TUGAS AKHIR – TI 141501

Analisis Kebijakan Pengendalian Persediaan untuk Produk-produk *Perishable* pada Pabrik Pakan Ternak di Krian

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FINAL PROJECT – TI 141501

Analysis of Inventory Control Policy for Perishable Products at Poultry Feed Factory in Krian

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ANALYSIS OF INVENTORY CONTROL POLICY FOR PERISHABLE PRODUCTS AT POULTRY FEED FACTORY IN KRIAN

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ANALISIS KEBIJAKAN PENGENDALIAN PERSEDIAAN UNTUK PRODUK-PRODUK PERISHABLE PADA PABRIK PAKAN TERNAK DI KRIAN

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ABSTRAK

Keberadaan persediaan tidak dapat dihindari pada setiap perusahaan. Dengan adanya ketidakpastian permintaan yang dihadapi perushaan, persediaan menjadi penting untuk menyeimbangkan pasokan dan persediaan. Walaupun persediaan memegang peranan penting dalam menyeimbangkan pasokan dan permintaan, memiliki persediaan dalam jumlah yang terlalu besar tidak diinginkan karena biaya penyimpanan persediaan akan meningkat. Di lain sisi, memliki persediaan dalam jumlah yang sangat sedikit akan meningkatkan kemungkinan *stockout*. Pabrik pakan ternak di Krian, yang memproduksi produk-produk *perishable*, masih belum mempertimbangkan karakteristik tersebut dalam penentuan kebijakan persediaan. Oleh karena itu, penelitian ini bertujuan untuk menentukan kebijakan pengendalian persediaan untuk produk-produk *perishable* untuk meminimalkan total biaya persediaan. Untuk itu, semua produk akan diklasifikasikan berdasarkan tingkat kepentingannya dengan menggunakan analisis ABC. Lalu, kebijakan pengendalian persediaan akan ditentukan berdasarkan klasifikasi produk. Grup A akan ditinjau dengan menggunakan (R, s, S) dan (s, S) sistem, sedangkan Grup B dan C akan ditinjau dengan menggunakan (R, S) dan (s, Q) sistem. Pada akhirnya, penelitian ini menyarankan bahwa *periodic review* dapat memberikan total biaya persediaan yang paling minimum.

Kata kunci: Kebijakan pengendalian persediaan, *continuous review*, *periodic review*, produk *perishable*.

ANALYSIS OF INVENTORY CONTROL POLICY FOR PERISHABLE PRODUCTS AT POULTRY FEED FACTORY IN KRIAN

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ABSTRACT

The presence of inventory is inevitable in every company. With the demand uncertainty and fierce competition that have to be faced by the company, inventory becomes more important in order to balance the supply and demand. Although inventory plays important role in ensuring the balance of supply and demand, having large quantity of inventory is not desirable because the inventory holding cost will increase. On the other hand, having too small inventory quantity also is not good because the probability of stockout will increase. Poultry feed factory in Krian, which produces perishable products still has not considered the perishable characteristic of its products in determining inventory control policy. Therefore, this research aims to determine the inventory policy for perishable products in order to minimize total inventory cost. To this end, all items in inventory should be classified based on their importance by using ABC analysis. Then, inventory policy will be determined according to their classification. Group A will be reviewed by using (R, s, S) and (s, S) systems, while Group B and C will be reviewed by using (R, S) and (s, Q) systems. Finally, this research suggests that periodic review gives the most minimum expected total inventory cost compared to continuous review.

Keywords: Inventory policy, continuous review, periodic review, perishable products.

PREFACE

Praise the Mighty Lord, Allah SWT, for blessing, guidance, and empowerment in helping the author finished this research report by the time this book had been published.

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Surabaya, July 2015

Author

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CHAPTER 1
INTRODUCTION

Chapter 1 consists of background, problem statement, research objectives, research benefits, research scope, and research outline.

1.1 Background

The presence of inventory is inevitable in every company. With the demand uncertainty and fierce competition that have to be faced by the company, inventory becomes more important in order to balance the supply and demand. Arnold et al. (2008) mentioned that inventory plays important role in maintaining customer service level and operation efficiency. By having inventory, the company still can meet customers' demand although the demand changes, therefore allowing the company to maintain maximum customer service level. Inventory also can make manufacturing operation become more productive by leveling the production size so that the overtime, hiring, firing, and subcontracting costs become lower, allowing the production to run longer so setup cost per item becomes lower, and allowing the company to purchase materials in larger quantity so that quantity discount becomes available for the company.

Although inventory plays important role in ensuring the balance of supply and demand, having large quantity of inventory is not desirable because the inventory holding cost will increase. Tersine (1994) stated that inventory holding cost ranges from 20% to 40% of the inventory investment on an annual basis. In the same way, having too small inventory quantity also is not good because the probability of stockout will increase. Arnold et al. (2008) mentioned that inventory represents 20%-60% of total asset. When the company holds inventory, the company will lose the opportunity to invest the money to other things to expand the business. Thus, the company will want to manage its inventory so that the inventory investment can be minimized along with maintaining maximum service level and low operation cost.

PT. X is a company engaged in agro business. It produces and sells poultry feed, day-old chicks and processed food products. Its largest business is the production of poultry feed, which accounted for 76.37% of the company's total sales. One of its poultry feed factory is located in Krian, East Java. PT. X undergoes asteady increase in sales in recent years, which is also accompanied by the increase in inventories as shown in Figure 1.1. This increase in inventories underlines the need of good inventory control policy so that the inventories can be reduced but still maintaining high sales.

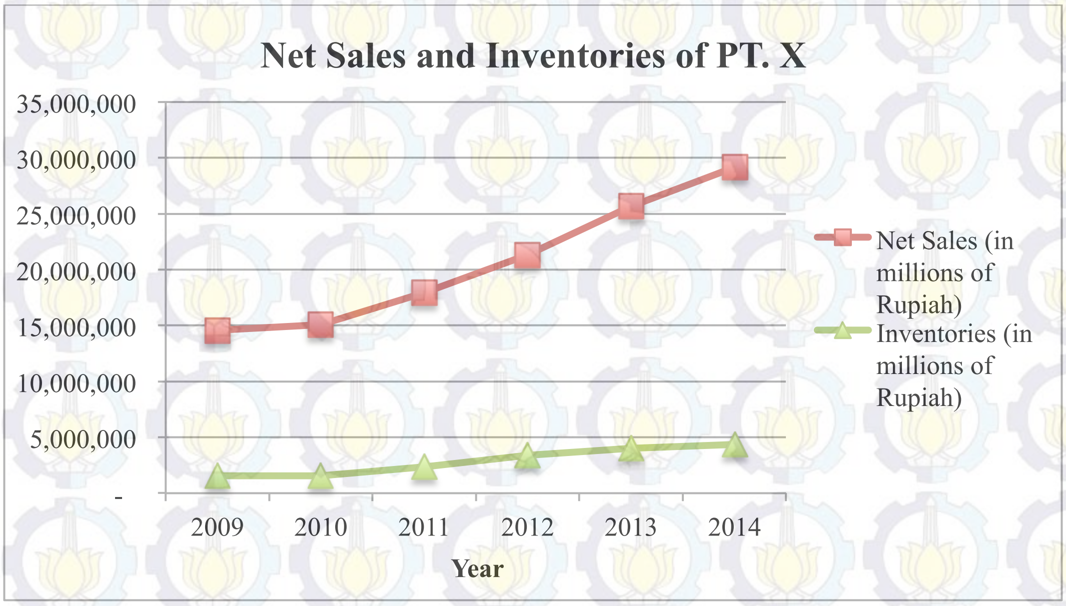

Figure 1.1 Net Sales and Inventories of PT. X (PT. X 2009-2014)

On the other hand, the capacity of warehouse remains the same. It makes the inventory days of supply (IDS) become small. Having small IDS is good for PT. X because it does not have many inventories, thus lowering the inventory holding cost. On the other hand, PT. X is having difficulties in fulfilling orders, especially at the end of the month when the demand increases as the result of additional orders obtained by marketing department that wants to achieve its sales target. This condition cannot be ignored because the company can lose its customers when competitors can offer better products with shorter lead time.

Moreover, the existing inventory control system in PT. X's poultry feed factory in Krian ignores the lifetime of the products although the products are perishable. Therefore, PT. X needs the appropriate inventory control system for perishable finished products that can minimize the total inventory cost along with maintaining maximum service level.

This research aims to determine the appropriate inventory control policy for PT. X's poultry feed factory in Krian that accommodates the perishability of its products in order to minimize total inventory cost. In this case, the existing inventory control policy will be analyzed. Since PT. X produces many types of products, they will be classified by using ABC classification in order to enable the company to give specific attention to specific group of products. From each group, two products will be selected as sample in reviewing the inventory. Subsequently, the inventory will be reviewed by using two systems, continuous and periodic review. The perishability characteristic will also be included in those reviews. From those two systems, the result will be compared in order to find the inventory control system for perishable products with the least total inventory cost.

1.2 Problem Statement

The problem statement for this research is how to determine inventory control policy for perishable products in order to minimize total inventory cost at poultry feed factory in Krian.

1.3 Research Objectives

The objectives of this research are, as follows:

1. To classify the inventory items based on their annual dollar usage.
2. To compare existing inventory control method with the proposed one.
3. To find the appropriate method to control the inventory of perishable products that can minimize total inventory cost.

1.4 Research Benefits

The benefits of this research are, as follows:

1. PT. X will be able to select the most appropriate inventory policy based on the recommendation given on this research.
2. PT. X will be able to minimize its total inventory cost.

3. PT. X will be able to generate more revenue due to good inventory policy, thus also obtaining more profit.

1.5 Research scope

The research scope can be divided into two sub-chapters, namely limitation and assumptions.

1.5.1 Limitation

The limitation of this research is the data used in this research is data from January2012 until December 2014.

1.5.2 Assumptions

The assumptions used in this research are, as follows:

1. All inventory costs are known and constant.
2. Lead time and lifetime of the products are constant.
3. Each product does not lose or decrease in utility before its useful lifetime ends.
4. Products that have not been used until the lifetime ends must be discarded.

1.6 Research Outline

The outline of this research can be seen, as follows:

1. Chapter 1 – Introduction

   Chapter 1 consists of background of the research, problem statement, objectives of the research, benefits of the research, research scope, and research outline.
2. Chapter 2 – Literature Review

   Chapter 2 reviews the existing literatures regarding research topic, such as the definition of inventory, types of inventory, costs associated with inventory, ABC classification, and inventory control policy for perishable products.
3. Chapter 3 – Methodology

   Chapter 3 tells about the methodology used in conducting this research.
4. Chapter 4 – Data Collection and Processing

Chapter 4 presents the data that have been collected and processed based on the methodology developed in the previous chapter.

5. Chapter 5 – Data Analysis and Interpretation

   Chapter 5 analyzes and interpretsthe data that have been gathered and processed for this research.

