9,132.60	16,171.22	16,953.28	(7,820.68)	7,820.68
24	3,632.00	14,917.29	16,171.22	(12,539.22)	12,539.22

4.2.1.3 Trend-corrected Exponential Smoothing Forecast

Trend-corrected Exponential Smoothing Forecast is started by determining the value of initial estimate of level L_0 and initial estimate of trend T_0 by running a linear regression of the demand data. Initial estimate of level L_0 can be identified by the value of intercept and initial estimate of trend T_0 can be identified by using the value of slope. After the calculation of initial estimate of level and initial estimate of trend, the calculation of estimate of level $L_t$and trend T_t is revised. The calculate the forecast for all future period. Below is an example of forecast calculation for product *Mulsa-35-6-440:*

1. By applying linear regression on demand data, the value of initial estimate of level L_0 can be identified by the value of intercept and initial estimate of trend T_0 can be identified by using the value of slope, which are:

$$L_0 = 57{,}444.46$$
$$T_0 = -2{,}596.38$$

2. Calculation of estimate of level and for the first period with the assumption of $\alpha = 0.1$ and $\beta = 0.1$

$$L_{t+1} = \alpha D_{t+1} + (1-\alpha)(L_t + T_t)$$
$$L_{0+1} = 0.1 \times 3{,}725.60 + (1-0.1)(57{,}444.46 + (-2{,}596.38))$$
$$L_1 = 49{,}735.84$$

$$T_{t+1} = \beta(L_{t+1} - L_t) + (1 - \beta)T_t$$

$$T_1 = 0.1\,(49{,}735.84 - 57{,}444.46) + (1 - 0.1) + (-2{,}596.38)$$

$$T_1 = -3{,}107.60$$

3. Calculation of future period demand of first period

$$F_{t+1} = L_t + T_t$$

$$F_1 = 49{,}735.84 + (-3{,}107.60)$$

$$F_1 = 54{,}848.09$$

After the calculation is done for all of the demand period, the forecast error is calculated as the input for calculating the MAD. In product *Mulsa-35-6-440* forecast case with of $\alpha = 0.1$ and $\beta = 0.1$, the calculated MAD value is 13,045.27. Below is the product *Mulsa-35-6-440* forecast result by using trend-corrected exponential smoothing method with $\alpha = 0.1$ and $\beta = 0.1$.

Table 4.7 Mulsa-35-6-440 Forecast Result By Using Trend-Corrected Exponential Smoothing Method

Month	Actual (Kg)	Level	Trend	Forecast (Kg)	Error	Abs. Error
		57,444.46	-2,596.38			
1	3,725.60	49,735.84	-3,107.60	54,848.09	-51,122.49	51,122.49
2	66,993.60	48,664.77	-2,903.95	46,628.24	20,365.36	20,365.36
3	76,460.60	48,830.80	-2,596.95	45,760.83	30,699.77	30,699.77
…	…	…	…	…	…	…
23	9,132.60	-3,638.69	-2,586.09	-5,057.72	14,190.32	14,190.32
24	3,632.00	-5,239.10	-2,487.52	-6,224.78	9,856.78	9,856.78

4.2.1.4 Croston's Method

Croston's method for forecasting started by inputting the demand value as Z_t and demand inter-arrival time as $P_t$which will be used to calculate the value of demand approximation Z'_t and demand inter-arrival time P'_t. Then calculate the demand approximation D'_t. Below is an example of forecast calculation for product *Mulsa-35-6-440* for period 2*:*

1. Since $D_2 > 0$, then:

$$Z'_2 = \alpha Z_2 + (1-\alpha)Z'_1$$

$$Z'_2 = 0.1 \times 66{,}993.60 + (1-0.1)\ 3{,}353.04$$

$$Z'_2 = 3{,}390.30$$

and

$$P'_2 = P'_1$$
$$P'_2 = 1.00$$

2. Calculate the demand approximation for period 2:

$$D'_t = \frac{Z'_t}{P'_t}$$

$$D'_t = \frac{3{,}390.30}{1.00}$$

$$D'_t = 3{,}390.30$$

After the calculation is done for all of the demand period, the forecast error is calculated as the input for calculating the MAD. In product *Mulsa-35-6-440* forecast case with of $\alpha = 0.1$, the calculated MAD value is 19,719.52. Below is the product *Mulsa-35-6-440* forecast result by using Croston's method with $\alpha = 0.1$.

Table 4.8 Mulsa-35-6-440 Forecast Result By Using Croston's Method

Month	Zt	Pt	Z't	P't	D't	Error	Absolute Error
0			3,725.60	1.00			
1	3,725.60	1.00	3,353.04	1.00	3,353.04	372.56	372.56
2	66,993.60	1.00	3,390.30	1.00	3,390.30	63,603.30	63,603.30
3	76,460.60	1.00	9,750.63	1.00	9,750.63	66,709.97	66,709.97
…	…	…	…	…	…	…	…
23	9,132.60	1.00	15,541.95	1.00	15,541.95	-6,409.35	6,409.35
24	3,632.00	1.00	14,901.02	1.00	14,901.02	-11,269.02	11,269.02

4.2.1.5 Synthetos-Boylan Approximation Method

Synthetos-Boylan approximation method is the development of Croston's method. The forecasting is started by inputting the demand value as Z_t and demand inter-arrival time as P_t which will be used to calculate the value of demand approximation Z'_t and demand inter-arrival time P'_t. Then calculate the demand approximation D'_t. Below is an example of forecast calculation for product *Mulsa-35-6-440* for period 2*:*

1. Since $D_2 > 0$, then:

$$Z'_2 = \alpha Z_2 + (1-\alpha)Z'_1$$

$$Z'_2 = 0.1 \times 66{,}993.60 + (1-0.1)\ 3{,}353.04$$

$$Z'_2 = 3{,}390.30$$

and

$$P'_2 = P'_1$$
$$P'_2 = 1.00$$

2. Calculate the demand approximation for period 2:

$$D'_t = (1-\frac{\alpha}{2})\frac{Z'_t}{P'_t}$$

$$D'_t = (1-\frac{0.1}{2})\frac{3{,}390.30}{1.00}$$

$$D'_t = 3{,}220.78$$

After the calculation is done for all of the demand period, the forecast error is calculated as the input for calculating the MAD. In product *Mulsa-35-6-440* forecast case with of $\alpha = 0.1$, the calculated MAD value is 19,306.70. Below is the product *Mulsa-35-6-440* forecast result by using SBA method with $\alpha = 0.1$.

Table 4.9 Mulsa-35-6-440 Forecast Result By Using SBA Method

Month	Zt	Pt	Z't	P't	D't	Error	Absolute Error
0			3,725.60	1.00			
1	3,725.60	1.00	3,353.04	1.00	3,185.39	540.21	540.21
2	66,993.60	1.00	3,390.30	1.00	3,220.78	63,772.82	63,772.82
3	76,460.60	1.00	9,750.63	1.00	9,263.10	67,197.50	67,197.50
…	…	…	…	…	…	…	…
23	9,132.60	1.00	15,541.95	1.00	14,764.86	-5,632.26	5,632.26
24	3,632.00	1.00	14,901.02	1.00	14,155.97	-10,523.97	10,523.97

4.2.1.6 Comparison of forecasting results

Based on the calculation result of demand forecasting and error rate using several forecasting methods in the previous sections, the selection of the best method with the smallest error rate is done in this section. The process of selecting the method to be chosen as forecasting method recommendation is done by comparing the value of MAD of each forecasting method and the resulting costs on aggregate planning. Below is the comparison of MAD of each forecasting method for all of the observed products.

Table 4.10 Comparison Of MAD Of Each Forecasting Method

No	Products	Simpe ES	Trend-corrected ES	Croston's	SBA
		MAD	MAD	MAD	MAD
1	Mulsa-35-6-440	10,808.53	13,477.46	10,205.33	11,205.31
2	Mulsa-27-6-560	14,335.78	14,417.58	13,902.25	12,161.09
3	Geomembrane - 500.6.50	12,464.49	12,319.02	13,712.15	13,161.90
4	DT - SGP - 30.69	10,064.42	9,998.62	9,989.92	9,844.21
5	Geomembrane - 300.6.50	6,157.61	8,472.36	8,091.63	7,540.84
6	Mulsa- 27-5-670	2,775.05	2,916.12	2,580.17	2,635.55
7	Mulsa-35-6-220	1,384.91	1,648.29	1,358.49	1,543.44
8	PB-30-99-87	1,938.97	1,911.63	1,980.46	1,957.03
9	PB-80-7-4	1,733.71	1,709.11	1,782.33	1,767.57
10	PB-80-5-4	1,275.99	1,136.61	1,226.77	1,276.60
11	PB-30-10-11	1,035.88	982.91	1,002.87	958.65
12	PB- 80-3-3	1,026.33	972.11	1,121.97	1,143.96

Based on the comparison above, two forecasting method with the smallest MAD will be selected as an input to the aggregate planning to determine the effect of the forecasting method to aggregate planning total costs. Forecasting method with the smallest total costs will be selected as the recommended forecasting method to the company.

Table 4.11 Selected Forecasting Method of Each Product

No	Products		Simpe ES	Trend-corrected ES	Croston's	SBA	Selected Forecasting Method
1	Mulsa-35-6-440	MAD	10,808.53	13,477.46	10,205.33	11,205.31	Simple ES
		Total Costs	*73,196,583.48*	*39,521,832.71*	*73,514,934.54*	*52,011,246.50*	
2	Mulsa-27-6-560	MAD	14,335.78	14,417.58	13,902.25	12,161.09	Croston SBA
		Total Costs	*1,793,519,809.08*	*2,025,175,971.73*	*1,793,519,809.08*	*485,639,659.34*	
3	Geomembrane - 500.6.50	MAD	12,464.49	12,319.02	13,712.15	13,161.90	Trend-Corrected ES
		Total Costs	*60,229,339.76*	*47,739,925.97*	*73,135,067.35*	*37,748,394.94*	
4	DT - SGP - 30.69	MAD	10,064.42	9,998.62	9,989.92	9,844.21	Croston SBA
		Total Costs	*378,501,089.71*	*207,467,343.53*	*517,566,307.39*	*228,185,634.34*	
5	Geomembrane - 300.6.50	MAD	6,157.61	8,472.36	8,091.63	7,540.84	Croston SBA
		Total Costs	*55,562,662.81*	*50,983,211.09*	*52,648,466.26*	*40,159,052.47*	

Table 4.12 Selected Forecasting Method of Each Product (Cont.)

No	Products		Simpe ES	Trend-corrected ES	Croston's	SBA	Selected Forecasting Method
6	Mulsa- 27-5-670	MAD	2,775.05	2,916.12	2,580.17	2,635.55	Croston SBA
		Total Costs	*56,729,469.49*	*57,978,410.87*	*56,729,469.49*	*49,235,821.21*	
7	Mulsa-35-6-220	MAD	1,384.91	1,648.29	1,358.49	1,543.44	Simple ES
		Total Costs	*26,202,604.64*	*25,786,290.85*	*26,341,375.90*	*21,206,839.12*	
8	PB-30-99-87	MAD	1,938.97	1,911.63	1,980.46	1,957.03	Trend-Corrected ES
		Total Costs	*43,447,165.85*	*40,116,655.51*	*43,308,394.59*	*39,700,341.72*	
9	PB-80-7-4	MAD	1,733.71	1,709.11	1,782.33	1,767.57	Trend-Corrected Exponential Smoothing
		Total Costs	*35,627,055.68*	*32,712,859.13*	*24,525,354.53*	*27,439,551.09*	
10	PB-80-5-4	MAD	1,275.99	1,136.61	1,226.77	1,276.60	Trend-Corrected ES
		Total Costs	*36,320,912.00*	*24,525,354.53*	*40,761,592.46*	*18,835,732.69*	
11	PB-30-10-11	MAD	1,035.88	982.91	1,002.87	958.65	Croston SBA
		Total Costs	*25,686,003.14*	*24,437,061.76*	*25,963,545.67*	*24,159,519.23*	
12	PB- 80-3-3	MAD	1,026.33	972.11	1,121.97	1,143.96	Simple ES
		Total Costs	*28,410,949.94*	*28,827,263.73*	*42,565,618.90*	*21,472,386.72*	

4.2.2 Inventory Control Policy Determination

This section will provide the calculation and determination of inventory control policy for each raw material. The inventory control policy will be chosen based on the annual total inventory costs incurred.

4.2.2.1 Raw material requirement calculation

The raw material requirement calculation is done according to the bill of material of each product. The raw material requirement is calculated for one year.

a. Material 1

Material 1 is required to produce Geomembrane - 300.6.50 and Geomembrane - 500.6.50. Below is an example of calculation of material 1 requirement for Geomembrane - 300.6.50 in month 1:

$$Demand\ for\ \text{Geomembrane} - 300.6.50\ in\ month\ 1 = 20292.4766\ kg$$

$$Material\ 1\ composistion\ for\ \text{Geomembrane} - 300.6.50 = 50\%$$

$$Material\ 1\ Requirement\ for\ \text{Geomembrane} - 300.6.50\ in\ month\ 1 = 20292.4766\ kg\ x\ 50\% = 10146.24\ kg$$

b. Material 2

Material 2 is required to produce all of the twelve observed products. Below is an example of calculation of material 2 requirement for Geomembrane - 300.6.50 in month 1:

$$Demand\ for\ \text{Geomembrane} - 300.6.50\ in\ month\ 1 = 20292.4766\ kg$$

$$Material\ 2\ composistion\ for\ \text{Geomembrane} - 300.6.50 = 44\%$$

$Material\ 2\ Requirement\ for$ Geomembrane

$$- \ 300.6.50\ in\ month\ 1 = 20292.4766\ kg\ x\ 44\%$$

$$= 8928.69 kg$$

c. Material 3

Material 3 is required to produce DT - SGP - 30.69, PB- 80-3-3, PB-80-5-4, PB-80-7-4, PB-30-10-11, and PB-30-99-87. Below is an example of calculation of material 3 requirement for DT - SGP - 30.69 in month 1:

$Demand\ for$ DT $-$ SGP $-$ $30.69\ in\ month\ 1 = \ 7629.6\ kg$

$Material\ 3\ composistion\ for$ DT $-$ SGP $-$ $30.69 = 5\%$

$Material\ 3\ requirement\ for$ DT $-$ SGP $-$ $30.69\ in\ month\ 1$

$$= 7629.6\ kg\ x\ 5\%$$

$$= 381.48 kg$$

d. Material 4

Material 4 is required to produce Geomembrane - 300.6.50, Geomembrane - 500.6.50, Mulsa- 27-5-670, Mulsa-27-6-560, Mulsa-35-6-220, and Mulsa-35-6-440. Below is an example of calculation of material 4 requirement for Geomembrane - 300.6.50 in month 1:

$Demand\ for$ Geomembrane $-$ $300.6.50\ in\ month\ 1$

$$= \ 20292.4766\ kg$$

$Material\ 4\ composistion\ for$ Geomembrane $-$ $300.6.50 = 6\%$

$Material\ 4\ Requirement\ for$ Geomembrane

$$- \ 300.6.50\ in\ month\ 1 \ = 20292.4766\ kg\ x\ 6\%$$

$$= 1217.55\ kg$$

e. Material 5

Material 5 is required to produce Mulsa - 27-5-670, Mulsa-27-6-560, Mulsa-35-6-220, and Mulsa-35-6-440. Below is an example of calculation of material 5 requirement for Mulsa - 27-5-670 in month 1:

$Demand\ for$ Mulsa $-\ 27-5-670\ in\ month\ 1 =\ 9902.128961\ kg$

$Material\ 5\ composistion\ for$ Mulsa $-\ 27-5-670 = 3.5\%$

$Material\ 5\ Requirement\ for$ Mulsa $-\ 27-5-670\ in\ month\ 1\ = 9902.128961\ x\ 3.5\%$

$= 346.57\ kg$

Below is the recapitulation of material requirement of all products for one year in kilograms.

Table 4.13 Recapitulation Of Material Requirement Of All Products

Material	Jan	Feb	Mar	…	Oct	Nov	Dec
Material 1	15,981.63	13,304.44	5,519.39	…	2,389.96	8,325.30	8,872.28
Material 2	63,170.32	47,921.33	74,764.53	…	46,515.29	47,174.32	46,965.59
Material 3	935.48	802.90	969.56	…	1,031.56	1,086.03	881.19
Material 4	4,180.69	3,110.19	4,380.74	…	2,078.81	2,386.67	2,683.56
Material 5	1,218.48	815.05	2,002.22	…	964.93	747.19	871.71

4.2.2.2 Inventory cost components

This section provide the calculation of inventory cost components which will be used to determine the raw material inventory control policy. The inventory cost components consists of ordering cost and inventory holding cost.

a. Ordering cost

The ordering costs consists of cost of electricity, administration, and telecommunication, cost of salary, and cost of asset. All of the ordering cost component unit will be converted into cost per Purchase Order (PO). The first ordering cost component is the cost of electricity, administration, and telecommunication, provided in the table below.

Table 4.14 Cost Of Electricity, Administration, And Telecommunication

Cost Components	Total Costs per Year (Rp)	PO per Year	Total Costs per PO (Rp)
Electricity	12,467,839	540	23,089
Administration	5,076,242	540	9,400
Internet & telephone	256,932	540	476
Total Costs Per PO (Rp/PO)			**32,965**

The other ordering cost component is the cost of salary. The cost of salary includes the salary of purchasing department manager and staff. The details is provided in the table below.

Table 4.15 Cost Of Salary

Title	Number of worker	Salary per Month per Worker (Rp)	Work load	Salary per Year (Rp)
Purchasing Manager	1	6,000,000	30%	21,600,000
Purchasing Staff	1	3,018,275	100%	36,219,300
Total Costs Per PO (Rp/PO)				**107,073**

The other ordering cost component is the depreciation cost of assets related to the purchasing activities. The details is provided in the table below.

Table 4.16 Cost Of Asset

Assets	Num -ber	Price per Unit	Life Time (Year)	Depreciation per Year	Depreciation per PO (Rp)
Computer	1	7,000,000	6	1,166,667	2,160
Table	1	1,200,000	6	200,000	370
Chair	1	200,000	6	33,333	62
Printer	1	1,500,000	6	250,000	463
Software License	1	1,500,000	6	250,000	463
Total Depreciation Per PO (Rp/PO)					3,519

The next is the cost of copying machine rent which is Rp 24,000,000.00 /year and under the assumption of 540 PO/year, the cost of copying machine rent per PO is Rp 44,444.4 / PO. The total ordering cost per PO is as follows.

Table 4.17 Total Ordering Cost Per PO

No	Cost Components	Total Costs per PO (Rp)
1	Costs Electricity, Administration, and Telecommunication	32,965
2	Costs of Salary	107,073
3	Costs of Assets	3,519
4	Cost of Rent	44,444
Total Ordering Costs Per PO (Rp/PO)		**188,001**

b. Inventory holding cost

Inventory holding cost or inventory carrying cost is cost incurred for carrying or holding a product. The inventory holding cost consists of non-worker cost, worker-cost, and cost of capital. Below is the detail of cost of cost of electricity, administration, and telecommunication.

Table 4.18 Cost Of Electricity, Administration, And Telecommunication

Cost Components	Total Costs per Year (Rp)
Electricity	12,467,839
Administration	5,076,242
Internet & telephone	256,932
Total Costs (Rp)	**17,801,013**

The next inventory holding cost component is the cost of asset depreciation. The detail is as follows.

Table 4.19 Cost of Asset

Assets	Number of Assets	Price per Unit	Life Time (Year)	Depreciation per Year
Computer	4	7,000,000	**6**	4,666,667
Table	4	1,200,000	**6**	800,000
Chair	4	200,000	**6**	133,333
Printer	1	6,500,000	**6**	1,083,333
Software License	1	1,500,000	**6**	250,000
Total Depreciation per Year (Rp)				**6,933,333**

The next inventory holding cost component is the cost of asset rent and tax. The detail is as follows.

Table 4.20 Cost of Rent and Tax

Assets	Quantity	Price / Month / Unit	Price / Year
Forklift	3	7,500,000	270,000,000
Material Warehouse (tax)	1,936.14		32,245,000
Total Costs per Year (Rp)			**302,245,000**

The next inventory holding cost component is the cost of salary which include the warehouse manager and staffs. The detail is as follows.

Table 4.21 Cost of Salary

Title	Number of worker	Salary per Month per Worker (Rp)	Salary per Year (Rp)
Manager warehouse	1	6,000,000	72,000,000
Staff warehouse	3	3,018,275	108,657,900
Total Costs per Year (Rp)			**180,657,900**

The next inventory holding cost component is the cost of capital. The cost of capital used in this research is the Weighted Average Cost of Capital (WACC). The formula used is as follows.

$$WACC = (Cost\ of\ Equity\ \times \%Equity) + Cost\ of\ Debt \times \%Debt \times (1 - Tax\ Rate) \quad (4.3)$$

The first component of calculating WASS is the cost of equity which can be calculated by using the following formula.

$$Cost\ of\ Equity = Rf + (Rm - Rf)\beta + SR \quad (4.4)$$

Which:

$Rf = risk\ of\ free$

$\beta = relative\ market\ risk$

$Rm = average\ expected\ rate\ of\ return\ on\ the\ market$

$SR = specified\ risk$

The data required to calculate the cost of equity and the value of cost of equity is as follows

Table 4.22 Cost of Equity Components

Cost of Equity Components	Value
Risk of Free	8.20%
Average Expected Rate of Return on the Market	12.70%
Risk Premium	4.50%
Beta	0.53
Specified Risk	2%
Cost of Equity	**12.60%**

The next step of calculating WACC is the cost of debt which can be calculated by using the following formula.

$$Cost\ of\ Debt\ (After\ tax) = Interest(1 - Tax\ Rate) \quad (4.5)$$

The data required to calculate the cost of debt and the value of cost of equity is as follows.