6. Chapter 6 – Conclusion and Suggestion

   Chapter 6 explains the conclusion obtained from this research. Also, several suggestions for future research are presented.

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CHAPTER 2
LITERATURE REVIEW

Chapter 2 consists of several theories related to this research, such as the definition of inventory, types of inventory, inventory costs, inventory control policy for perishable items, ABC classification, and interval halving.

2.1 Inventory

Tersine (1994, p.3) defined inventory as "material held in an idle or incomplete state awaiting future sale, use, or transformation." All companies require inventory in order to balance supply and demand. Inventory needs to be managed properly in order to enable companies to these following objectives, as stated by Arnold et al. (2008):

1. Maximum customer service
2. Low-cost plant operation
3. Minimum inventory investment

All these objectives eventually lead to companies' goal to maximize profit.

2.1.1 Types of Inventory

Arnold et al. (2008) classified inventory into five different types based on the flow of material, as follows:

1. Raw materials

   Raw material inventories are purchased items that will serve as inputs for the production process, such as purchased materials, component parts, and subassemblies.

2. Work-in-process (WIP)

   Work-in-process (WIP) inventories are items that have been partially processed or waiting to be processed.

3. Finished goods

   Finished good inventories are the final products or completed items as the outputs of the production process that are ready to be sold.

4. Distribution inventories

   Distribution inventories are the final products that are placed in the distribution system.

5. Maintenance, repair, and operational supplies (MROs)

   Maintenance, repair, and operational supplies (MROs) are items consumed in the production process but are not part of the finished goods, such as lubricant, spare parts, and cleaning supplies.

Another inventory classification is based on its utility as mentioned by Tersine (1994). There are six types of inventory, as follows:

1. Working stock

   Working stocks (cycle or lot size stocks) are inventories held in advance due to ordering on a lot size in order to minimize ordering and holding costs, achieve quantity discount, or reduce shipping cost.

2. Safety stock

   Safety stocks (buffer or fluctuation stocks) are inventories held as a protection against the uncertainties of supply and demand.

3. Anticipation stock

   Anticipation stocks (seasonal or stabilization stocks) are inventories held to cover seasonal demand, promotional programs, vacation shutdown, or deficiencies in production capacity.

4. Pipeline stock

   Pipeline stocks (transit stocks or work-in-process) are inventories held in transit due to the time needed to move items from a location to another.

5. Decoupling stock

   Decoupling stocks are inventories held in order to smooth the production or distribution process and reduce the requirement for completely synchronized operations.

6. Psychic stock

   Psychic stocks are inventories held in display in order to increase the chance of an item being seen and purchased, thus stimulating demand.

2.1.2 Inventory Costs

There are several costs associated to inventory, as mentioned by Tersine (1994). They are, as follows:

1. Purchase cost

   Purchase cost is the cost incurred to purchase an item, which is the purchase price plus the freight cost. For item produced internally, purchase cost is the unit production cost, including direct material, direct labor, and factory overhead costs.

2. Order/setup cost

   Order/setup cost is the cost incurred to issue a purchase order to supplier or to set up the production process. According to Fogarty et al. (1991), setup cost consists of cost of obtaining tools, mounting fixtures, receiving information concerning the job, adjusting of machine settings, checking the first item produced, and cleaning the equipment when the job is complete.

3. Holding cost

   Holding cost or carrying cost is the cost incurred due to keeping inventory in warehouse. It consists of several components, such as capital costs, taxes, insurance, handling, storage, shrinkage, obsolescence, and deterioration. Fogarty et al. (1991) stated that holding cost is 24% of total inventory investment, which consists of cost of capital, insurance cost, taxes, spoilage and damage cost, obsolescence cost, and storage and handling cost.

4. Stockout cost

   Stockout cost or depletion cost is the cost incurred as a result of stockout, both internally and externally. Internal shortage happens when order of department within the organization cannot be fulfilled that can result in lost production and delay in completion date. External shortage occurs when customer’s order cannot be fulfilled. It incurs backorder costs, present profit loss, and future profit loss.

2.1.3 Safety Stock

Safety stocks are the extra inventories held as protection against the uncertainties of supply and demand. They are needed due to the possibility of forecast error and supplier's failure in delivering goods on time. Safety stocks affect the inventory cost in two ways; they decrease stockout cost and increase holding cost (Tersine 1994).

The formula to calculate the quantity of safety stocks required by the company for periodic review as written by Madduri (2009) is, as follows

$$SS = \sigma_{R+L} \: x \: k_{sl} \quad (2.1)$$

where

SS = safety stocks

σ_{R+L} = standard deviation of demand during review interval and lead time with the formula $\sigma_{R+L} = (R + L)^{1/2}\sigma_D$

k_{sl} = the factor corresponding the service level from the standard normal table

σ_D = standard deviation of demand

R = review interval

L = lead time

Similarly, the formula to compute the required safety stocks for continuous review, as stated by Madduri (2009) is, as follows

$$SS = \sigma_L \: x \: k_{sl} \quad (2.2)$$

where

σ_L = standard deviation of demand during lead time with formula $\sigma_L = L^{1/2}\sigma_D$

2.2 ABC Classification

Tersine (1994) and Arnold et al. (2008) used ABC analysis to classify the items in inventory. In this analysis, each inventory item is valued by multiplying the unit cost by the annual demand in order to get annual dollar usage. Then, all items are listed in descending order based on their annual dollar usage. After that, classification can be made. Group A or high value item group consists of items whose dollar usage accounts for 75-80% of total inventory value, while representing only 15-20% of inventory items. Group B consists of items with dollar usage accounts for 10-15% of total inventory value, while representing 20-25% of inventory items. Lastly, group C (low value items) consists of items with dollar usage accounts for 5-10% of total inventory value, while representing 60-

65% inventory items. The classifying of inventory items enables the company to give specific attention to specific group of items. For example, group A requires tighter control and more frequent review, group B only requires normal control, and while group C requires simple control.

2.3 Inventory Control Systems

There are various types of inventory control systems. Two of the most commonly used ones are continuous and periodic inventory systems.

2.4.1 Periodic Inventory System

Under periodic inventory system, inventory position is checked at a fixed review interval. Replenishment order is placed when at the time of review, the inventory position is at or below the reorder point. The major advantage of periodic inventory system is that it allows orders consolidation, which is very desirable if items are produced on the same equipment or purchased from the same supplier. On the other hand, the major disadvantage that the safety stock for protection against demand fluctuation during review period and lead time is higher (Tersine 1994).

There are two common control systems for periodic inventory system, as stated by Silver et al. (1998):

1. Periodic-review, order-up-to-level (R, S) system

   In (R, S) system, enough replenishment quantity is ordered every *R* units of time in order to raise the inventory position up to level *S*. This system is often preferred than continuous review system because sometimes it is necessary to coordinate replenishments so that shipping cost can be minimized. On the other hand, the inventory holding costs are higher compared to continuous review systems.
2. (R, s, S) system

   (R, s, S) system is a combination of (s, S) and (R, S) systems. The inventory position will be checked every *R* units of time. If it already reaches the reorder point *s* or even below it, replenishment is ordered to raise inventory position to *S*. If the inventory level is still above the reorder point at the time of review, no action is taken until at least the next review. At its best, this system gives a lower total of replenishment, holding, and shortage costs than any other system. However, it is not as simple as the other systems to compute, therefore it can lead to more errors.

2.4.2 Continuous Inventory System

Under continuous inventory continuous system, inventory position is checked each time a unit is issued from stock. If the inventory position is at or below the reorder point, then replenishment order is placed. If the inventory position is still above the reorder point, no action is taken. In this case, the review period is variable. It is very suitable for independent demand items that need close control. On the other hand, the main disadvantage is it requires continuous monitoring of the inventory position (Tersine 1994).

According to Silver et al. (1998), there are two common control systems for continuous review. They are:

1. Order-point, order-quantity (s, Q) system

   In (s, Q) system, replenishment in the size of *Q* is ordered when the inventory position reaches the reorder point *s* or lower. This system is very simple to understand, thus the occurrence of errors can be reduced. Also, the production requirements for the supplier are predictable, since the same amount of fixed quantity *Q* is always ordered. On the other hand, it is not effective enough in the case where individual transactions are very large because a replenishment of size *Q* will not be able to raise the inventory position above the reorder point *s*.

2. Order-point, order-up-to-level (s, S) system

   (s, S) system is similar to the (s, Q) system. The replenishment order will be placed whenever the inventory position reaches the reorder point *s* or lower, but instead of ordering in fixed quantity of *Q* like in (s, Q) system, the replenishment quantity should be enough to raise the inventory position to the order-up-to-level *S*. This control system is frequently used in practice, although the variable order quantity makes suppliers often make errors. It is suitable for items where the potential saving is appreciable (A items).

2.4 Perishable Inventory Systems

Many inventory models have been developed under the assumption of infinite lifetime of products. This assumption is not really suitable in practice, especially for products with short lifetime. Therefore, the lifetime of products must be considered in developing inventory policy.

Several researches have been conducted in order to develop inventory model for perishable items, such as Chiu (1995) and Chiu (1999). The notation used in this research is, as follows:

Q = order quantity

s = reorder point

R = review interval

S = order-up-to-level

m = fixed lifetime of the perishable item

D = average demand

L = positive order lead time

d_1 = demand in unit time

d_L = demand during lead time with probability function $f_L(d_L)$ and mean LD

d_{m+L} = demand during m + L time units with probability function $f_{m+L}(d_{m+L})$and mean (m + L)D

C = replenishment cost per unit

h = holding cost per unit per time

K = fixed ordering cost per order

W = outdate cost per unit

P = backorder cost per unit

ET = expected cycle length

EI = expected inventory level per unit time

ER = expected outdate quantity of the current order size Q

ES = expected shortage quantity per cycle

E_S = approximate quantity of expected shortage per review interval

E_O = approximate expected outdating per review interval

E_O^a = adjusted outdating per review interval making the approximations of E_S and E_O more accurate

E_H = approximate average inventory level

EOC = expected ordering cost per period

EHC = expected holding cost per period

ESC = expected backorder cost per period

ERC = expected outdate cost per period

EAC = total expected cost per period

2.5.1 *(R, S) Periodic Review Model for Perishable Items*

Chiu (1995) developed a model of (R, S) periodic review for perishable items with positive lead time and fixed lifetime. The implementation of periodic review is needed, especially when the use of continuous review is costly and when replenishment orders should be placed periodically. The paper shows the approximation to the exact expected outdating rather than the optimal one due to complex computation. The approximate expected outdating per review interval is expressed by

$$E_O = \frac{R}{m}\int_0^S (S - d_{m+L} + E_s) f_{m+L}(d_{m+L})\, d\, d_{m+L} \quad (2.3)$$

The approximate quantity of expected shortage per review interval is given by

$$E_s = \int_{S-E_O^a}^{\infty} [d_{R+L} - (S - E_O^a)] f_{R+L}(d_{R+L})\, d\, d_{R+L} \quad (2.4)$$

where

$$E_O^a = \frac{R}{m}\int_0^S (S - d_{m+L}) f_{m+L}(d_{m+L})\, d\, d_{m+L} \quad (2.5)$$

The expected ordering cost per period is

$$EOC = \frac{K}{R} \quad (2.6)$$

The expected holding cost per period is

$$EHC = h\left[S - DL - \frac{(DR + E_O)}{2}\right] \quad (2.7)$$

The expected backorder cost per period is

$$ESC = \frac{P}{R} E_s \quad (2.8)$$

and the expected outdate cost per period is

$$ERC = \frac{W}{R} E_O \tag{2.9}$$

Therefore, the total expected cost per period is given by

$$EAC = EOC + EHC + ESC + ERC \tag{2.10}$$

2.5.2 (s, Q) Continuous Review Model for Perishable Items

Chiu (1999) proposed an (s, Q) continuous review model for perishable items with positive lead time and fixed lifetime. The model uses expected outdating approximation instead of the optimal one because of the extreme difficulty to obtain the optimal expected outdating for a long lifetime item. The approximate expected outdate quantity of the current order size Q is given by

$$ER = \begin{cases} \int_0^{s+Q} (s + Q - d_{m+L}) f_{m+L}(d_{m+L})\, dd_{m+L} - \int_0^{s} (s - d_{m+L}) f_{m+L}(d_{m+L})\, dd_{m+L}, \\ \quad if\ d_{m+L}\ is\ a\ nonnegative\ continuous\ random\ variable \\ \sum_{d_{m+L} < s+Q} (s + Q - d_{m+L}) f_{m+L}(d_{m+L}) - \sum_{d_{m+L} < s} (s - d_{m+L}) f_{m+L}(d_{m+L}), \\ \quad if\ d_{m+L}\ is\ a\ nonnegative\ discrete\ random\ variable \end{cases} \tag{2.11}$$

The expected shortage quantity per cycle can be expressed by

$$ES = \begin{cases} \int_s^{\infty} (d_L - s) f_L(d_L)\, dd_L, \\ if\ d_L\ is\ a\ nonnegative\ continuous\ random\ variable \\ \sum_{d_L > s} (d_L - s) f_L(d_L), \\ if\ d_L\ is\ a\ nonnegative\ discrete\ random\ variable \end{cases} \tag{2.12}$$

The expected cycle length is shown by

$$ET = \frac{(Q - ER)}{D} \tag{2.13}$$

The expected inventory level per unit time is given by

$$EI = \left(s - DL + \frac{Q}{2}\right) + \frac{DL\,(ES - ER)}{2\,(Q - ER)} \tag{2.14}$$

Therefore, the total expected cost per unit time is

$$EAC = \frac{K + P\,(ES) + W\,(ER)}{ET} + h\,(EI) \tag{2.15}$$

2.5 Interval Halving

Ravindran et al. (2006) mentioned region elimination methods, which are search methods that find optimal point in a given interval. The initial phase is bounding phase, which searches the boundaries of the optimum, when they are still unknown. The steps are, as follows:

1. Select x_0 as the starting point and Δ as step-size parameter.
2. Determine the sign of Δ by comparing $f(x_0)$, $f(x_0 + |\Delta|)$, and $f(x_0 - |\Delta|)$. If $f(x_0 - |\Delta|) \geq f(x_0) \geq f(x_0 + |\Delta|)$, Δ is chosen to be positive. Otherwise, Δ is chosen to be negative.
3. Set $x_{k+1} = x_k + 2^k\Delta$, for $k = 0, 1, 2, \ldots$
4. Compute $f(x_{k+1})$.
5. Keep doing the iteration until the value of $f(x_{k+1})$ is bigger than $f(x_k)$.

The second phase is interval refinement phase that reduce the initial search interval to desired accuracy. One of the methods of this phase is interval halving. The steps to find the minimum of function $f(x)$over the interval (a, b) are, as follows:

1. Let $x_m = \frac{1}{2}(a + b)$ and $L = b - a$. Compute $f(x_m)$.
2. Set $x_1 = a + \frac{1}{4}L$ and $x_2 = b - \frac{1}{4}L$. Compute $f(x_1)$ and $f(x_2)$.
3. Compare $f(x_1)$ and $f(x_m)$.
   a. If $f(x_1) < f(x_m)$, set $b = x_m$ and $x_m = x_1$. Go to step 5.
   b. If $f(x_1) \geq f(x_m)$, go to step 4.
4. Compare $f(x_2)$ and $f(x_m)$.
   a. If $f(x_2) < f(x_m)$, set $a = x_m$ and $x_m = x_2$. Go to step 5.
   b. If $f(x_2) \geq f(x_m)$, set $a = x_1$ and $b = x_2$. Go to step 5.
5. Compute $L = b - a$. If $|L|$ is small, stop. Otherwise, return to step 2.

2.6 Related Researches

Bakker et al. (2012) mentioned that over two hundred researches related to inventory control policy for perishable items have been published. Although the perishability has become an important consideration in determining inventory policy, there are still a few researches that have not incorporated perishability although the products are perishable. Table 2.1 shows the previous researches that have been conducted in the field of inventory control policy and also the position of this research regarding the previous ones.

Table 2.1 Previous Researches in Inventory Control Policy

	Author	Object	Method	Perishability	Output
Previous Research	Maulidya (2011)	Raw material	(s, Q) system	No	Reducing safety stock, minimizing total expected cost
	Vivihapsari (2011)	Spare part	(R, s, S) system	No	Maximizing service level
	Deviabahari (2013)	Finished product	Periodic and continuous review	No	Minimizing total inventory cost
	Rahayu (2014)	Consumable product	(R, s, S) system	No	Minimizing total inventory cost
Proposed research	Ghaisani (2015)	Finished product	Periodic and continuous review	Yes	Minimizing total inventory cost

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CHAPTER 3
METHODOLOGY

This chapter explains the methodology that is used in this research. The research methodology is presented in the form of flowchart, as shown in Figure 3.1.

3.1 Literature Review and Field Study Phase

In literature review and field study phases, information related to the problem discussed in this research is gathered. In the literature review phase, information on ABC classification, inventory management, and inventory control policy for perishable items is reviewed. In the field study phase, the information on the company's existing condition and business process is gathered.

3.2 Data Collection Phase

In data collection phase, all the data needed in this research is obtained from PT. X's poultry feed factory in Krian. The data obtained from PT. X is, as follows:

1. Sales
2. Unit price
3. Lead time of products
4. Lifetime of perishable products
5. Inventory costs e.g. setup cost, production cost, backorder cost, outdate cost, and holding cost.

Figure 3.1 Research Methodology

3.3 Data Processing Phase

In data processing phase, data obtained from the previous phase is processed. There are several steps in data processing phase, such as classifying products by using ABC classification system, forecasting demand by using Monte Carlo simulation, calculating the inventory parameters of the existing inventory control system, and calculating the inventory parameters of the proposed inventory control systems for perishable products.

3.3.1 Product Classification

Finished products of PT. X are classified by using ABC Classification. The procedure of ABC classification as stated by Arnold et al. (2008) is as follows:

1. Multiply the annual demand by the price of the product in order to obtain the annual dollar usage.
2. List all products in descending order based on their annual dollar usage.
3. Calculate the cumulative dollar usage and cumulative percentage.
4. Classify the products based on the following criteria:
   a. Group A: 20% of the products that account for 80% of dollar usage.
   b. Group B: 30% of the products that account for 15% of dollar usage.
   c. Group C: 50% of the products that account for 5% of dollar usage.

3.3.2 Calculation of Inventory Parameters of Existing Inventory Control System

The existing inventory control system that is used at PT. X is (R, S) periodic review, regardless of product classification. Therefore, in the calculation of inventory parameters of existing inventory control system, the six samples, two from each group, are calculated by using (R, S) system. The parameters that are sought are review interval *R*, maximum inventory level *S*, and total inventory cost. The procedure as developed by Silver et al. (1998) is as follows:

1. Calculate $Q = \sqrt{\frac{2KD}{Cr}}$
2. Calculate $\frac{Qr}{DB_2}$

3. If $\frac{Qr}{DB_2}$> 1, go to step 4. Otherwise, select k as to satisfy $p_{u\geq}(k) = \frac{Qr}{DB_2}$

   Where

   r = holding cost fraction

   B_2 = backorder cost fraction

   k = safety factor

   $p_{u\geq}$ (k) = probability that a unit normal variable takes on a value of k or larger

   If the value of k is lower than the minimum allowable value specified by management, go to step 4. Otherwise, proceed directly to step 5.
4. Set k at its lowest allowable value.
5. Calculate order-up-to-level $S = \mu_{R+L} + k\,\sigma_{R+L}$ where μ_{R+L} is mean of demand during review interval and lead time and σ_{R+L} is standard deviation of demand during review interval and lead time. Round it to the nearest integer, except if step 4 was used, raise it to next highest integer.
6. Calculate the total expected inventory cost

$$EAC = \left(\frac{K}{R}\right) + \left[\left(\frac{S}{2} + k\,\sigma_{R+L}\right) C\,r\right] + \left(\frac{B_2\,C\,\sigma_{R+L} G_u(k) D}{S}\right)$$

   whereGu(k) is the expected shortage per replenishment cycle, obtained from Table B1 in Appendix B of Silver et al. (1998).

3.3.3 Calculation of Inventory Parameters of Proposed Inventory Control Systems for Perishable Products

The control system used in this research will be different for each group. Group A is reviewed by using (R, s, S) and (s, S) control systems for perishable items, while group B and C is reviewed by using (R, S) and (s, Q) control systems for perishable items.

3.3.4.1 Group A

For products in Group A, the control systems that are used are (R, s, S) for periodic review and (s, S) for continuous review. The procedure is:

1. For periodic review, the expected order-up-to-level$S$ is computed by using formula written by Madduri (2009), as follows:

   $$S = \mu_{R+L} + SS$$

   where

   $SS = \sigma_{R+L}\ x\ k_{sl}$

   $\sigma_{R+L} = (R + L)^{1/2}\sigma_D$

   $\mu_{R+L} = (R + L)\ x\ D$
2. Minimize the expected total inventory cost equations written by Chiu (1995), as shown in Equation 2.3 until Equation 2.10, over the interval 1≤ R <21.
3. Calculate the reorder point $s = S - DR$
4. For continuous review, the reorder point s is computed by using the following formula as stated by Madduri (2009)

   $$s = \mu_L + SS$$

   where

   $SS = \sigma_L\ x\ k_{sl}$

   $\sigma_L = L^{1/2}\sigma_D$

   $\mu_L = L\ x\ D$
5. Search the boundaries of order quantity Q that gives the minimum of the expected total inventory cost equations written by Chiu (1999), as shown in Equation 2.11 until 2.15, by using bounding phase method.
6. Minimize the expected total inventory cost equations written by Chiu (1999), as shown in Equation 2.11 until 2.15, by using interval halving method with interval obtained from bounding phase.
7. Calculate the maximum order quantity $S = s + Q$

3.3.4.2 Group B and C

The review systems for products in both group B and C are (R, S) system for periodic review and (s, Q) system for continuous review. The procedure is, as follows:

1. For periodic review, calculate the maximum order quantity S by using the formula written in Madduri (2009), as follows

   $$S = \mu_{R+L} + SS$$

   where

   $SS = \sigma_{R+L} \ x \ k_{sl}$

   $\sigma_{R+L} = (R + L)^{1/2}\sigma_D$

   $\mu_{R+L} = (R + L) \ x \ D$
2. Minimize the expected total inventory cost equations written by Chiu (1995), as shown in Equation 2.3 until Equation 2.10, over the interval $1 \leq R < 21$.
3. For continuous review, calculate reorder point s by using the formula mentioned by Madduri (2009) as follows

   $$s = \mu_L + SS$$

   where

   $SS = \sigma_L \ x \ k_{sl}$

   $\sigma_L = L^{1/2}\sigma_D$

   $\mu_L = L \ x \ D$
4. Search the boundaries of order quantity Q that gives the minimum of the expected total inventory cost equations written by Chiu (1999), as shown in Equation 2.11 until 2.15, by using bounding phase method.
5. Minimize the expected total inventory cost equations written by Chiu (1999), as shown in Equation 2.11 until 2.15, by using interval halving method with interval obtained from bounding phase.