Table 4.23 Cost of Debt (After Tax)

Cost of Debt (After Tax)	Value
Interest	9.95%
Tax rate	25%
Cost of Debt (After Tax)	**7.46%**

After calculating both of cost of equity and cost of debt, the next step is to calculate the WACC under the assumption that the company financing consists of 84% of equity and 16% of long-term debt. The calculation of WACC is as follows:

$$WACC = (Cost\ of\ Equity\ \times \%Equity) + Cost\ of\ Debt \times \%Debt \times (1 - Tax\ Rate)$$

$$WACC = (12.60\%\ \times 84\%) + 7.46\% \times 16\% \times (1 - 25\%)$$

$$WACC = 11.48\%$$

After the value of all inventory holding cost component which consist of non-worker cost (cost of electricity, administration, and telecommunication, and cost of asset), worker-cost (cost of salary), and cost of capital, the inventory holding cost value can be calculated.

$$Holding\ Cost = Non - worker\ Cost + Worker\ Cost + (WACC \times Product\ Price) \quad (4.6)$$

The recapitulation of material holding cost is provided in the table below.

Table 4.24 Raw Material Holding Cost

Materials	Unit Price (Rp/Kg)	Holding Cost / Kg / Year	% Holding Cost
Material 1	12,200.00	3,487.97	28.6%
Material 2	12,800.00	3,556.85	27.8%
Material 3	15,750.00	3,895.50	24.7%
Material 4	25,000.00	4,957.35	19.8%
Material 5	91,000.00	12,533.82	13.8%
Average		**5,686.30**	**22.9%**

4.2.2.3 Continuous review (s,S) system

Under the continuous review (s,S) system inventory policy, the material replenishment will be done when the inventory level reach or below the reorder point s. The replenishment quantity will vary since the quantity is meant to fill the inventory level up to maximum inventory level S. Below is the calculation of inventory control parameter of continuous review (s,S) system inventory control policy for material 1.

Step 1: Calculating q

$$q = \sqrt{\frac{2kr}{h}}$$

$$q = \sqrt{\frac{2 \times \ 81{,}813.46 \ \times \ 188{,}001}{3{,}487.97}}$$

$$q = \ 2{,}969.75 \ kg$$

Step 2: Calculate SS

$$SS = K \ \times \ \sigma_L$$

$$SS = 1.53 \ \times \ \ 3{,}969.94 \sqrt{0.47}$$

$$SS = \ \ 4{,}146.96 \ \ kg$$

Step 3: Calculate s

$$s = \ \mu + SS$$

$$s = \ 6{,}817.79 + \ \ 4{,}146.96$$

$$s = \ \ 10{,}964.74 \ kg$$

Step 4: Calculate S

$$S = q + s$$

$$S = \ \ 2{,}969.75 + \ 10{,}964.74$$

$$S = 13{,}934.50$$

Below is the calculation of inventory control parameter of continuous review (s,S) system inventory control policy for all material.

Table 4.25 Inventory Control Parameter Of Continuous Review (s,S) System

Material	s	S
Material 1	10,964.74	13,934.50
Material 2	72,707.45	81,251.09
Material 3	1,013.95	2,061.39
Material 4	4,780.39	6,497.85
Material 5	1,618.13	2,303.41

4.2.2.4 Continuous review (s,Q) system

Under the continuous review (s,Q) system inventory policy, the material replenishment will be done when the inventory level reach or below the reorder point s. The replenishment quantity will be fixed to the amount of Q. Below is the calculation of inventory control parameter of continuous review (s,S) system inventory control policy for material 1.

Step 1. Calculate q

$$q = q_w = \sqrt{\frac{2kr}{h}}$$

$$q = \sqrt{\frac{2 \times 81{,}813.46 \times 188{,}001}{3{,}487.97}}$$

$$q = 2{,}969.75\ kg$$

Step 2. Calculate $F(K)$

$$F(K) = \frac{\pi r - hq}{\pi r}$$

$$F(K) = \frac{2000 \times\ 81{,}813.46\ -\ 3{,}487.97\ \times 2{,}969.75}{2000 \times\ 81{,}813.46}$$

$$F(K) =\ 0.937$$

Step 3. Determine the K value from the safety factor table

$$F(K) =\ 0.937$$

$$K =\ \ 1.53$$

Step 4. Calculate N_k

$$N_k = \sigma_L \times E(K)$$

$$N_k =\ \ 3{,}969.94\ \times \sqrt{0.47}\ \times\ \ 0.03$$

$$N_k =\ \ 74.64$$

Step 5. Calculate

$$q = \sqrt{\frac{2r(k + \pi N_k)}{h}}$$

$$q = \sqrt{\frac{2 \times 81{,}813.46\ (1.53 + 2000 \times 74.64)}{3{,}487.97}}$$

$$q =\ 2{,}646.38$$

Step 6. I$|q_{new} - q_{old}| < \varepsilon$ f, calculate

$$s = \mu + K_{\sigma_L}$$

$$|2{,}646.38 - 2{,}969.75| < 0.5$$

$$323.37\ < 0.5$$

Since the value of $|q_{new} - q_{old}| > \varepsilon$ the calculation will be done again by replacing the initial order quantity with the previous new order quantity. For material 1, the iteration will be done for thirteen times to get the following result.

$$q =\ \ 2{,}253.48$$

$$s =\ 7{,}700.63$$

Below is the calculation of inventory control parameter of continuous review (s,Q) system inventory control policy for all material.

Table 4.26 Inventory Control Parameter Of Continuous Review (s,Q) System

Material	S	Q
Material 1	7,700.63	2,253.48
Material 2	43,460.85	5,297.89
Material 3	394.67	49.35
Material 4	11,562.98	1,110.84
Material 5	2,308.88	625.87

4.2.2.5 Periodic review (R,S) system

Under the continuous review (R,S) system inventory policy, the material replenishment will be done every R period. The replenishment quantity will vary since the quantity is meant to fill the inventory level up to maximum inventory level S. Below is the calculation of inventory control parameter of continuous review (R,S) system inventory control policy for material 1.

Step 1: Calculate review period

$$t^* = \sqrt{\frac{2k}{rh}}$$

$$t^* = \sqrt{\frac{2 \times\ 81{,}813.46}{188{,}001 \times\ 3{,}487.97}}$$

$$t^* =\ 6\ days$$

Step 2: Calculate

$$S^* = \pi_{L+t_p} + K^*_{\sigma_L + t_p}$$

$$S^* =\ 6{,}817.79 \times \left(0.47 + \frac{6}{30}\right) +\ 1.53\ \times\ 3{,}969.94\ \times \left(0.47 + \frac{6}{30}\right)$$

$$S^* =\ \ 9{,}501.75\ \ kg$$

Below is the calculation of inventory control parameter of periodic review (R,S) system inventory control policy for all material.

Table 4.27 Inventory Control Parameter Of Periodic Review (R,S) System

Material	t	S
Material 1	6.00	9,501.75
Material 2	17.00	82,027.19
Material 3	3.00	395.49
Material 4	4.00	11,727.93
Material 5	2.00	2,364.25

4.2.2.6 Periodic review (R,s,S) system

Under the continuous review (R,s,S) system inventory policy, the inventory review will be done every R period. The material replenishment will be done when the inventory level reach or below the reorder point s. the replenishment quantity will vary since the quantity is meant to fill the inventory level up to maximum inventory level S. Below is the calculation of inventory control parameter of continuous review (R,s,S) system inventory control policy for material 1.

Step 1: Calculate q

$$q = \sqrt{\frac{2kr}{h}}$$

$$q = \sqrt{\frac{2 \times 81{,}813.46 \times 188{,}001}{3{,}487.97}}$$

$$q = 2{,}969.75\ kg$$

Step 2: Calculate SS

$$SS = K \times \sigma_{L+w}$$

$$SS = 1.53 \times 3{,}969.94 \times \sqrt{0.47 + (\frac{6}{30})}$$

$$SS = 4{,}956.56\ kg$$

Step 3: Calculate s

$$s = \mu_{L+w} + SS + \frac{rw}{2}$$

$$s = 6{,}817.79 \times \left(0.47 + \frac{6}{30}\right) + 5{,}315.96 + (81{,}813.46 \times \left(\frac{6}{365}\right))/2$$

$$s = 10{,}174.19 \ kg$$

Step 4: Calculate SS

$$S = q_w + s - \frac{rw}{2}$$

$$S = 2{,}969.75 + 10{,}174.19 - (81{,}813.46 \times \left(\frac{6}{365}\right))/2$$

$$S = 12{,}471.51$$

Below is the calculation of inventory control parameter of periodic review (R,s,S) system inventory control policy for all material.

Table 4.28 Of Inventory Control Parameter Of Periodic Review (R,s,S) System

Material	R	s	S
Material 1	6.00	10,174.19	12,471.51
Material 2	17.00	90,570.83	98,107.29
Material 3	3.00	442.20	1,442.93
Material 4	4.00	11,941.02	13,445.38
Material 5	2.00	2,407.14	3,049.53

4.2.2.7 Continuous review (s,S) system cost calculation

The material requirement for each period can be calculated by using material requirement planning (MRP). The material replenishment will be done when the inventory level reach or below the reorder point s. The replenishment quantity will vary since the quantity is meant to fill the inventory level up to maximum inventory level S. According to the MRP result, the quantity of PO, quantity of order size, and the quantity of inventory in one year of material 1 can be summarized in the table below.

Table 4.29 Total Annual Inventory Costs Of Material 1 Using (s,S) System

	Unit	Costs (Rp)
Total Purchased (Kg)	90,690.51	1,106,424,268.04
Total PO	26.00	4,888,015.05
Total Inventory (Kg)	4,460,260.29	42,622,666.86
Total Costs (Rp)		**1,153,934,949.95**

Below is the recapitulation of total annual inventory costs of all materials using (s,S) system.

Table 4.30 Total Annual Inventory Costs Of All Materials Using (s,S) System

Material	Total Annual Inventory Costs (Rp)
Material 1	1,153,934,949.95
Material 2	9,204,112,233.77
Material 3	193,378,411.58
Material 4	1,029,400,636.40
Material 5	1,475,407,686.35
Total (Rp)	**13,056,233,918.04**

4.2.2.8 Continuous review (s,Q) system cost calculation

The material requirement for each period can be calculated by using material requirement planning (MRP). the material replenishment will be done when the inventory level reach or below the reorder point s. The replenishment quantity will be fixed to the amount of Q. According to the MRP result, the quantity of PO, quantity of order size, and the quantity of inventory in one year of material 1 can be summarized in the table below.

Table 4.31 Total Annual Inventory Costs Of Material 1 Using (s,Q) System

	Unit	Costs (Rp)
Total Purchased (Kg)	87,885.87	1,072,207,661.26
Total PO	39.00	7,332,022.57
Total Inventory (Kg)	3,130,527.46	29,915,614.90
Total Costs (Rp)		**1,109,455,298.73**

Below is the recapitulation of total annual inventory costs of all materials using (s,Q) system.

Table 4.32 Total Annual Inventory Costs Of All Materials Using (s,Q) System

Material	Total Annual Inventory Costs (Rp)
Material 1	1,109,455,298.73
Material 2	8,659,150,466.33
Material 3	211,713,253.56
Material 4	1,233,282,790.21
Material 5	1,564,357,704.23
Total (Rp)	**12,777,959,513.07**

4.2.2.9 Periodic review (R,S) system cost calculation

The material requirement for each period can be calculated by using material requirement planning (MRP). The material replenishment will be done every R period. The replenishment quantity will vary since the quantity is meant to fill the inventory level up to maximum inventory level S. According to the MRP result, the quantity of PO, quantity of order size, and the quantity of inventory in one year of material 1 can be summarized in the table below.