3.4 Data Analysis and Interpretation Phase

In the data analysis and interpretation phase, each method is compared to find out which method that can generate the biggest savings. In the end, the method that can produce the lowest total inventory cost will be chosen for each product classification.

3.5 Conclusion and Suggestion Phase

In this phase, the conclusion is given based on the results. Also, the suggestion for future improvement is given.

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CHAPTER 4
DATA COLLECTION AND PROCESSING

This chapter presents the data that have been collected and processed according to the methodology presented in Chapter 3.

4.1 Data Collection

In this sub-chapter, the data collected during this research is presented. The data is obtained from the interview with PPIC Manager of PT. X's poultry feed factory in Krian.

4.1.1 Company Overview

PT. X is a company engaged in agro business. It produces and sells poultry feed, day-old chicks and ready-to-eat processed food products. Its largest business is the production of poultry feed, which accounted for 76.37% of the company's total sales in 2014. The production of Day Old Chicks (DOC), which accounted for 11.18% of the company's total sales, is the second-largest business, followed by the production of processed food products with 9.8% and other businesses, such as packaging, poultry equipment and other sales. PT. X has 8 poultry feed factories, 5 processed chicken factories, 1 poultry equipment factory, 1 corn dryer and storage facility, and 29 subsidiaries located in various regions in Indonesia (PT.X 2014).

The vision and mission of PT. X as shown in its 2014 annual report is, as follows:

Vision: *feed a growing world.*

Mission: *to produce and market the highest quality and innovative feed, day old chicks and food products.*

Figure 4.1 shows the organization structure of PT. X.

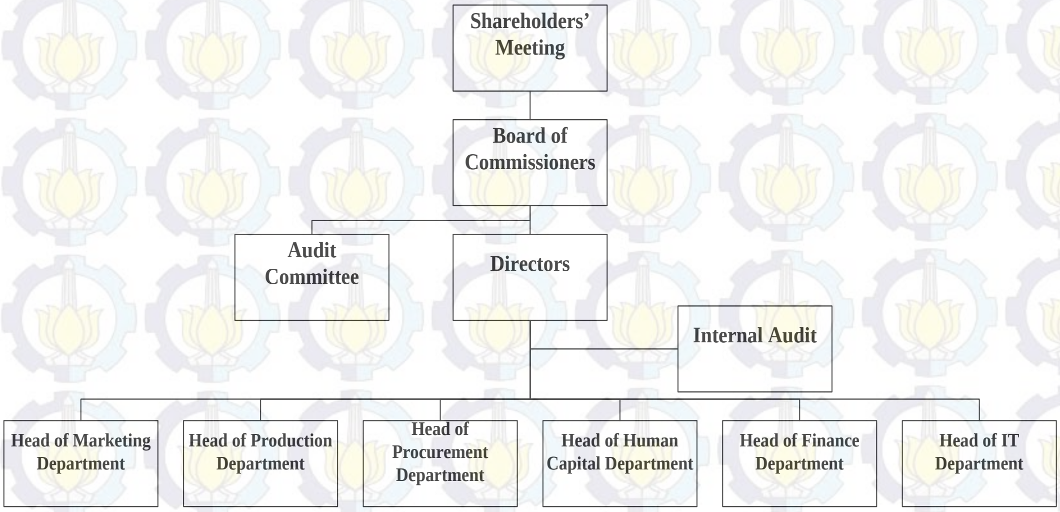

Figure 4.1 Organization Structure of PT. X (PT. X 2014)

PT. X produces various forms of poultry feed products, namely concentrate, mash, pellet, and crumble, which are produced from raw materials such as corn, rice bran, fish meal, soybean meal, meat bone meal, wheat bran, canola, vitamins, trace minerals, and antioxidants. PT. X produces poultry feed for broiler, layer, breeding flock, duck, native chicken, fighting cock, quail, cattle, and swine.

The production process of poultry feed is shown in Figure 4.2. Firstly, the raw materials are grinded in hammer mill. The raw materials can be divided into two, soft and hard ones. The hard materials should be grinded first, while the soft ones can go to the mixing process directly. In mixing process, additives, such as vitamin, are added. The results are products in concentrate form. Some part of them is further processed to be products in concrete form. In the end,products are checked by the quality control department.

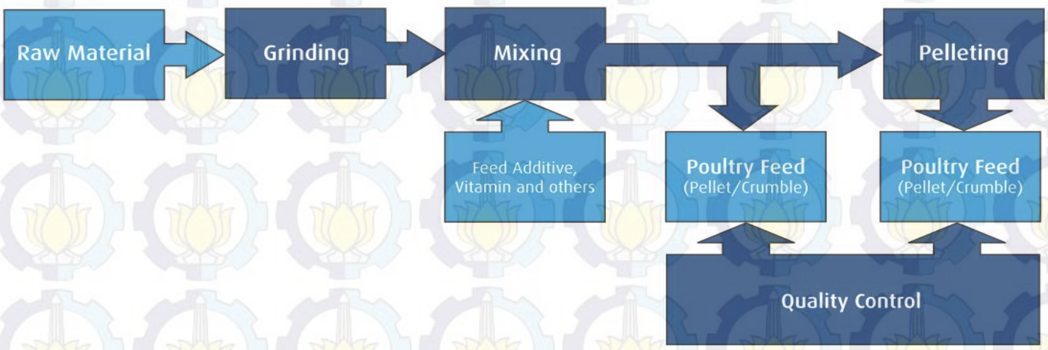

Figure 4.2 Production Process of Poultry Feed (PT. X 2014)

4.1.2 Data Obtained from PT. X

The data obtained from PT. X's poultry feed factory in Krian consists of sales, product price, inventory costs (setup cost, production cost, backorder cost, holding cost, and outdate cost), lead time of the product, and lifetime of the product.

The sales data that is collected for this research is from January 2012 until December 2014. It consists of 65 products. Table 4.1 and Table 4.2 present only several parts of sales data.

Table 4.1 Sales Data of PT. X's Poultry Feed Factory in Krian

Month	Sales (kg)								
	511	512	520	521	…	LK104B	NP104	NP11B	S10
Jan-12	3937700	226750	51120	500220	…	47200	125500	2465500	0
Feb-12	2590000	243000	43440	413760	…	16450	117750	1711000	0
Mar-12	2632050	126650	44100	511980	…	21500	117150	2494000	0
Apr-12	2537950	208500	90240	454740	…	24500	144550	1803000	0
May-12	2744500	113500	53940	424920	…	31000	165000	2290750	90500
Jun-12	3372700	191650	94980	416640	…	35000	86050	1534000	0
Jul-12	3234850	197000	74460	687480	…	42950	160300	1636750	0
Aug-12	3451250	154100	91020	592500	…	39000	100600	2034000	548200
Sep-12	3184050	315650	108840	268140	…	34050	128400	2676000	318600
Oct-12	2866650	308300	50820	401340	…	20750	137700	1540250	0
Nov-12	2868050	203500	28140	489180	…	23850	135250	2055250	0
Dec-12	2605300	245000	82200	605940	…	16900	119950	1685500	0
Jan-13	2336400	222350	21300	358020	…	0	0	0	0
Feb-13	2409950	189000	40140	295440	…	0	0	0	0
Mar-13	2647150	334400	69360	367920	…	0	0	0	0
Apr-13	2668350	187800	78240	332940	…	0	0	0	0
May-13	2508250	203250	38880	409920	…	0	0	0	0
Jun-13	2895400	251750	78540	315240	…	0	0	0	0
Jul-13	3817150	288250	61440	381900	…	0	0	0	0
Aug-13	4193800	173750	71400	559800	…	0	0	0	0
Sep-13	3749650	299750	96180	518460	…	0	0	0	0
Oct-13	3146150	300750	56220	573900	…	0	0	0	0
Nov-13	3769050	305650	86340	517920	…	0	0	0	0
Dec-13	3974100	182000	96960	628260	…	0	0	0	0
Jan-14	1616900	212150	105600	424140	…	20350	96500	1671250	0
Feb-14	1615950	259750	149760	537420	…	18150	131150	1365750	0
Mar-14	2023400	274250	67080	636540	…	27000	87900	1890500	0

Table 4.2 Sales Data of PT. X's Poultry Feed Factory in Krian (Cont'd)

Month	Sales (kg)								
	511	512	520	521	...	LK104B	NP104	NP11B	S10
Apr-14	2431400	418250	97140	750960	...	32300	133850	1782000	0
May-14	3056600	230750	100860	646320	...	25000	74550	2817000	0
Jun-14	3583700	172500	55740	642540	...	15000	51750	2755350	0
Jul-14	4782850	279300	140880	616020	...	18950	97300	2455500	0
Aug-14	3877500	149250	111240	669000	...	13000	75000	1638000	0
Sep-14	4468350	247250	102000	509400	...	26400	67050	2262000	0
Oct-14	2979950	270500	47820	535260	...	10250	28000	2651750	0
Nov-14	3577400	320500	186660	611040	...	11250	61000	2260000	0
Dec-14	4021550	372750	77700	669660	...	12400	45350	2057000	0

The price data is also collected for each product. Table 4.3 shows the price per 1 kilogram of some products.

Table 4.3 Product Price

Product	Price/kg (Rp)
511	5,600
512	5,300
520	5,500
521	5,500
⋮	⋮
LK104B	5,500
NP104	5,400
NP11B	5,500
S10	5,500

The lead time of the product is 1 day and assumed to be constant. The lifetime of the product is 21 days.

The inventory costs of the products, which consist of setup, production, holding, backorder, and outdate costs, are shown in Table 4.4. The holding cost is 24% per unit per year, while the backorder cost is 30% per unit short.

Table 4.4 Inventory Costs

Product	Setup Cost (Rp)	Production Cost (Rp)	Holding Cost (Rp/unit/month)	Backorder Cost (Rp)	Outdate Cost (Rp)
511	2,220,570	4,780	96	1,434	1,912
512	2,220,570	4,481	90	1,344	1,792
520	2,220,570	4,680	94	1,404	1,872
521	2,220,570	4,680	94	1,404	1,872
.	.	.	.	.	.
LK104B	2,220,570	4,481	90	1,344	1,792
NP104	2,220,570	4,581	92	1,374	1,832
NP11B	2,220,570	4,680	94	1,404	1,872
S10	2,220,570	4,680	94	1,404	1,872

4.2 Data Processing

Data that have been collected is processed based on the methodology in Chapter 3. Data processing consists of product classification, Monte Carlo simulation, calculation of inventory parameters of existing inventory control system, and calculation of inventory parameters of proposed inventory control systems for perishable products.

4.2.1 Product Classification

The 65 products are classified by using ABC classification. In this case, the products are divided into three groups based on their total dollar usage. The total dollar usage is obtained by multiplying annual demand and the price of the product. Then, products are sorted based on their total dollar usage in descending order. The calculation of product dollar usage is presented in Table 4.5until Table 4.7.

Table 4.5 Product Dollar Usage

Product	Price/kg (Rp)	Annual Demand (kg)	Annual DollarUsage (Rp)
511B	5,600	5069050	114,486,050
511	5,600	38035550	38,035,550
534IJ	5,500	1623450	38,004,650
551	5,700	11150750	30,515,350
NP11B	5,500	218100	25,606,100
BP104	5,500	827800	22,050,750
S11	5,500	169350	18,285,750
532J	5,400	2642800	17,657,500
524P	5,300	3357250	16,940,350
552	5,400	10441150	11,668,800
S12G	5,300	155600	11,150,750

Table 4.6 Product Dollar Usage (Cont'd)

Product	Price/kg (Rp)	Annual Demand (kg)	Annual Dollar Usage (Rp)
512BG	5,300	4798000	10,441,150
CP11	5,500	596000	9,386,800
594	5,500	6770950	7,904,350
521	5,500	25606100	7,248,300
591	5,500	7904350	6,975,850
534HG	5,400	1797450	6,770,950
534IJ42	5,400	1399450	5,372,950
592	5,400	7248300	5,069,050
550	5,500	11668800	4,940,200
535	5,400	17657500	4,930,100
511SB	5,500	4940200	4,798,000
524	5,400	18285750	3,357,250
522	5,400	22050750	3,286,560
512	5,300	38004650	3,207,200
BP104B	5,500	765850	3,050,600
531J	5,400	3207200	2,815,100
593	5,400	6975850	2,642,800
534IJL	5,400	1032450	2,502,700
534IJ87	5,400	1086800	2,481,750
BP11B	5,500	751450	2,085,500
512B	5,300	4930100	2,079,650
534ISY	5,300	949400	1,797,450
BP12BG	5,300	653850	1,623,450
532HG	5,400	2815100	1,399,450
520	5,500	30515350	1,242,480
5104P	5,400	5372950	1,086,800
CP12G	5,400	521000	1,032,450
NP104	5,400	230050	949,400
582M	5,400	852900	852,900
534IJ45	5,400	1242480	827,800
532J45	5,400	2481750	765,850
555	5,300	9386800	751,450
532J42	5,400	2502700	699,850
544	5,300	16940350	653,850
532Y	5,300	2085500	596,000
HG12B20	5,500	0	521,000
532B	5,400	3050600	403,100
511BL	5,400	0	350,300
SB11	5,400	0	262,250
533RK	5,300	2079650	250,550
L11	5,400	262250	230,800
LK104B	5,300	230800	230,050
L104	5,400	350300	218,100
HG11B	5,500	403100	193,500
531H	5,400	3286560	169,350
LK104	5,300	250550	155,600
SB11SP	5,400	0	141,000
510	5,500	114486050	-

Table 4.7 Product Dollar Usage (Cont'd)

Product	Price/kg (Rp)	Annual Demand (kg)	Annual Dollar Usage (Rp)
BP11J	5,400	699850	-
S10	5,500	193500	-
SB10B	5,500	141000	-
SB11B	5,500	0	-
SB12B	5,300	0	-
NP52	5,300	0	-

After obtaining the annual dollar usage, the cumulative dollar usage and cumulative percentage are also calculated in order to assign products to their respective group. The classification of products is shown in Table 4.8 and Table 4.9.

Table 4.8 Product Classification

Product	Product Value (Rp)	CumulativeDollar Usage	Cumulative Percentage	Classification
511B	114,486,050	114,486,050	24.72%	A
511	38,035,550	152,521,600	32.93%	A
534IJ	38,004,650	190,526,250	41.14%	A
551	30,515,350	221,041,600	47.73%	A
NP11B	25,606,100	246,647,700	53.25%	A
BP104	22,050,750	268,698,450	58.02%	A
S11	18,285,750	286,984,200	61.96%	A
532J	17,657,500	304,641,700	65.78%	A
524P	16,940,350	321,582,050	69.43%	A
552	11,668,800	333,250,850	71.95%	A
S12G	11,150,750	344,401,600	74.36%	A
512BG	10,441,150	354,842,750	76.61%	A
CP11	9,386,800	364,229,550	78.64%	A
594	7,904,350	372,133,900	80.35%	B
521	7,248,300	379,382,200	81.91%	B
591	6,975,850	386,358,050	83.42%	B
534HG	6,770,950	393,129,000	84.88%	B
534IJ42	5,372,950	398,501,950	86.04%	B
592	5,069,050	403,571,000	87.14%	B
550	4,940,200	408,511,200	88.20%	B
535	4,930,100	413,441,300	89.27%	B
511SB	4,798,000	418,239,300	90.30%	B
524	3,357,250	421,596,550	91.03%	B
522	3,286,560	424,883,110	91.74%	B
512	3,207,200	428,090,310	92.43%	B
BP104B	3,050,600	431,140,910	93.09%	B
531J	2,815,100	433,956,010	93.70%	B
593	2,642,800	436,598,810	94.27%	B
534IJL	2,502,700	439,101,510	94.81%	B
534IJ87	2,481,750	441,583,260	95.34%	C
BP11B	2,085,500	443,668,760	95.79%	C

Table 4.9 Product Classification (Cont'd)

Product	Product Value (Rp)	CummulativeDollar Usage	Cummulative Percentage	Classification
512B	2,079,650	445,748,410	96.24%	C
534ISY	1,797,450	447,545,860	96.63%	C
BP12BG	1,623,450	449,169,310	96.98%	C
532HG	1,399,450	450,568,760	97.28%	C
520	1,242,480	451,811,240	97.55%	C
5104P	1,086,800	452,898,040	97.79%	C
CP12G	1,032,450	453,930,490	98.01%	C
NP104	949,400	454,879,890	98.21%	C
582M	852,900	455,732,790	98.40%	C
534IJ45	827,800	456,560,590	98.58%	C
532J45	765,850	457,326,440	98.74%	C
555	751,450	458,077,890	98.90%	C
532J42	699,850	458,777,740	99.06%	C
544	653,850	459,431,590	99.20%	C
532Y	596,000	460,027,590	99.33%	C
HG12B20	521,000	460,548,590	99.44%	C
532B	403,100	460,951,690	99.52%	C
511BL	350,300	461,301,990	99.60%	C
SB11	262,250	461,564,240	99.66%	C
533RK	250,550	461,814,790	99.71%	C
L11	230,800	462,045,590	99.76%	C
LK104B	230,050	462,275,640	99.81%	C
L104	218,100	462,493,740	99.86%	C
HG11B	193,500	462,687,240	99.90%	C
531H	169,350	462,856,590	99.94%	C
LK104	155,600	463,012,190	99.97%	C
SB11SP	141,000	463,153,190	100.00%	C
510	-	463,153,190	100.00%	C
BP11J	-	463,153,190	100.00%	C
S10	-	463,153,190	100.00%	C
SB10B	-	463,153,190	100.00%	C
SB11B	-	463,153,190	100.00%	C
SB12B	-	463,153,190	100.00%	C
NP52	-	463,153,190	100.00%	C

After obtaining the product classification, two products from each group are selected as samples to be further processed. They are product 511B and 511 from group A, product 594 and 521 from group B, and product 534IJ87 and BP11B from group C.

4.2.2 Calculation of Inventory Parameters of Existing Inventory Control System

The existing inventory control system for all products in PT. X's poultry feed factory in Krian is (R, S) periodic system with 1-day review interval. The perishable characteristic of the products is still ignored. The calculation of the expected total inventory cost is based on procedure in sub-chapter 3.3.3. The safety stock has been predetermined by the company and is different for each group, as the following:

a. Group A: $SS = 4\ k\ \sigma_{R+L}$
b. Group B: $SS = 2\ k\ \sigma_{R+L}$
c. Group C: $SS = k\ \sigma_{R+L}$

The calculation result of product 511B by using existing inventory control system is presented in Table 4.10.

Table 4.10 Expected Inventory Cost of Product 511B by Using Existing System

PRODUCT 511B	
Lead time (day)	1
Review interval (day)	1
Setup cost (Rp)	2,220,570
Production cost (Rp)	4,780
Holding cost fraction (Rp/kg/year)	0.24
Backorder cost fraction (Rp/kg)	0.30
Demand (kg)	6,470,625
Order quantity (kg)	158,271
$p_{u\geq}(k)$	0.019568
Safety factor	2.06
μ_{R+L} (kg)	431,375
σ_{R+L} (kg)	1,173,901
Safety stock (kg)	9,672,948
Order-up-to-level (kg)	10,104,323
$G_u(k)$	0.007219
Expected total inventory cost (kg)	2,853,652,724

The calculation of other products is the same as product 511B. The result is shown in Appendix.

4.2.3 Calculation of Inventory Parameters of Proposed Inventory Control Systems for Perishable Products

4.2.4.1 Group A

The calculation of inventory parameters of proposed inventory control systems for perishable products in Group A is done by using the procedure in sub-chapter 3.3.4.1. The (R, s, S) and (s, S) inventory control systems are used for this group.

For (R, s, S) periodic review, the review interval (R) that gives the optimum expected total inventory cost is search with boundaries $1 \leq R < 20$. The calculation of product 511B is shown in Table 4.11.

Table 4.11 Search of Minimum Expected Inventory Cost of Product 511B

Review Interval	Expected Total Inventory Cost (Rp)
1	1,434,897,029
2	1,250,571,472
3	1,169,666,685
4	1,161,840,926
5	1,217,561,919
6	1,391,913,290
7	1,551,825,971
8	1,771,143,255
9	2,049,460,899
10	2,386,589,439
11	2,782,984,184
12	3,238,973,938
13	3,766,483,210
14	4,342,720,168
15	4,982,387,301
16	5,687,515,177
17	6,460,468,489
18	7,304,533,067
19	8,224,621,702
20	9,226,660,488

After obtaining the review interval that can give the optimum expected total inventory cost, the review interval is used to calculate the inventory parameters. In the case of product 511B, the review interval is 4 days. The calculation of product 511B by using (R, s, S) periodic inventory control system for perishable product is shown in Table 4.12.