Table 4.33 Total Annual Inventory Costs Of Material 1 Using (R,S) System

	Unit	Costs (Rp)
Total Purchased (Kg)	86,257.77	1,052,344,787.61
Total PO	43.00	8,084,024.88
Total Inventory (Kg)	2,938,306.89	28,078,737.02
Total Costs (Rp)		**1,088,507,549.51**

Below is the recapitulation of total annual inventory costs of all materials using (R,S) system.

Table 4.34 Total Annual Inventory Costs Of All Materials Using (R,S) System

Material	Total Annual Inventory Costs (Rp)
Material 1	1,088,507,549.51
Material 2	9,033,444,740.86
Material 3	186,169,811.60
Material 4	1,215,320,221.96
Material 5	1,545,522,612.83
Total (Rp)	**13,068,964,936.76**

4.2.2.10 Periodic review (R,s,S) system cost calculation

The material requirement for each period can be calculated by using material requirement planning (MRP). the inventory review will be done every R period. The material replenishment will be done when the inventory level reach or below the reorder point s. the replenishment quantity will vary since the quantity is meant to fill the inventory level up to maximum inventory level S. According to the MRP result, the quantity of PO, quantity of order size, and the quantity of inventory in one year of material 1 can be summarized in the table below.

Table 4.35 Total Annual Inventory Costs Of Materials 1 Using (R,s,S) System

	Unit	Costs (Rp)
Total Purchased (Kg)	85,597.95	1,044,295,016.32
Total PO	21.00	3,948,012.15
Total Inventory (Kg)	3,765,787.44	35,986,218.99
Total Costs (Rp)		**1,084,229,247.46**

Below is the recapitulation of total annual inventory costs of all materials using (R,s,S) system.

Table 4.36 Total Annual Inventory Costs Of All Materials Using (R,s,S) System

Material	Total Annual Inventory Costs (Rp)
Material 1	1,084,229,247.46
Material 2	9,139,729,216.13
Material 3	189,399,017.12
Material 4	1,254,867,659.70
Material 5	1,552,709,329.44
Total (Rp)	**13,220,934,469.86**

CHAPTER V
ANALYSIS AND INTERPRETATION

This chapter will explain about the analysis and interpretation of the data collection and processing results of the previous chapter. The analysis is done on the result of forecasting method selection and raw material inventory control policy selection. The analysis will be used to obtain conclusion and recommendation on forecasting method and raw material inventory control policy for the company.

5.1 Analysis of Forecast Method Selection

There are twelve products which are observed for this research:. Each product has different demand pattern from the other product. The most notable difference between each product is the presence of several months with no demand during the two years of demand observation data. The example of product which has some moths with zero demand are Geomembrane - 300.6.50, Geomembrane - 500.6.50, , Mulsa-35-6-220, Mulsa-35-6-440, PB- 80-3-3, PB-80-5-4, PB-80-7-4, and PB-30-10-11. While the rest of product, DT - SGP - 30.69, Mulsa- 27-5-670, Mulsa-27-6-560, and PB-30-99-87, has no month or period with zero demand during the observation period of two years.

Different demand pattern will result in different forecasting which is appropriately used to forecast the demand (Pham, 2006). There are four categories of demand pattern that can be used to differentiate between demand pattern having several period with zero demand, those are smooth, lumpy, erratic, and intermittent demand. by using those classification. ADI – CV classification is used to classify demand pattern into those four categories based on the value of ADI (Average inter-Demand Interval) and CV (Coefficient of Variation). Based on the ADI – CV calculation and classification, the demand pattern of the observed products are put into two categories, erratic and lumpy demand. Products which fall into erratic categories are DT - SGP - 30.69., Geomembrane - 500.6.50, Mulsa- 27-5-670, Mulsa-27-6-560, Mulsa-35-6-220, Mulsa-35-6-440, , PB-30-10-11, and PB-30-99-

87. While Geomembrane - 300.6.50, PB- 80-3-3, PB-80-5-4, and PB-80-7-4 are products which fall into lumpy categories.

Both erratic and lumpy demand pattern are recommended to be forecasted using exponential smoothing method and Croston's method (Pham, 2006). The selected exponential smoothing method used in this research is the simple exponential smoothing method and the trend-corrected exponential smoothing method. The selected Croston's method is the original Croston's method and the developed model of Croston's method by Synthetos and Boylan, the Synthetos-Boylan Approximation method.

Table 5.1 Comparison Of MAD of Each Forecasting Method

No	Products	Simpe ES	Trend-corrected ES	Croston's	SBA
1	Mulsa-35-6-440	10,808.53	13,477.46	10,205.33	11,205.31
2	Mulsa-27-6-560	14,335.78	14,417.58	13,902.25	12,161.09
3	Geomembrane - 500.6.50	12,464.49	12,319.02	13,712.15	13,161.90
4	DT - SGP - 30.69	10,064.42	9,998.62	9,989.92	9,844.21
5	Geomembrane - 300.6.50	6,157.61	8,472.36	8,091.63	7,540.84
6	Mulsa- 27-5-670	2,775.05	2,916.12	2,580.17	2,635.55
7	Mulsa-35-6-220	1,384.91	1,648.29	1,358.49	1,543.44
8	PB-30-99-87	1,938.97	1,911.63	1,980.46	1,957.03
9	PB-80-7-4	1,733.71	1,709.11	1,782.33	1,767.57
10	PB-80-5-4	1,275.99	1,136.61	1,226.77	1,276.60
11	PB-30-10-11	1,035.88	982.91	1,002.87	958.65
12	PB- 80-3-3	1,026.33	972.11	1,121.97	1,143.96

The determination of which forecasting method to be recommended to the company is based on the value of Mean Absolute Deviation (MAD) of the forecasting result compared to the actual value of demand and the total cost incurred by applying the forecasting result into an aggregate planning. The value of MAD can be used to show the accuracy of demand forecasting. Two forecasting method with the lowest value of MAD will be selected for each product. Based on the MAD calculation and comparison of each forecasting method and the total cost from the aggregate planning, simple exponential smoothing is chosen as the forecasting method for three products (Mulsa-35-6-440, Mulsa-35-6-220, and PB- 80-3-3), the trend-corrected exponential smoothing is chosen for four products (Geomembrane - 500.6.50, PB-30-99-87, PB-80-7-4, and PB-80-5-4), and the SBA method is chosen for five products (Mulsa-27-6-560, DT - SGP - 30.69, Geomembrane - 300.6.50, Mulsa- 27-5-670, and PB-30-10-11).

Table 5.2 Selected Forecasting Method

No	Products	Selected Method
1	Mulsa-35-6-440	Simple Exponential Smoothing
2	Mulsa-27-6-560	SBA
3	Geomembrane - 500.6.50	Trend-Corrected Exponential Smoothing
4	DT - SGP - 30.69	SBA
5	Geomembrane - 300.6.50	SBA
6	Mulsa- 27-5-670	SBA
7	Mulsa-35-6-220	Simple Exponential Smoothing
8	PB-30-99-87	Trend-Corrected Exponential Smoothing
9	PB-80-7-4	Trend-Corrected Exponential Smoothing
10	PB-80-5-4	Trend-Corrected Exponential Smoothing
11	PB-30-10-11	SBA
12	PB- 80-3-3	Simple Exponential Smoothing

5.2 Analysis of Inventory Control Policy Determination

In the current condition of the company, the company don't have any clear policy regarding the inventory control. The process of purchasing is only based on the value of forecasting which will be translated into material requirement. The ordering quantity is only based on the maximum ordering value which has been set by the supplier. This condition results in excessive quantity of raw material inventory at the end of period. There's no clearly specified policy regarding the maximum number of inventory that should be kept by the company. The minimum number of inventory also not clearly specified for each raw material. The company never had an attempt to calculate the total inventory costs of their inventory both for finished product and raw material.

The table below stated the total annual inventory costs of the four method used in this research in Indonesian Rupiah.

Table 5.3 Total Annual Inventory Costs of (s,S) System, (s,S) System, (R,S) System, and (R,s,S) System

Material	(s,S) System	(s,Q) System	(R,S) System	(R,s,S) System
Material 1	1,153,934,949.95	1,109,455,298.73	1,088,507,549.51	1,084,229,247.46
Material 2	9,204,112,233.77	8,659,150,466.33	9,033,444,740.86	9,139,729,216.13
Material 3	193,378,411.58	211,713,253.56	186,169,811.60	189,399,017.12
Material 4	1,029,400,636.40	1,233,282,790.21	1,215,320,221.96	1,254,867,659.70
Material 5	1,475,407,686.35	1,564,357,704.23	1,545,522,612.83	1,552,709,329.44
Total Annual Inventory Costs (Rp)	**13,056,233,918.04**	**12,777,959,513.07**	**13,068,964,936.76**	**13,220,934,469.86**

Based on the result of the table above, the inventory control policy which generate the lowest total annual inventory costs is the continuous review (s,Q) system which is Rp 12,758,926,337.12. This result is obtained since the total number of units purchased in one year is the lowest of the four other policy, which is 825,792.74 kg of material, compared to (s,S) system with 855,286.67 kg of purchased materials, (R,S) system with 838,393.68 kg of purchased materials, and (R,s,S) system with 855,878.61 kg of purchased materials. This result is also obtained from the total inventory in one year which is the lowest of all four inventory policy which is 24,929,875.36 kg of raw material inventory in one year, compared to (s,S) system with 34,833,495.73 kg of inventory, (R,S) system with 25,338,586.61 kg of inventory, and (R,s,S) system with 32,440,795.01 kg of inventory. While the total number of purchased product and total number of inventory of (s,Q) system is the lowest of four policy, the number of order is the highest of four policy, which is 471 orders per year, compared to (s,S) system with 152 orders per year, (R,S) system with 344 orders per year, and (R,s,S) system with 90 orders per year.

For Material 1, the inventory control policy which generate the lowest total annual inventory costs is the periodic review system (R,s,S) system which is Rp 1,084,229,247.46. This result is obtained since the total number of units purchased and the total number of PO in one year is the lowest of the four other policy, which is 85,597.95 kg of materials and 21 POs.

Table 5.4 Total Annual Inventory Costs of Material 1

Material 1	**(s,S) System**	**(s,Q) System**	**(R,S) System**	**(R,s,S) System**
Total Unit Purchased (Kg)	90,690.51	87,885.87	86,257.77	85,597.95
Total PO	26.00	39.00	43.00	21.00
Total Inventory (Kg)	4,460,260.29	3,130,527.46	2,938,306.89	3,765,787.44
Total Purchase Costs (Rp)	1,106,424,268.04	1,072,207,661.26	1,052,344,787.61	1,044,295,016.32
Total Ordering Costs (Rp)	4,888,015.05	7,332,022.57	8,084,024.88	3,948,012.15
Total Inventory Carrying Costs (Rp)	42,622,666.86	29,915,614.90	28,078,737.02	35,986,218.99
Total Annual Inventory Costs (Rp)	**1,153,934,949.95**	**1,109,455,298.73**	**1,088,507,549.51**	**1,084,229,247.46**

For Material 2, the inventory control policy which generate the lowest total annual inventory costs is the continuous review system (s,Q) system which is Rp 8,659,150,466.33. This result is obtained since the total number of units purchased and the total number of inventory in one year is the lowest of the four other policy, which is 85,597.95 kg of materials and 16,318,530.38 kg of materials respectively.