Table 4.12 Expected Inventory Cost of Product 511B by Using (R, s, S) System

PRODUCT 511B	
Lead time (day)	1
Lifetime (day)	21
Review interval (day)	4
Setup cost (Rp)	2,220,570
Holding cost (Rp)	96
Backorder cost (Rp)	1,434
Outdate cost (Rp)	1,912
Demand (kg)	6,470,625
μ_{m+L} (kg)	4,745,125
σ_{m+L} (kg)	3,893,390
μ_{R+L}(kg)	1,078,438
σ_{R+L} (kg)	1,856,101
k_{sl}	1.645
Safety stock (kg)	3,053,286
Order-up-to-level (kg)	4,131,724
Reorder point (kg)	3,268,974
f_{m+L} (d_{m+L})	0.00000008
f_{R+L} (d_{R+L})	0.00000006
Expected backorder quantity (kg)	367,150
Expected outdate quantity (kg)	153,181
Expected total inventory cost (Rp)	1,161,840,926

For continuous review, order quantity (Q) that gives the optimum total inventory cost is searched by using interval halving method. But, since the boundaries of Q are unknown, the boundaries are searched first by using bounding phase method with initial Q equal to the optimum order quantity (EOQ). Then, with step size of Δ, the boundaries are searched until the iteration result shows higher value than the previous iteration. In the case of product 511B, the step size is 500000. The bounding phase method of product 511B is shown in Table 4.13.

Table 4.13 Bounding Phase of Product 511B

Iteration	Q	EAC
0	548,266	19,767,191,452
1	1,048,266	12,033,645,784
2	2,048,266	8,509,959,440
3	4,048,266	8,163,670,521
4	8,048,266	12,400,716,952

After obtaining the boundaries of Q, the interval halving calculation of product 511B is done in 15 iterations with boundaries $2048266 \leq Q \leq 8048266$, as shown in Table 4.14.

Table 4.14 Interval Halving of Product 511B

Iteration	a	b	L	Q_1	Q_m	Q_2	EAC(1)	EAC(m)	EAC(2)
1	2,048,266	8,048,266	6,000,000	3,548,266	5,048,266	6,548,266	7,975,403,908	8,821,162,884	10,329,657,250
2	2,048,266	5,048,266	3,000,000	2,798,266	3,548,266	4,298,266	7,958,581,796	7,975,403,908	8,296,740,803
3	2,048,266	3,548,266	1,500,000	2,423,266	2,798,266	3,173,266	8,133,624,977	7,958,581,796	7,918,463,114
4	2,798,266	3,548,266	750,000	2,985,766	3,173,266	3,360,766	7,924,491,299	7,918,463,114	7,936,460,826
5	2,985,766	3,360,766	375,000	3,079,516	3,173,266	3,267,016	7,918,212,944	7,918,463,114	7,924,684,048
6	2,985,766	3,173,266	187,500	3,032,641	3,079,516	3,126,391	7,920,493,010	7,918,212,944	7,917,585,105
7	3,079,516	3,173,266	93,750	3,102,954	3,126,391	3,149,829	7,917,674,957	7,917,585,105	7,917,850,023
8	3,102,954	3,149,829	46,875	3,114,672	3,126,391	3,138,110	7,917,585,264	7,917,585,105	7,917,673,634
9	3,114,672	3,138,110	23,438	3,120,532	3,126,391	3,132,250	7,917,541,945	7,917,585,105	7,917,629,002
10	3,114,672	3,126,391	11,719	3,117,602	3,120,532	3,123,461	7,917,563,478	7,917,541,945	7,917,606,200
11	3,117,602	3,123,461	5,859	3,119,067	3,120,532	3,121,997	7,917,552,680	7,917,541,945	7,917,531,273
12	3,120,532	3,123,461	2,930	3,121,264	3,121,997	3,122,729	7,917,579,394	7,917,531,273	7,917,568,737
13	3,121,264	3,122,729	1,465	3,121,630	3,121,997	3,122,363	7,917,598,118	7,917,531,273	7,917,550,005
14	3,121,630	3,122,363	732	3,121,813	3,121,997	3,122,180	7,917,607,480	7,917,531,273	7,917,540,639
15	3,121,813	3,122,180	366	3,121,905	3,121,997	3,122,088	7,917,569,376	7,917,531,273	7,917,578,740

After obtaining the order quantity that can give the optimum expected total inventory cost, the order quantity is used to calculate the inventory parameters. In the case of product 511B, the order quantity is 341,773kilograms. The calculation result of product 511B by using (s, S) continuous inventory control system for perishable product is shown in Table 4.15.

Table 4.15Expected Inventory Cost of Product 511B by Using (s, S)System

PRODUCT 511B	
Lead time	1
Lifetime (day)	21
Setup cost (Rp)	2,220,570
Holding cost (Rp)	96
Backorder cost (Rp)	1,434
Outdate cost (Rp)	1,912
Demand (kg)	6,470,625
Order quantity (kg)	3,121,997
μ_{m+L}(kg)	4,745,125
σ_{m+L} (kg)	3,893,390
μ_{L}(kg)	215,688
σ_{L}(kg)	830,074
k_{sl}	1.645
Safety stock (kg)	1,365,471
Reorder point (kg)	1,581,159
Order-up-to-level (kg)	4,703,155
f_{m+L} (d_{m+L})	0.0000001
f_{L} (d_{L})	0.0000000547
Expected outdate quantity (kg)	784,780
Expected shortage quantity (kg)	875,820
Expected total inventory cost (Rp)	7,917,531,273

The calculation of product 511, both using (R, s, S) periodic system and (s, S) continuous system, is done in the same manner of product 511B. The result is presented in Appendix.

4.2.4.2 Group B and C

The calculation of inventory parameters of proposed inventory control systems for perishable products in Group B and C is done by using the procedure in sub-chapter 3.3.4.2. The (R, S) and (s, Q) inventory control systems are sued for these groups.

For (R, S) periodic review, the review interval (R) that gives the optimum expected total inventory cost is search with boundaries $1 \leq R < 20$. The calculation of product 594 is shown in Table 4.16.

Table 4.16 Search of Minimum Expected Inventory Cost of Product 594

Review Interval	Expected Total Inventory Cost (Rp)
1	153,297,584
2	142,916,948
3	138,465,971
4	162,767,598
5	193,885,441
6	231,411,721
7	252,866,729
8	302,906,818
9	360,610,786
10	399,742,936
11	444,690,927
12	495,981,526
13	554,221,640
14	620,174,427
15	1,090,735,015
16	1,212,212,277
17	1,350,384,201
18	1,507,811,565
19	1,687,297,935
20	1,892,315,627

After obtaining the review interval that can give the optimum expected total inventory cost, the review interval is used to calculate the inventory parameters. In the case of product 594, the review interval is 3 days. The calculation result of product 594 by using (R, S) periodic inventory control system for perishable product is shown in Table 4.17.

Table 4.17Expected Inventory Cost of Product 594 by Using (R, S) System

PRODUCT 594	
Lead time (day)	1
Lifetime (day)	21
Review interval (day)	3
Setup cost (Rp)	2,220,570
Holding cost (Rp)	94
Backorder cost (Rp)	468
Outdate cost (Rp)	1,872
Demand (kg)	467,857
μ_{m+L} (kg)	343,095
σ_{m+L}(kg)	143,149
μ_{R+L} (kg)	62,381
σ_{R+L} (kg)	61,039
k_{sl}	1.645
Safety stock (kg)	100,409
Order-up-to-level (kg)	162,790
f_{m+L} (d_{m+L})	0.000002
f_{R+L} (d_{R+L})	0.0000005
Expected backorder quantity	176,820
Expected outdate quantity (kg)	12,010
Expected total inventory cost (kg)	138,465,971

For continuous review, order quantity (Q) that gives the optimum total inventory cost is searched by using interval halving method. But, since the boundaries of Q are unknown, the boundaries are searched first by using bounding phase method with initial Q equal to the optimum order quantity (EOQ). Then, with step size of Δ, the boundaries are searched until the iteration result shows higher value than the previous iteration. In the case of product 594, the step size is 100000. The bounding phase method of product 594 is shown in Table 4.18.

Table 4.18 Bounding Phase of Product 594

Iteration	Q	EAC
0	148,993	1,433,556,523
1	248,993	1,305,040,626
2	448,993	1,852,159,536

After obtaining the boundaries of Q, the interval halving calculation of product 594 is done in 15 iterations with boundaries 148993≤ Q ≤ 448993, as shown in Table 4.19.

Table 4.19 Interval Halving of Product 594

Iteration	a	b	L	Q_1	Q_m	Q_2	EAC(1)	EAC(m)	EAC(2)
1	148,993	448,993	300,000	223,993	298,993	373,993	1,300,486,849	1,360,714,380	1,543,516,000
2	148,993	298,993	150,000	186,493	223,993	261,493	1,332,405,058	1,300,486,849	1,313,538,411
3	186,493	261,493	75,000	205,243	223,993	242,743	1,309,769,121	1,300,486,849	1,302,273,640
4	205,243	242,743	37,500	214,618	223,993	233,368	1,303,628,507	1,300,486,849	1,300,115,952
5	223,993	242,743	18,750	228,680	233,368	238,055	1,299,971,239	1,300,115,952	1,300,881,385
6	223,993	233,368	9,375	226,337	228,680	231,024	1,300,144,830	1,299,971,239	1,299,962,688
7	228,680	233,368	4,688	229,852	231,024	232,196	1,299,937,342	1,299,962,688	1,300,017,461
8	228,680	231,024	2,344	229,266	229,852	230,438	1,299,946,849	1,299,937,342	1,299,942,646
9	229,266	230,438	1,172	229,559	229,852	230,145	1,299,942,080	1,299,937,342	1,299,947,336
10	229,559	230,145	586	229,706	229,852	229,999	1,299,947,068	1,299,937,342	1,299,942,339
11	229,706	229,999	293	229,779	229,852	229,926	1,299,942,203	1,299,937,342	1,299,947,196
12	229,779	229,926	146	229,816	229,852	229,889	1,299,947,130	1,299,937,342	1,299,942,269
13	229,816	229,889	73	229,834	229,852	229,871	1,299,949,593	1,299,937,342	1,299,939,806
14	229,834	229,871	37	229,843	229,852	229,862	1,299,943,468	1,299,937,342	1,299,945,931
15	229,843	229,862	18	229,848	229,852	229,857	1,299,947,762	1,299,937,342	1,299,941,637

After obtaining the order quantity that can give the optimum expected total inventory cost, the order quantity is used to calculate the inventory parameters. In the case of product 594, the order quantity is 229,852 kilograms. The calculation result of product 594 by using (s, Q) continuous inventory control system for perishable product is shown in Table 4.20.

Table 4.20 Expected Inventory Cost of Product 594 by Using (s, Q) System

PRODUCT 594	
Lead time (day)	1
Lifetime (day)	21
Setup cost (Rp)	2,220,570
Holding cost (Rp)	94
Backorder cost (Rp)	1,404
Outdate cost (Rp)	1,872
Demand (kg)	467,857
Order quantity (kg)	229,852
μ_{m+L} (kg)	343,095
σ_{m+L} (kg)	143,149
μ_L (kg)	15,595
σ_L (kg)	30,519
k_{sl}	1.645
Safety stock (kg)	50,205
Reorder point (kg)	65,800
f_{m+L} (d_{m+L})	0.000002
f_L (d_L)	0.0000004
Expected outdate quantity (kg)	83,080
Expected shortage quantity (kg)	174,550
Expected total inventory cost (Rp)	1,299,937,342

The calculation of product 521 of group B, and 534IJ87 and BP11B of group C, both using (R, S) periodic system and (s, Q) continuous system, is done in the same manner of product 594. The result is presented in Appendix.

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CHAPTER 5
DATA ANALYSIS AND INTERPRETATION

Chapter 5 presents the data analysis that consists of three sub-chapters, namely analysis of product classification, analysis of existing inventory control system, and analysis of proposed inventory control systems for perishable products.

5.1 Analysis of Product Classification

PT. X's poultry feed factory in Krian produces many types of product. In order to enable the company to give specific attention to specific group of products, products are classified based on their value. In this research, ABC classification is used, where those products are classified into three groups. In order to do that, the annual demand is multiplied by the price of the product in order to obtain the annual dollar usage. Then, all products are listed in descending order based on their dollar usage. Subsequently, the cumulative dollar usage and cumulative percentage are computed. Then, 20% of the products that account for 80% of dollar usage are classified into Group A, 30% of the products that account for 15% of dollar usage are grouped into Group B, while 50% of the products that account for 5% of dollar usage are considered to be in Group C.

Based on the classification, Group A consists of 13 products, which represents 20% of total product. They are product 511B, 511, 534IJ, 551, NP11B, BP104, S11, S32J, 524P, 552, S12G, 512BG, and CP11. Those 13 products account for 78.95% of total annual dollar usage. In conclusion, Group A consists of products that have high and frequent demand.

Group B consists of 16 products which represents 24.62% of total products, namely product 594, 521, 591, 534HG, 534IJ42, 592, 550, 535, 511SB, 524, 522, 512, BP104B, 531J, 593, and 534IJL. All of 16 products in Group B account for 15.97% of total annual dollar usage. To conclude, Group B is made up of products that have medium demand.

Similarly, Group C consists of 36 products, which represent 55.38% of total products, such as product 534IJ87, BP11B, 512B, 534ISY, and other products, but only account for 5.08% of total annual dollar usage. To sum up, products in Group C are products that have low and less frequent demand.

5.2 Analysis of Existing Inventory Control System

The existing inventory control system at poultry feed factory in Krian is (R, S) periodic system with predetermined 1-day review interval. The safety stock has been predetermined by the company and is different for each group. In this case, the amount of safety stock of products in Group A should cover demand in 4 days, the amount of safety stock of products in Group B should cover demand in 2 days, while the amount of safety stock of products in Group C is equal to demand in 1 day. In addition, the existing inventory control policy does not include the perishable characteristic of the products into calculation even though the products are perishable.

Based on the calculation in sub-chapter 4.2.3, this existing system makes the expected total inventory cost become expensive. In Group A, product 511B has expected total inventory cost as much as Rp 2,853,652,724 with safety stock of 9,672,948 kilograms and order-up-to-level of 10,104,323 kilograms. Similarly, the expected total inventory cost of product 511 is Rp 500,916,099 with safety stock of 1,492,050 kilograms and order-up-to-level of 1,699,783 kilograms.

In Group B, product 594's expected total cost is Rp 142,938,309 with safety stock of 125,167 kilograms and order-up-to-level of 156,358 kilograms. In the same manner, product 521 has expected total inventory cost as much as Rp 125,398,407 with safety stock of 94,580 kilograms and order-up-to-level of 128,423 kilograms.

In Group C, the expected total inventory cost of product 534IJ87 is Rp 117,166,464 with safety stock as much as 37,539 kilograms and order-up-to-level as much as 50,950 kilograms. Likewise, product BP11B has expected total inventory cost as much as Rp 105,026,420 with safety stock of 26,054 kilograms and order-up-to-level of 33,872 kilograms.

5.3 Analysis of Proposed Inventory Control Systems for Perishable Products

The inventory control policy that is proposed for this research is different for each group. For Group A, the proposed inventory control policies are (R, s, S) periodic system and (s, S) continuous systems, while for Group B and Group C, the proposed inventory control policies are (R, S) periodic system and (s, Q) periodic system. Here, the periodic and continuous review systems are compared in order to find the system that can give the minimum expected total inventory cost. In addition, the proposed inventory control policies consider the perishable characteristic of products.

5.4.1 Proposed Inventory Control Systems for Perishable Products in Group A

Group A consists of products that have high and frequent demand. Therefore they require tighter control and more frequent review. In this case, the most two appropriate inventory control systems are (R, s, S) periodic system and (s, S) continuous system.

In (R, s, S) periodic system, the inventory position will be checked every *R* units of time. If it already reaches the reorder point *s* or even below it, replenishment is ordered to raise inventory position to *S*. If the inventory level is still above the reorder point at the time of review, no action is taken until at least the next review.

The review interval (R) that gives the optimum expected total inventory cost is search with boundaries $1 \leq R < 20$. In the case of product 511B, the review interval is 4 days, the safety stock is 3,053,286 kilograms, order-up-to-level is 4,131,724 kilograms, reorder point is 3,268,974 kilograms, and the expected total inventory cost is Rp 1,161,840,926. Similarly, product 511 has review interval of 1 day, safety stock of 321,259 kilograms, order-up-to-level of 528,993 kilograms, reorder point of 425,126 kilograms and expected total inventory cost as much as Rp 460,521,599.

With the review interval, reorder point, and order-up-to-level computed as in procedure in 3.3.4.1, the expected backorder quantity and the expected outdate quantity of product 511B are 367,150 and 153,181 kilograms, respectively. Similarly, the amount that is expected to be backordered and outdated of product 511 are 243,160 and 5,115 kilograms, respectively.

In (s, S) system, the replenishment order will be placed whenever the inventory position reaches the reorder point *s* or lower. The replenishment quantity should be enough to raise the inventory position to the order-up-to-level *S*.

The order quantity that gives the minimum expected total inventory cost is searched by using interval halving method. But, since the boundaries of Q have not been predetermined, the boundaries are searched first by using bounding phase method with initial Q equal to the optimum order quantity (EOQ). Then, with step size of Δ, the boundaries are searched until the iteration result shows higher value than the previous iteration. In the case of product 511B, the step size is 500000. After obtaining the boundaries of Q, the interval halving calculation of product 511B is done in 15 iterations with boundaries $2048266 \leq Q \leq 8048266$. In the same way, the step size of product 511 is 300000, thus the boundaries for the interval halving calculation is $380467 \leq Q \leq 1280467$.

Based on the result of the calculation, the safety stock, reorder point and order-up-to-level of product 511B are 1,365,471, 1,581,159, and 4,703,155 kilograms, respectively. In the same way, product 511 has safety stock, reorder point, and order-up-to-level as much as 227,165, 331,031, and 1,070,092 kilograms, respectively. The expected total inventory cost of product 511B is Rp 7,917,531,273. Similarly, the expected total inventory cost of product 511 is Rp 4,548,457,958.

Product 511B has expected backorder and outdate quantity of 875,820 and 784,780 kilograms, respectively. Likewise, product 511 has expected backorder quantity of 256,970 kilograms and expected outdate quantity of 207,100 kilograms.

5.4.2 Proposed Inventory Control Systems for Perishable Products in Group B and C

Group B consists of products that have medium demand, while Group C is made up of products with low and less frequent demand. In this case, the most two appropriate inventory control systems are (R, S) periodic system and (s, Q) continuous system.

In (R, S) system, enough replenishment quantity is ordered every *R* units of time in order to raise the inventory position up to level *S*.

The review interval that can give the minimum expected total inventory cost is searched with boundaries of $2 \leq R \leq 20$. In Group B, product 594 has review interval of 3 days, 100,409 kilograms of safety stock, 162,790 kilograms of maximum order quantity, 176,820 kilograms of expected backorder quantity, and 12,010 kilograms of expected outdate quantity. In the same manner, product 521 should be reviewed in 3 days. It has 74,840 kilograms of safety stock, 142,525 kilograms as the amount of order-up-to-level, 37,012 kilograms of expected backorder quantity and 4,409 kilograms of expected outdate quantity. The expected total inventory costs of product 594 and 521 are Rp 138,465,971 and Rp 91,598,887, respectively.

Similarly, in Group C, product 534IJ87 should be reviewed in 5 days. The safety stock is 88,395 kilograms, order-up-to-level is 128,626 kilograms, expected backorder quantity is 16,201 kilograms, and expected outdate quantity is 7,397 kilograms. Product BP11B has 6 days of review interval, 76,364 kilograms of safety stock, 103,728 kilograms of maximum order quantity, 34,848 kilograms of expected backorder quantity, and 10,279 kilograms of outdate quantity. The expected total inventory costs of product 534IJ87 and BP11B are Rp 58,439,107, and Rp 87,036,788, respectively.

In (s, Q) system, replenishment in the size of *Q* is ordered when the inventory position reaches the reorder point *s* or lower. The order quantity that gives the minimum expected total inventory cost is searched by using interval halving method. But, since the boundaries of Q have not been predetermined, the boundaries are searched first by using bounding phase method with initial Q equal to the optimum order quantity (EOQ). Then, with step size of Δ, the boundaries are searched until the iteration result shows higher value than the previous iteration. In the case of product 594, the step size is 100000. After obtaining the boundaries of Q, the interval halving calculation of product 594 is done in 15 iterations with boundaries $148993 \leq Q \leq 448993$. Product 521 has step size of

100000 and boundaries of 155198≤ Q ≤ 255198, while product 534IJ87 has step size of 90000 and boundaries of 98745≤ Q ≤ 188745. In the same way, the step size of product BP11B is 70000, thus the boundaries for the interval halving calculation is 74596≤ Q ≤ 284596.

Based on the result of the calculation, the safety stock, reorder point and order quantity of product 594 are 50,205, 65,800, and 229,852 kilograms, respectively. The expected total inventory cost of product 594 is Rp 1,299,937,342. Product 521 has 37,420 kilograms of safety stock, 54,341 kilograms as reorder point, and 155,207 kilograms of order quantity. The expected total inventory cost is Rp 640,263,174. Product 534IJ87 has 36,087 kilograms of safety stock, 42,792 kilograms as reorder point, and 108,152 kilograms of order quantity. The expected total inventory cost of product 534IJ87 is Rp 319,820,759. Product BP11B has 28,863 kilograms of safety stock, 32,772 kilograms as reorder point, and 107,001 kilograms of order quantity. The expected total inventory cost of product BP11B is Rp 293,502,491.