Table 5.5 Total Annual Inventory Costs of Material 2

Material 2	(s,S) System	(s,Q) System	(R,S) System	(R,s,S) System
Total Unit Purchased (Kg)	697,019.72	662,236.69	687,121.81	695,665.46
Total PO	71.00	125.00	16.00	16.00
Total Inventory (Kg)	27,595,421.93	16,318,530.38	20,701,783.14	23,828,440.62
Total Purchase Costs (Rp)	8,921,852,375.65	8,476,629,609.07	8,795,159,230.92	8,904,517,862.39
Total Ordering Costs (Rp)	13,348,041.09	23,500,072.34	3,008,009.26	3,008,009.26
Total Inventory Carrying Costs (Rp)	268,911,817.04	159,020,784.92	201,734,698.36	232,203,344.48
Total Annual Inventory Costs (Rp)	**9,204,112,233.77**	**8,659,150,466.33**	**9,033,444,740.86**	**9,139,729,216.13**

For Material 3, the inventory control policy which generate the lowest total annual inventory costs is the periodic review system (R,S) system which is Rp 186,169,811.60. This result is obtained since the total number of units purchased and the total number of inventory in one year is the lowest of the four other policy, which is 10,703.46 kg of materials and 115,655.39 kg of materials respectively.

Table 5.6 Total Annual Inventory Costs of Material 3

Material 3	(s,S) System	(s,Q) System	(R,S) System	(R,s,S) System
Total Unit Purchased (Kg)	11,768.55	10,758.18	10,703.46	11,670.79
Total PO	11.00	218.00	87.00	11.00
Total Inventory (Kg)	558,040.43	120,660.34	115,655.39	329,444.19
Total Purchase Costs (Rp)	185,354,666.67	169,441,368.61	168,579,418.27	183,814,986.89
Total Ordering Costs (Rp)	2,068,006.37	40,984,126.16	16,356,050.35	2,068,006.37
Total Inventory Carrying Costs (Rp)	5,955,738.54	1,287,758.79	1,234,342.98	3,516,023.86
Total Annual Inventory Costs (Rp)	**193,378,411.58**	**211,713,253.56**	**186,169,811.60**	**189,399,017.12**

For Material 4, the inventory control policy which generate the lowest total annual inventory costs is the continuous review system (s,S) system which is   Rp 1,029,400,636.40. This result is obtained since the total number of units purchased and the total number of inventory in one year is the lowest of the four other policy, which is 39,906.69 kg of materials and 2,031,933.43 kg of materials respectively.

Table 5.7 Total Annual Inventory Costs of Material 4

Material 4	(s,S) System	(s,Q) System	(R,S) System	(R,s,S) System
Total Unit Purchased (Kg)	39,906.69	46,655.31	45,868.65	47,586.11
Total PO	22.00	42.00	66.00	20.00
Total Inventory (Kg)	2,031,933.43	4,344,341.44	4,137,597.48	4,524,808.81
Total Purchase Costs (Rp)	997,667,347.38	1,166,382,868.76	1,146,716,237.87	1,189,652,682.49
Total Ordering Costs (Rp)	4,136,012.73	7,896,024.31	12,408,038.19	3,760,011.57
Total Inventory Carrying Costs (Rp)	27,597,276.29	59,003,897.14	56,195,945.89	61,454,965.63
Total Annual Inventory Costs (Rp)	**1,029,400,636.40**	**1,233,282,790.21**	**1,215,320,221.96**	**1,254,867,659.70**

For Material 5, the inventory control policy which generate the lowest total annual inventory costs is the continuous review system (s,S) system which is   Rp 1,475,407,686.35. This result is obtained since the total number of units purchased, total number of PO and the total number of inventory in one year is the lowest of the four other policy, which is 15,901.20 kg of materials, 22 POs, and 706,562.08 kg of materials respectively.

Table 5.8 Total Annual Inventory Costs of Material 5

Material 5	(s,S) System	(s,Q) System	(R,S) System	(R,s,S) System
Total Unit Purchsed (Kg)	15,901.20	16,706.59	16,397.89	16,647.31
Total PO	22.00	50.00	131.00	22.00
Total Inventory (Kg)	706,562.08	1,009,279.35	835,394.75	980,451.70
Total Purchase Costs (Rp)	1,447,008,873.26	1,520,299,795.77	1,492,207,721.42	1,514,905,356.65
Total Ordering Costs (Rp)	4,136,012.73	9,400,028.94	24,628,075.81	4,136,012.73
Total Inventory Carrying Costs (Rp)	24,262,800.36	34,657,879.53	28,686,815.59	33,667,960.07
Total Annual Inventory Costs (Rp)	**1,475,407,686.35**	**1,564,357,704.23**	**1,545,522,612.83**	**1,552,709,329.44**

Based on the result above, it can be seen that Material 2, Material 4, and Material 5 generates lower total annual inventory costs by implementing the continuous review system. While Material 1 and Material 3 generates lower total annual inventory costs by implementing the periodic review system. Continuous review system is mostly used to manage high-value product and high total product volume, while the low-value products and low total product volume is managed by using the periodic review system (Chopra & Meindl, 2016). Material 2 has the highest total volume of purchased material and inventory throughout the year, while Material 4 and Material 5 are two materials which product value is the highest among five materials. This condition aligns with the previous statement of . continuous review system is mostly used to manage high-value product and high total product volume. While Material 1 has the lowest product value and Material 3 has the lowest total product volume throughout the year. Since, the implementation of continuous review system require

require more works to do (if done manually) and higher investment (if done automatically) which generates higher costs. The implementation of continuous review system will make sense if the savings generated is higher than the costs of implementation.

The selection of a continuous review system can bring the advantage of accurate inventory accounting since the review process is done in real time, or at least, once a day, which will result in lower uncertainty and lower total inventory costs, the downside is that it requires a more complex and sophisticated system of hardware and software to track the changes in inventory compared to the implementation of periodic review system. The selection a periodic review system will be easier to be done since it doesn't need the use sophisticated hardware and software and the review process is done periodically, the downside is that the accuracy is lower than the continuous review system and the need of more buffer or safety stock as a buffer against the demand uncertainty during the period between review, especially when the reviewing period is long (Wisner, et al 2012.)

The result of inventory control calculation of total costs did not administer any of capital costs regarding the assets needed to implement the review method. The selection of inventory control policy is purely based on the total annual inventory costs which only account for the ordering costs, purchasing costs, and inventory carrying costs without accounting the inventory reviewing related costs.

CHAPTER VI

CONCLUSION AND RECOMMENDATION

This chapter provides the conclusion of this research and recommendation for this research.

6.1 Conclusion

The conclusion of this research are as follows.

1. The demand pattern of each product will determine which forecasting method is suitable to be used. the demand pattern of the observed products are put into two categories, erratic and lumpy demand. Products which fall into erratic categories are DT - SGP - 30.69., Geomembrane - 500.6.50, Mulsa- 27-5-670, Mulsa-27-6-560, Mulsa-35-6-220, Mulsa-35-6-440, , PB-30-10-11, and PB-30-99-87. While Geomembrane - 300.6.50, PB- 80-3-3, PB-80-5-4, and PB-80-7-4 are products which fall into lumpy categories. For both erratic and lumpy demand pattern are recommended to be forecasted using exponential smoothing method and Croston's method.
2. The forecasting method selected as recommendation for the company for each product are based on the accuracy of the forecast. simple exponential smoothing is chosen as the forecasting method for three products (Mulsa-35-6-440, Mulsa-35-6-220, and PB- 80-3-3), the trend-corrected exponential smoothing is chosen for four products (Geomembrane - 500.6.50, PB-30-99-87, PB-80-7-4, and PB-80-5-4), and the SBA method is chosen for five products (Mulsa-27-6-560, DT - SGP - 30.69, Geomembrane - 300.6.50, Mulsa- 27-5-670, and PB-30-10-11).
3. The inventory control policy which is selected is the one that generate the lowest total annual inventory costs for each material. For Material 1, the selected inventory control policy is the periodic review system (R,s,S) system. For Material 2, the selected inventory control is the continuous review system (s,Q) system. For Material 3, the selected inventory control policy is the periodic review system (R,S) system. For Material 4 and

Material 5, the selected inventory control policy is the continuous review system (s,S) system.

6.2 Recommendation

There are several recommendation for further research:

1. The forecasting need to take into account the consumption or purchasing pattern of customer in determining the demand pattern and accuracy of forecasting result.
2. The selection of inventory control policy need to take into account different backorder cost for each raw material and the possibility of purchasing from multiple supplier.

REFERENCES

Aini, Q. A. (2016). *by Qurrotul Ayuni Aini (2016) under the title “Pengendalian Persediaan Bahan Baku Pupuk Bersubsidi Di Pt Petrokimia Gresik.* Surabya.

Arnold, J., Chapman, S., & Clive, l. (2008). *Introduction to Materials Management.* London: Prentice Hall.

Azizah, I. N. (2017). *Kebijakan Pengendalian Persediaan Bahan Baku Obat Nyamuk Bakar Berupa Tepung Dan Material Packaging (Studi Kasus: Pt X).* Surabaya.

Bank Mandiri. (2020). *Rupiah Prime Lending Rate*. Retrieved from Mandiri: https://www.bankmandiri.co.id/en/suku-bunga-dasar-kredit [Accessed 26 July 2020]

Chopra, S., & Meindl, P. (2016). *Supply Chain Management: Strategy, Planning, and Operation, 6th Edition.* New York: Pearson.

Direktorat Jenderal Pajak. (2020). *Mekanisme Perhitungan Pajak Penghasilan badan*. Retrieved from DJP: https://www.pajak.go.id/id/mekanisme-penghitungan-pajak-penghasilan-badan) [Accessed 26 July 2020]

Indonesia, P. C. (2020). *Annual Report 2019.*

Lamont, W. (2017). *A Guide to the Manufacture, Performance, and Potential of Plastics in Agriculture.* Elsevier.

Pham, H. (2006). *Springer Handbook of Engineering Statistics.* London: Springer.

Pujawan, I. N. (2017). *Supply Chain Management.* Yogyakarta: Andi.

Rumah123.com. (2020, July 26). *Penjualan Gudang*. Retrieved from Rumah123.com: https://www.rumah123.com/en/property/malang/was2616509/[Accessed 26 July 2020]

Sedayu, M. G. (2019). *Inventory Management Analysis of Fast-Moving Consumer Goods at Stockpoint: Case Study on Distribution Company.* Surabaya.

Smith, S. (1989). *Computer Based Production and Inventory Control.* United States of America: Prentice-Hall, Inc.

Tersine, R. J. (1994). *Principles of Inventory and Materials Management.* New Jersey: PTR Prentice Hall, Inc.

Waters, D. (2003). *Inventory Control and Management.* West Sussex: John Wiley & Sons Ltd.

APPENDIX

APPENDIX A: FORECASTING RESULT

Mulsa-35-6-440

Month	Forecast			
	Simple Exponential Smoothing	Trend-Corrected Exponential Smoothing	Croston's Method	SBA Method
1	24,989.76	54,848.09	372.56	1,043.17
2	5,852.02	21,578.22	3,390.30	1,982.02
3	60,879.44	41,118.82	60,633.27	28,930.12
4	74,902.48	59,156.80	74,877.87	43,685.50
5	71,295.93	66,566.93	71,293.47	47,250.18
6	67,254.81	68,251.18	67,254.57	46,958.51
7	59,478.26	64,033.81	59,478.24	43,401.37
8	43,126.38	51,000.34	43,126.37	34,710.54
9	40,265.66	42,697.51	40,265.66	30,662.29
10	31,682.67	32,739.84	31,682.67	25,171.10
11	13,437.63	15,968.76	13,437.63	14,860.81
12	2,958.90	1,357.90	2,958.90	6,698.05
13	17,036.79	4,179.99	17,036.79	10,491.64
14	10,731.58	1,891.13	10,731.58	8,409.68
15	20,178.36	8,278.89	20,178.36	12,279.63
16	16,045.78	9,382.84	16,045.78	11,458.22

Mulsa-35-6-440

Month	Forecast			
	Simple Exponential Smoothing	Trend-Corrected Exponential Smoothing	Croston's Method	SBA Method
17	12,681.06	8,587.55	12,681.06	9,752.31
18	10,942.75	7,627.31	10,942.75	8,415.76
19	10,113.53	7,022.50	10,942.75	8,415.76
20	1,011.35	1,007.14	1,094.27	3,366.30
21	8,723.14	3,646.75	8,731.43	5,370.12
22	2,928.09	1,182.40	2,928.92	3,107.41
23	7,415.77	3,438.53	7,415.85	4,567.01
24	8,960.92	5,745.09	8,960.93	5,662.50

Mulsa-27-6-560

Month	Forecast			
	Simple Exponential Smoothing	Trend-Corrected Exponential Smoothing	Croston's Method	SBA Method
1	18,289.63	2,316.20	311.77	171.47
2	4,634.89	4,498.68	2,837.11	1,560.41
3	6,135.47	7,745.29	5,955.69	3,275.63
4	10,034.75	12,064.22	10,016.77	5,509.22
5	3,021.09	4,208.51	3,019.30	1,660.61
6	14,347.60	16,476.60	14,347.42	7,891.08
7	8,517.76	9,966.32	8,517.74	4,684.76
8	2,740.16	3,412.54	2,740.15	1,507.08
9	2,162.40	2,638.87	2,162.40	1,189.32
10	299.04	526.71	299.04	164.47
11	18,778.25	20,808.47	18,778.25	10,328.04
12	8,085.67	9,044.16	8,085.67	4,447.12
13	7,079.23	7,743.64	7,079.23	3,893.57
14	5,748.82	6,190.99	5,748.82	3,161.85
15	44,046.50	48,256.42	44,046.50	24,225.58
16	7,732.85	8,309.28	7,732.85	4,253.07
17	3,633.49	3,384.76	3,633.49	1,998.42
18	38,615.51	41,804.85	38,615.51	21,238.53
19	57,689.56	62,843.07	57,689.56	31,729.26
20	77,813.15	84,711.62	77,813.15	42,797.23
21	58,437.09	62,951.60	58,437.09	32,140.40

Mulsa-27-6-560

Month	Forecast			
	Simple Exponential Smoothing	Trend-Corrected Exponential Smoothing	Croston's Method	SBA Method
22	31,782.79	32,987.16	31,782.79	17,480.53
23	11,325.44	10,044.67	11,325.44	6,228.99
24	12,116.50	10,781.59	12,116.50	6,664.08

Geomembrane - 500.6.50

Month	Forecast			
	Simple Exponential Smoothing	Trend-Corrected Exponential Smoothing	Croston's Method	SBA Method
1	13,868.50	22,797.08	11,075.20	761.42
2	13,846.45	21,035.85	11,628.96	6,928.92
3	53,468.09	24,221.73	20,877.27	29,338.79
4	51,210.36	26,665.30	26,893.71	28,158.83
5	12,012.34	24,344.18	26,893.71	28,158.83
6	1,201.23	21,246.03	26,893.71	28,158.83
7	120.12	18,245.24	21,514.97	2,815.88
8	1,603.21	15,556.55	17,565.58	1,156.75
9	19,373.52	15,152.65	18,322.06	10,682.93
10	16,828.75	14,322.87	17,966.85	9,258.56
11	21,861.78	14,244.55	18,857.68	12,024.25
12	13,354.28	13,154.50	17,567.94	7,344.88
13	8,451.73	11,670.79	15,635.75	4,648.45
14	3,855.67	9,795.99	15,635.75	4,648.45
15	385.57	7,676.21	12,508.60	464.85
16	10,638.76	6,987.22	12,362.48	5,876.59
17	39,451.94	9,811.34	18,420.67	21,701.09
18	21,293.59	10,109.95	18,591.73	11,711.73
19	2,813.36	8,433.60	15,025.39	1,547.37
20	8,719.74	7,795.91	13,895.51	4,795.86
21	1,136.57	6,238.77	11,175.21	625.12

Geomembrane - 500.6.50

Month	Forecast			
	Simple Exponential Smoothing	Trend-Corrected Exponential Smoothing	Croston's Method	SBA Method
22	378.26	4,777.89	8,998.97	208.04
23	9,947.19	4,597.07	9,401.25	5,470.95
24	20,189.11	5,633.30	9,401.25	5,470.95

DT - SGP - 30.69

Month	Forecast			
	Simple Exponential Smoothing	Trend-Corrected Exponential Smoothing	Croston's Method	SBA Method
1	16,291.30	25,189.41	19,368.80	6,779.08
2	18,667.21	24,308.04	20,337.24	12,880.25
3	31,944.25	27,772.26	28,854.59	31,580.18
4	33,482.87	28,397.97	30,498.27	28,202.73
5	25,948.11	25,890.20	26,072.02	14,795.23
6	20,806.23	23,506.53	22,619.32	9,617.66
7	17,151.74	21,194.03	19,820.37	7,469.40
8	17,627.56	20,099.53	19,603.86	10,857.63
9	14,493.41	17,829.55	17,119.17	7,358.82
10	19,710.95	18,397.61	20,072.37	16,335.31
11	20,883.48	18,134.50	20,781.78	16,454.27
12	16,643.68	16,097.00	17,975.58	9,417.05
13	14,409.70	14,438.88	16,219.89	7,629.60
14	11,547.91	12,418.22	13,949.99	5,097.41
15	12,338.32	11,548.49	13,996.51	7,995.66
16	8,901.96	9,329.21	11,373.97	3,569.46
17	8,894.17	8,126.54	10,874.38	5,155.70
18	8,985.80	7,087.23	10,539.42	5,926.11
19	11,025.14	6,897.21	11,588.26	8,999.56
20	16,619.50	8,342.90	15,205.20	16,062.48
21	16,264.57	8,291.29	15,251.44	12,908.28

DT - SGP - 30.69

Month	Forecast			
	Simple Exponential Smoothing	Trend-Corrected Exponential Smoothing	Croston's Method	SBA Method
22	16,016.12	8,316.29	15,288.44	11,646.60
23	16,842.46	8,776.76	15,984.87	12,542.29
24	14,377.22	8,175.10	14,512.89	8,639.42

Geomembrane - 300.6.50

Month	Forecast			
	Simple Exponential Smoothing	Trend-Corrected Exponential Smoothing	Croston's Method	SBA Method
1	9,800.78	16,368.34	3,240.80	3,159.78
2	14,923.36	15,779.17	13,611.36	8,320.75
3	31,789.15	17,431.34	31,526.75	18,878.77
4	24,902.31	17,693.29	24,849.83	16,210.81
5	19,002.54	17,362.08	24,849.83	16,210.81
6	3,800.51	15,137.62	24,849.83	16,210.81
7	760.10	12,984.22	4,969.97	4,863.24
8	5,145.62	11,602.95	5,987.59	4,299.08
9	7,153.92	10,461.73	7,322.32	4,773.20
10	1,867.58	8,624.47	1,901.26	1,680.39
11	20,951.92	9,659.63	20,958.65	12,208.08
12	20,402.38	10,151.52	20,403.73	12,883.00
13	20,292.48	10,695.36	20,292.75	13,085.47
14	16,812.90	10,805.09	20,292.75	13,085.47
15	3,362.58	9,201.50	4,058.55	3,925.64
16	2,470.12	7,913.42	2,609.31	2,200.08
17	1,819.62	6,632.59	1,847.46	1,413.96
18	860.72	5,316.12	866.29	706.74
19	252.94	4,027.15	866.29	706.74
20	50.59	2,816.71	866.29	706.74
21	10.12	1,699.14	481.27	415.73

Geomembrane - 300.6.50

Month	Forecast			
	Simple Exponential Smoothing	Trend-Corrected Exponential Smoothing	Croston's Method	SBA Method
22	2.02	676.34	96.25	124.72
23	12,053.52	1,406.35	6,715.43	4,069.89
24	12,111.26	1,876.49	6,732.29	4,466.38

Mulsa- 27-5-670

Month	**Forecast**			
	Simple Exponential Smoothing	**Trend-Corrected Exponential Smoothing**	**Croston's Method**	**SBA Method**
1	7,307.47	7,176.96	171.90	825.12
2	2,277.85	6,587.93	1,564.29	1,045.15
3	1,388.96	5,961.95	1,317.61	1,039.96
4	6,971.52	6,045.03	6,964.38	3,053.35
5	15,854.95	7,152.78	15,854.24	7,221.45
6	9,446.91	7,354.88	9,446.83	7,128.04
7	7,994.66	7,451.38	7,994.65	6,783.48
8	5,895.18	7,303.21	5,895.18	5,881.90
9	3,893.51	6,934.45	3,893.51	4,703.89
10	3,676.96	6,567.93	3,676.96	3,991.26
11	7,727.90	6,706.67	7,727.90	5,011.72
12	10,886.09	7,182.74	10,886.09	6,602.87
13	9,902.13	7,492.88	9,902.13	7,095.42
14	5,743.29	7,298.74	5,743.29	5,947.23
15	7,739.77	7,398.68	7,739.77	6,116.05
16	10,339.36	7,787.57	10,339.36	7,070.66
17	11,051.66	8,221.27	11,051.66	7,804.25
18	10,397.13	8,552.00	10,397.13	7,986.36
19	9,110.55	8,718.12	9,110.55	7,661.45
20	8,173.52	8,771.33	8,173.52	7,179.08
21	6,470.25	8,615.47	6,470.25	6,317.37

Mulsa- 27-5-670

Month	Forecast			
	Simple Exponential Smoothing	**Trend-Corrected Exponential Smoothing**	**Croston's Method**	**SBA Method**
22	5,965.49	8,410.98	5,965.49	5,681.43
23	3,818.37	7,945.66	3,818.37	4,554.39
24	5,731.80	7,743.33	5,731.80	4,634.84

Mulsa-35-6-220

Month	Forecast			
	Simple Exponential Smoothing	Trend-Corrected Exponential Smoothing	Croston's Method	SBA Method
1	2,905.98	3,857.14	98.00	117.60
2	1,172.60	1,012.38	891.80	493.92
3	1,175.30	626.02	1,147.22	663.07
4	7,901.09	7,810.57	7,898.28	4,283.85
5	6,357.69	7,017.82	6,357.41	3,826.15
6	6,203.35	6,726.21	6,203.32	3,734.61
7	4,222.67	4,485.23	4,222.67	2,668.17
8	1,391.57	1,151.24	1,391.57	1,050.59
9	885.80	235.06	885.80	608.33
10	835.22	146.95	835.22	519.87
11	2,556.99	2,080.50	2,556.99	1,423.16
12	3,667.15	3,574.57	3,667.15	2,104.07
13	3,981.20	4,124.51	3,981.20	2,348.54
14	3,650.36	3,830.75	3,650.36	2,204.24
15	5,062.68	5,279.02	5,062.68	2,946.26
16	3,979.19	4,252.80	3,979.19	2,441.48
17	2,159.94	2,159.55	2,159.94	1,428.04
18	1,290.23	974.99	1,290.23	858.54
19	1,194.80	764.03	1,290.23	858.54
20	119.48	(347.76)	129.02	171.71
21	62.71	(460.34)	63.66	61.41

Mulsa-35-6-220

Month	Forecast			
	Simple Exponential Smoothing	Trend-Corrected Exponential Smoothing	Croston's Method	SBA Method
22	1,195.26	813.94	1,195.36	646.41
23	3,885.13	3,898.32	3,885.14	2,137.60
24	3,549.13	3,915.60	3,549.13	2,113.18

PB-30-99-87

Month	Forecast			
	Simple Exponential Smoothing	Trend-Corrected Exponential Smoothing	Croston's Method	SBA Method
1	3,949.74	5,114.26	3,318.56	2,986.70
2	3,989.43	4,906.73	3,484.49	3,136.04
3	4,047.14	4,726.65	3,643.19	3,278.87
4	3,710.32	4,349.44	3,387.15	3,048.44
5	4,726.45	4,697.16	4,467.92	4,021.13
6	5,733.84	5,158.02	5,527.02	4,974.32
7	4,986.25	4,764.41	4,820.79	4,338.71
8	4,450.92	4,416.99	4,318.56	3,886.70
9	4,487.00	4,338.63	4,381.10	3,942.99
10	4,295.88	4,150.04	4,211.16	3,790.05
11	4,856.62	4,366.62	4,788.85	4,309.97
12	5,305.22	4,588.88	5,251.00	4,725.90
13	4,535.29	4,193.17	4,491.92	4,042.73
14	3,918.68	3,809.29	3,883.98	3,495.58
15	4,403.36	3,978.11	4,375.60	3,938.04
16	3,928.41	3,679.21	3,906.20	3,515.58
17	3,718.35	3,487.14	3,700.58	3,330.52
18	3,356.66	3,201.68	3,342.44	3,008.20
19	3,414.19	3,122.63	3,402.82	3,062.53
20	3,172.05	2,898.22	3,162.95	2,846.66
21	2,911.10	2,652.32	2,903.82	2,613.44

PB-30-99-87

Month	Forecast			
	Simple Exponential Smoothing	Trend-Corrected Exponential Smoothing	Croston's Method	SBA Method
22	3,073.04	2,627.04	3,067.22	2,760.50
23	3,126.49	2,573.37	3,121.83	2,809.65
24	2,990.81	2,434.60	2,987.09	2,688.38

PB-80-7-4

Month	Forecast			
	Simple Exponential Smoothing	**Trend-Corrected Exponential Smoothing**	**Croston's Method**	**SBA Method**
1	2,075.23	2,931.45	3,919.23	4,031.21
2	2,779.96	3,150.41	3,919.23	4,031.21
3	2,223.97	2,756.09	3,919.23	4,031.21
4	1,779.17	2,373.63	2,743.46	3,224.97
5	1,618.42	2,112.98	2,213.04	2,755.55
6	1,734.08	2,001.37	2,208.14	2,599.84
7	2,726.82	2,397.98	3,555.04	3,285.48
8	3,039.56	2,533.14	3,775.68	3,400.67
9	2,820.15	2,414.06	3,225.72	3,070.19
10	2,930.98	2,459.68	3,270.30	3,063.52
11	3,503.44	2,775.98	3,270.30	3,063.52
12	2,802.75	2,453.55	3,270.30	3,063.52
13	2,242.20	2,138.83	2,289.21	2,450.82
14	2,641.94	2,300.70	1,430.75	1,750.59
15	2,113.55	1,999.28	1,001.53	1,400.47
16	2,009.76	1,883.41	931.65	1,289.90
17	1,607.81	1,600.84	652.16	1,031.92
18	1,597.47	1,501.69	727.92	1,009.81
19	1,696.15	1,471.82	874.24	1,055.46
20	1,869.04	1,502.80	1,058.58	1,147.60
21	2,015.73	1,545.87	1,009.29	1,079.42

PB-80-7-4

Month	Forecast			
	Simple Exponential Smoothing	Trend-Corrected Exponential Smoothing	Croston's Method	SBA Method
22	1,612.59	1,308.92	706.50	863.54
23	1,731.31	1,325.26	684.20	824.36
24	1,385.05	1,106.10	478.94	659.49

PB-80-5-4

Month	Forecast			
	Simple Exponential Smoothing	Trend-Corrected Exponential Smoothing	Croston's Method	SBA Method
1	1,380.02	0.00	0.00	0.00
2	828.01	21.45	0.00	0.00
3	496.81	182.66	0.00	0.00
4	298.08	278.74	0.00	0.00
5	178.85	305.44	0.00	0.00
6	107.31	271.81	0.00	0.00
7	64.39	195.99	0.00	0.00
8	38.63	100.05	0.00	0.00
9	23.18	5.29	0.00	0.00
10	748.51	626.40	217.66	114.56
11	1,804.82	1,931.17	683.35	196.44
12	1,082.89	1,949.52	1,194.47	305.69
13	649.74	1,613.28	238.89	152.84
14	1,213.92	1,836.78	1,387.75	419.34
15	2,042.79	2,521.63	2,414.85	756.64
16	2,540.12	3,207.12	2,839.64	1,048.08
17	1,524.07	2,521.01	567.93	524.04
18	1,971.16	2,522.22	328.35	470.06
19	1,182.70	1,540.83	65.67	235.03
20	3,042.86	2,694.95	60.56	223.52
21	1,825.71	1,966.53	12.11	111.76

PB-80-5-4

Month	Forecast			
	Simple Exponential Smoothing	Trend-Corrected Exponential Smoothing	Croston's Method	SBA Method
22	2,210.31	2,088.96	1,138.99	604.08
23	2,441.07	2,312.58	1,364.36	850.23
24	2,546.72	2,545.75	1,376.00	957.19

PB-30-10-11

Month	Forecast			
	Simple Exponential Smoothing	Trend-Corrected Exponential Smoothing	Croston's Method	SBA Method
1	2,052.81	2,420.31	3,181.12	2,863.01
2	2,437.53	2,559.53	3,340.18	3,006.16
3	2,734.44	2,693.01	3,340.18	3,006.16
4	2,187.55	2,394.01	2,672.14	2,404.93
5	2,078.44	2,281.59	2,466.11	2,219.50
6	2,305.77	2,347.06	2,615.91	2,354.32
7	2,663.24	2,511.23	2,911.35	2,620.21
8	2,342.63	2,341.20	2,541.12	2,287.01
9	2,169.35	2,221.11	2,328.13	2,095.32
10	2,089.92	2,138.15	2,216.95	1,995.25
11	2,284.51	2,201.79	2,386.14	2,147.52
12	2,221.76	2,147.55	2,303.06	2,072.75
13	2,171.56	2,096.97	2,236.60	2,012.94
14	1,935.15	1,942.24	1,987.18	1,788.46
15	1,693.40	1,764.52	1,735.02	1,561.52
16	1,996.12	1,867.05	2,029.42	1,826.48
17	1,971.93	1,826.23	2,029.42	1,826.48
18	1,577.55	1,583.72	1,623.53	1,461.18
19	1,590.60	1,530.32	1,627.39	1,464.65
20	1,556.32	1,458.79	1,585.75	1,427.18
21	1,544.35	1,402.53	1,567.90	1,411.11

PB-30-10-11

Month	Forecast			
	Simple Exponential Smoothing	Trend-Corrected Exponential Smoothing	Croston's Method	SBA Method
22	1,784.82	1,490.35	1,803.66	1,623.29
23	1,754.38	1,459.40	1,769.45	1,592.50
24	1,632.98	1,379.91	1,645.04	1,480.53

PB- 80-3-3

Month	Forecast			
	Simple Exponential Smoothing	Trend-Corrected Exponential Smoothing	Croston's Method	SBA Method
1	1,292.40	1,150.99	839.24	2,496.74
2	1,873.16	1,498.26	839.24	2,496.74
3	1,498.53	1,376.20	466.24	1,920.57
4	1,198.82	1,252.58	304.07	1,379.41
5	959.06	1,128.80	60.81	965.59
6	974.17	1,119.92	312.05	821.67
7	998.63	1,117.88	380.24	729.65
8	1,229.39	1,231.98	776.22	842.80
9	983.51	1,107.11	155.24	589.96
10	1,082.63	1,146.36	906.26	653.67
11	1,514.26	1,378.79	1,144.67	733.26
12	1,211.41	1,250.12	1,208.25	801.59
13	969.13	1,121.81	241.65	561.11
14	1,193.84	1,225.31	1,699.24	810.39
15	1,388.07	1,335.09	2,047.80	999.32
16	1,543.46	1,442.19	2,070.80	1,069.05
17	1,234.77	1,307.65	414.16	748.33
18	1,414.15	1,407.99	230.66	622.41
19	1,131.32	1,271.03	46.13	435.69
20	1,342.20	1,375.49	980.34	693.07
21	1,292.54	1,357.51	682.09	679.38

PB- 80-3-3

Month	Forecast			
	Simple Exponential Smoothing	**Trend-Corrected Exponential Smoothing**	**Croston's Method**	**SBA Method**
22	1,248.55	1,336.35	612.98	666.02
23	1,322.40	1,374.64	841.39	753.47
24	1,392.22	1,417.43	910.94	824.22

APPENDIX B: Inventory Control Policy (s,S) System

Material 1							…					
Month		**January**					**…**	**December**				
Date		1	2	3	4	5	…	27	28	29	30	31
Gross Requirement		694.9	694.9	694.9	694.9		…	403.3	0.0	403.3	403.3	403.3
Scheduled Receipts							…					
PAB	4147.0	3452.1	13239.6	12544.8	11849.9	11849.9	…	10708.2	13934.5	13531.2	13127.9	12724.6
POR		10482.4	0.0	0.0	0.0	0.0	…	3226.3	0.0	0.0	0.0	0.0

Material 2												
Month		**January**					**…**	**December**				
Date		1	2	3	4	5	…	27	28	29	30	31
Gross Requirement		2746.5	2746.5	2746.5	2746.5		…	2134.8	0.0	2134.8	2134.8	2134.8
Scheduled Receipts							…					
PAB	72707.5	69960.9	78504.6	75758.0	73011.5	73011.5	…	74846.7	74846.7	72711.9	70577.1	79116.3
POR		11290.2	0.0	0.0	0.0	0.0	…	0.0	0.0	0.0	10674.0	0.0

Material 3												
Month		**January**					**…**	**December**				
Date		1	2	3	4	5	…	27	28	29	30	31
Gross Requirement		40.7	40.7	40.7	40.7		…	40.1	0.0	40.1	40.1	40.1
Scheduled Receipts							…					
PAB	1013.9	973.3	2020.7	1980.0	1939.4	1939.4	…	1540.7	1540.7	1500.6	1460.6	1420.5
POR		1088.1	0.0	0.0	0.0	0.0	…	0.0	0.0	0.0	0.0	0.0

Material 4							…					
Month		**January**					**…**	**December**				
Date		1	2	3	4	5	…	27	28	29	30	31
Gross Requirement		181.8	181.8	181.8	181.8		…	122.0	0.0	122.0	122.0	122.0
Scheduled Receipts							…					
PAB	4780.4	4598.6	6316.1	6134.3	5952.5	5952.5	…	6131.9	6131.9	6009.9	5888.0	5766.0
POR		1899.2	0.0	0.0	0.0	0.0	…	0.0	0.0	0.0	0.0	0.0

Material 5												
Month		**January**					**…**	**December**				
Date		1	2	3	4	5	…	27	28	29	30	31
Gross Requirement		53.0	53.0	53.0	53.0		…	39.6	0.0	39.6	39.6	39.6
Scheduled Receipts							…					
PAB	1618.1	1565.2	2250.4	2197.5	2144.5	2144.5	…	1986.4	1986.4	1946.8	1907.2	1867.6
POR		738.3	0.0	0.0	0.0	0.0	…	0.0	0.0	0.0	0.0	0.0

APPENDIX C: Inventory Control Policy (s,Q) System

Material 1

Month		**January**					**…**	**December**				
Date		1	2	3	4	5	…	27	28	29	30	31
Gross Requirement		694.9	694.9	694.9	694.9	0.0	…	403.3	0.0	403.3	403.3	403.3
Scheduled Receipts							…					
PAB	4147.0	3452.1	5010.7	6569.4	8128.0	8128.0	…	8876.4	8876.4	8473.1	8069.8	7666.5
POR		2253.5	2253.5	2253.5	0.0	0.0	…	0.0	0.0	0.0	0.0	2253.5

Material 2

Month		**January**					**…**	**December**				
Date		1	2	3	4	5	…	27	28	29	30	31
Gross Requirement		2746.5	2746.5	2746.5	2746.5	0.0	…	2134.8	0.0	2134.8	2134.8	2134.8
Scheduled Receipts							…					
PAB	72707.5	69960.9	67214.4	64467.8	61721.3	61721.3	…	45439.8	45439.8	43305.0	46468.1	44333.3
POR		0.0	0.0	0.0	0.0	0.0	…	0.0	0.0	5297.9	0.0	0.0

Material 3

Month		**January**					**…**	**December**				
Date		1	2	3	4	5	…	27	28	29	30	31
Gross Requirement		40.7	40.7	40.7	40.7	0.0	…	40.1	0.0	40.1	40.1	40.1
Scheduled Receipts							…					
PAB	1013.9	973.3	932.6	891.9	851.3	851.3	…	332.9	382.3	342.2	351.5	360.8
POR		0.0	0.0	0.0	0.0	0.0	…	49.3	0.0	49.3	49.3	49.3

Material 4												
Month		**January**					**…**	**December**				
Date		1	2	3	4	5	…	27	28	29	30	31
Gross Requirement		181.8	181.8	181.8	181.8	0.0	…	122.0	0.0	122.0	122.0	122.0
Scheduled Receipts							…					
PAB	4780.4	4598.6	5527.7	6456.8	7385.8	8496.7	…	11769.7	11769.7	11647.7	11525.7	12514.6
POR		1110.8	1110.8	1110.8	1110.8	0.0	…	0.0	0.0	0.0	1110.8	0.0

Material 5												
Month		**January**					**…**	**December**				
Date		1	2	3	4	5	…	27	28	29	30	31
Gross Requirement		53.0	53.0	53.0	53.0	0.0	…	39.6	0.0	39.6	39.6	39.6
Scheduled Receipts							…					
PAB	1618.1	1565.2	1846.3	2127.5	2408.6	2742.8	…	2791.8	2791.8	2752.2	2712.6	2673.0
POR		334.1	334.1	334.1	334.1	0.0	…	0.0	0.0	0.0	0.0	0.0

APPENDIX D: Inventory Control Policy (R,S) System

Material 1												
Month		**January**					**…**	**December**				
Date		1	2	3	4	5	…	27	28	29	30	31
Gross Requirement		694.9	694.9	694.9	694.9	0.0	…	403.3	0.0	403.3	403.3	403.3
Scheduled Receipts							…					
PAB	4147.0	3452.1	8806.9	8112.0	7417.2	7417.2	…	3855.8	9501.8	9098.5	8695.2	8291.9
POR		6049.7					…	5646.0				

Material 2												
Month		**January**					**…**	**December**				
Date		1	2	3	4	5	…	27	28	29	30	31
Gross Requirement		2746.5	2746.5	2746.5	2746.5	0.0	…	2134.8	0.0	2134.8	2134.8	2134.8
Scheduled Receipts							…					
PAB	72707.5	69960.9	79280.7	76534.1	73787.6	73787.6	…	75622.8	75622.8	73488.0	71353.2	69218.4
POR		12066.3					…					

Material 3												
Month		**January**					**…**	**December**				
Date		1	2	3	4	5	…	27	28	29	30	31
Gross Requirement		40.7	40.7	40.7	40.7	0.0	…	40.1	0.0	40.1	40.1	40.1
Scheduled Receipts							…					
PAB	1013.9	973.3	354.8	314.1	273.5	395.5	…	275.3	395.5	355.4	315.4	355.4
POR		-577.8			122.0		…	120.2			80.1	

Material 4												
Month		**January**					**…**	**December**				
Date		1	2	3	4	5	…	27	28	29	30	31
Gross Requirement		181.8	181.8	181.8	181.8	0.0	…	122.0	0.0	122.0	122.0	122.0
Scheduled Receipts							…					
PAB	4780.4	4598.6	11546.2	11364.4	11182.6	11182.6	…	11240.0	11727.9	11605.9	11484.0	11362.0
POR		7129.3				0.0	…	487.9				365.9

Material 5												
Month		**January**					**…**	**December**				
Date		1	2	3	4	5	…	27	28	29	30	31
Gross Requirement		53.0	53.0	53.0	53.0	0.0	…	39.6	0.0	39.6	39.6	39.6
Scheduled Receipts							…					
PAB	1618.1	1565.2	2311.3	2258.3	2311.3	2311.3	…	2285.0	2364.2	2324.6	2324.6	2285.0
POR		799.1		106.0		0.0	…	79.2		39.6		79.2

APPENDIX E: Inventory Control Policy (R,s,S) System

Material 1												
Month		**January**					**…**	**December**				
Date		1	2	3	4	5	…	27	28	29	30	31
Gross Requirement		694.9	694.9	694.9	694.9	0.0	…	403.3	0.0	403.3	403.3	403.3
Scheduled Receipts							…					
PAB	4147.0	3452.1	11776.7	11081.8	10386.9	10386.9	…	8841.9	8841.9	8438.7	8035.4	7632.1
POR		9019.4					…		0.0			

Material 2												
Month		**January**					**…**	**December**				
Date		1	2	3	4	5	…	27	28	29	30	31
Gross Requirement		2746.5	2746.5	2746.5	2746.5	0.0	…	2134.8	0.0	2134.8	2134.8	2134.8
Scheduled Receipts							…					
PAB	72707.5	69960.9	87824.3	85077.8	82331.2	82331.2	…	84166.4	84166.4	82031.6	79896.8	77762.0
POR		12066.3					…					

Material 3												
Month		**January**					**…**	**December**				
Date		1	2	3	4	5	…	27	28	29	30	31
Gross Requirement		40.7	40.7	40.7	40.7	0.0	…	40.1	0.0	40.1	40.1	40.1
Scheduled Receipts							…					
PAB	1013.9	973.3	932.6	891.9	851.3	851.3	…	331.6	1442.9	1402.9	1362.8	1322.8
POR		0.0			0.0		…	1111.4			0.0	

Material 4												
Month		**January**					**…**	**December**				
Date		1	2	3	4	5	…	27	28	29	30	31
Gross Requirement		181.8	181.8	181.8	181.8	0.0	…	122.0	0.0	122.0	122.0	122.0
Scheduled Receipts							…					
PAB	4780.4	4598.6	13263.6	13081.8	12900.1	12900.1	…	11981.6	11981.6	11859.6	11737.7	11615.7
POR		8846.8				0.0	…	0.0				1829.7

Material 5												
Month		**January**					**…**	**December**				
Date		1	2	3	4	5	…	27	28	29	30	31
Gross Requirement		53.0	53.0	53.0	53.0	0.0	…	39.6	0.0	39.6	39.6	39.6
Scheduled Receipts							…					
PAB	1618.1	1565.2	2996.6	2943.6	2890.6	2890.6	…	2732.5	2732.5	2692.9	2653.3	2613.7
POR		1484.4		0.0		0.0	…	0.0		0.0		0.0

AUTHOR'S BIOGRAPHY

Mohammad Alfian Ghiffari was born in Proboliggo, 24th of July, 1998. Author is the first child of three siblings from Mohammad Fatir Harijadi and Kusnul Khotimah. The author has passed the formal education from MI TPIM Ngletih 1 Kediri, SD Negeri Ngletih 1 Kediri, SMP Negeri 1 Kediri, SMA Negeri 2 Kediri, and moves to undergraduate study on Industrial and System Engineering of Institut Teknologi Sepuluh Nopember Surabaya. During his study as university student, the author was active in several activities such as organization, competition, and internship.

The author was a part of Departemen Keprofesian, Kajian, dan Keilmiahan of Himpunan Mahasiswa Teknik Industri 2017/2018 as a department staff. The assistant of Logistic and Supply Chain Management Laboratory ITS from 2019 to 2020 with the responsibility of as teaching assistant of Production Planning and Inventory Control class, Logistic System class, and Industrial Planning class. The author also active in several national competition and got several achievement such as the 2nd Winner of Competition of Industrial Engineering (CONSTRAIN) 2019 by Industrial Engineering Department of Universitas Hasanuddin. Author also awarded with two scholarships, Beasiswa Peningkatan Prestasi Akademik (PPA) 2017 by Ministry of Research and Technology/National Research and Innovation Agency and Beasiswa Bank Indonesia 2018 and Beasiswa Bank Indonesia 2019 by Bank Indonesia. The author also has experience on internship program on Departemen Penerimaan Barang dan Jasa PT. Petrokimia Gresik in 2019. For further information, author is able to be contacted via email on *alfian.ghiffari@gmail.com.*