Product 594 has expected backorder and outdate quantity of 174,550 and 83,080 kilograms, respectively. Product 521 has expected backorder and outdate quantity of 44,714 and 40,957 kilograms, respectively. Likewise, product 534IJ87 has expected backorder quantity of 42,935 kilograms and expected outdate quantity of 31,429 kilograms. Product BP11B has expected backorder quantity of 70,782 kilograms and expected outdate quantity of 36,924 kilograms.

5.4 Analysis of Comparison of Existing and Proposed Inventory Control Systems

Table 5.1 shows the summary of calculation of all 6 samples by using both existing and proposed systems. The proposed continuous system results in the highest expected total inventory cost of all products, while the proposed periodic system that includes the perishability factor results in the lowest expected total inventory cost.

Table 5.1 Summary of Calculation of All Samples

Group	Product	Total Inventory Cost		
		Existing System	Periodic Review	Continuous Review
A	511B	2,853,652,724	1,161,840,926	7,917,531,273
	511	500,916,099	460,521,599	4,548,457,958
B	594	142,938,309	138,465,971	1,299,937,342
	521	125,398,407	91,598,887	640,263,174
C	534IJ87	117,166,464	58,439,107	319,820,759
	BP11B	105,026,420	87,036,788	293,502,491

Based on the calculation, (R, s, S) periodic review for product 511B and product 511 of Group A gives 59.29% and 8.06% savings in expected total inventory cost, respectively, while the (s, S) continuous review is 63.96% and 88.99% higher than the existing system.

For Group B, the (R, S) periodic review results in 3.13% and 26.95% reduction in expected total inventory cost of product 594 and 521, respectively. On the other hand, (s, Q) continuous review is 89.00% higher than the existing system for product 594 and 80.41% higher for product 521.

Similarly, in Group C, the (R, S) periodic review gives 50.12% reduction of expected total inventory cost for product 534IJ87 and 17.13% for product BP11B. The (s, Q) continuous review results in 63.36% higher expected cost of product 534IJ87, while product BP11B is 64.22%.

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CHAPTER 6
CONCLUSION AND SUGGESTION

Chapter 6 consists of two sub-chapters, namely the conclusions of this research and the suggestions for the company.

6.1 Conclusions

The conclusions of this research are, as follows:

1. The 65 products of PT. X's poultry feed factory in Krian have been classified into three groups based on the annual dollar usage. In Group A, there are 13 products, such as product 511B, 511, 534IJ, 551, CP11, and others. Group B consists of 16 products, namely product 594, 521, 591, 534HG, 534IJ42, and other products. Group C is made up of 36 products, from product 534IJ87, BP11B, 512B, until product NP52.
2. The existing inventory control system results in worse expected total inventory cost than the proposed periodic review, but still better than the proposed continuous review for all groups. The savings of using proposed periodic review for product 511B and 511 of Group A are 59.29% and 8.06%, respectively. The savings of using proposed periodic review for product 594 and 521 of Group B are 3.13% and 26.95%, respectively. In the same way, he savings of using proposed periodic review for product 534IJ87 and BP11B of Group C are 50.12% and 17.13% respectively.
3. The appropriate inventory control system for products in Group A is (R, s, S) periodic system for perishable products, while the appropriate inventory control system for products in Group B and C is (R, S) periodic system for perishable products. In Group A, the expected total inventory cost of product 511B and product 511 is Rp 1,161,840,926 and Rp 460,521,599, respectively. In Group B, the expected total inventory cost of product 594 and product 521 is Rp 138,465,971 and Rp 91,598,887, respectively. Likewise, in Group C, the expected total inventory cost of product 534IJ87 and product BP11B is Rp 58,439,107 and Rp 87,036,788, respectively.

6.2 Suggestions

The suggestions based on the result of this research are, as follows:

1. PT. X's poultry feed factory in Krian should use (R, s, S) periodic system for products in Group A and (R, S) periodic system for products in Group B and C as stated in this research in order to minimize its expected total inventory cost.
2. For future research, the lead time can be stated as probabilistic in order to better represent the real condition.

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APPENDIX

Appendix 1 Expected Inventory Cost of All Products by Using Existing System

	511B	511	594	521	534IJ87	BP11B
Lead time (day)	1	1	1	1	1	1
Review interval (day)	1	1	1	1	1	1
Setup cost (Rp)	2,220,570	2,220,570	2,220,570	2,220,570	2,220,570	2,220,570
Production cost (Rp)	4,780	4,780	4,680	4,680	4,581	4,680
Holding cost fraction (Rp/kg/year)	0.24	0.24	0.24	0.24	0.24	0.24
Backorder cost fraction (Rp/kg)	0.30	0.30	0.30	0.30	0.30	0.30
Demand (kg)	6,470,625	3,116,000	467,857	507,635	201,153	117,276
Order quantity (kg)	158,271	109,831	43,011	44,802	28,505	21,534
$p_{u\geq}(k)$	0.019568	0.028198	0.073545	0.070605	0.113367	0.146894
Safety factor	2.06	1.91	1.45	1.47	1.21	1.05
μ_{R+L} (kg)	431,375	207,733	31,190	33,842	13,410	7,818
σ_{R+L} (kg)	1,173,901	195,295	43,161	32,170	31,024	24,813
Safety stock (kg)	9,672,948	1,492,050	125,167	94,580	37,539	26,054
Order-up-to-level (kg)	10,104,323	1,699,783	156,358	128,423	50,950	33,872
$G_u(k)$	0.007219	0.010770	0.032810	0.031370	0.054960	0.075680
Expected total inventory cost (kg)	2,853,652,724	500,916,099	142,938,309	125,398,407	117,166,464	105,026,420

Appendix 2 Expected Inventory Cost of Group A by Using (R, s, S) System

	511B	511
Lead time (day)	1	1
Lifetime (day)	21	21
Review interval (day)	4	1
Setup cost (Rp)	2,220,570	2,220,570
Holding cost (Rp)	96	96
Backorder cost (Rp)	1,434	1,434
Outdate cost (Rp)	1,912	1,912
Demand (kg)	6,470,625	3,116,000
μ_{m+L} (kg)	4,745,125	2,285,067
σ_{m+L} (kg)	3,893,390	647,719
μ_{R+L}(kg)	1,078,438	207,733
σ_{R+L} (kg)	1,856,101	195,295
ksl	1.645	1.645
Safety stock (kg)	3,053,286	321,259
Order-up-to-level (kg)	4,131,724	528,993
Reorder point (kg)	3,268,974	425,126
f_{m+L} (d_{m+L})	0.00000008	0.0000004
f_{R+L} (d_{R+L})	0.00000006	0.00000001
Exp backorder quantity (kg)	367,150	243,160
Exp outdate quantity (kg)	153,181	5,115
Expected total inventory cost (Rp)	1,161,840,926	460,521,599

Appendix 3 Expected Inventory Cost of Group A by Using (s, S) System

	511B	511
Lead time (day)	1	1
Lifetime (day)	21	21
Setup cost (Rp)	2,220,570	2,220,570
Holding cost (Rp)	96	96
Backorder cost (Rp)	1,434	1,434
Outdate cost (Rp)	1,912	1,912
Demand (kg)	6,470,625	3,116,000
Order quantity (kg)	3,121,997	739,061
μ_{m+L}(kg)	4,745,125	2,285,067
σ_{m+L} (kg)	3,893,390	647,719
μ_L(kg)	215,688	103,867
σ_L(kg)	830,074	138,094
ksl	1.645	1.645
Safety stock (kg)	1,365,471	227,165
Reorder point (kg)	1,581,159	331,031
Order-up-to-level (kg)	4,703,155	1,070,092
f_{m+L} (d_{m+L})	0.0000001	0.0000004
f_L (d_L)	0.0000000547	0.00000001
Exp outdate quantity (kg)	784,780	207,100
Exp shortage quantity (kg)	875,820	256,970
Expected total inventory cost (Rp)	7,917,531,273	4,548,457,958

Appendix 4 Expected Inventory Cost of Group B and C by Using (R, S) System

	594	521	534IJ87	BP11B
Lead time (day)	1	1	1	1
Lifetime (day)	21	21	21	21
Review interval (day)	3	3	5	6
Setup cost (Rp)	2,220,570	2,220,570	2,220,570	2,220,570
Holding cost (Rp)	94	94	92	94
Backorder cost (Rp)	468	1,404	1,374	1,404
Outdate cost (Rp)	1,872	1,872	1,832	1,872
Demand (kg)	467,857	507,635	201,153	117,276
μ_{m+L} (kg)	343,095	372,266	147,512	86,003
σ_{m+L}(kg)	143,149	106,697	102,896	82,297
μ_{R+L} (kg)	62,381	67,685	40,231	27,364
σ_{R+L} (kg)	61,039	45,496	53,736	46,422
ksl	1.645	1.645	1.645	1.645
Safety stock (kg)	100,409	74,840	88,395	76,364
Order-up-to-level (kg)	162,790	142,525	128,626	103,728
f_{m+L} (d_{m+L})	0.000002	0.000002	0.000003	0.000004
f_{R+L} (d_{R+L})	0.0000005	0.0000001	0.000002	0.000003
Exp backorder quantity (kg)	176,820	37,012	16,201	34,848
Exp outdate quantity (kg)	12,010	4,409	7,397	10,279
Expected total inventory cost (Rp)	138,465,971	91,598,887	58,439,107	87,036,788

Appendix 5 Expected Inventory Cost of Group B and C by Using (s, S) System

	594	521	534IJ87	BP11B
Leadtime (day)	1	1	1	1
Life time (day)	21	21	21	21
Setup cost (Rp)	2,220,570	2,220,570	2,220,570	2,220,570
Holding cost (Rp)	94	94	92	94
Backorder cost (Rp)	1,404	1,404	1,374	1,404
Outdate cost (Rp)	1,872	1,872	1,832	1,872
Demand (kg)	467,857	507,635	201,153	117,276
Order quantity (kg)	229,852	155,207	108,152	107,001
μ_{m+L} (kg)	343,095	372,266	147,512	86,003
σ_{m+L} (kg)	143,149	106,697	102,896	82,297
μ_L (kg)	15,595	16,921	6,705	3,909
σ_L (kg)	30,519	22,748	21,937	17,546
ksl	1.645	1.645	1.645	1.645
Safety stock (kg)	50,205	37,420	36,087	28,863
Reorder point (kg)	65,800	54,341	42,792	32,772
f_{m+L} (d_{m+L})	0.000002	0.000002	0.000003	0.000004
f_L (d_L)	0.0000004	0.00000007	0.000002	0.000003
Exp outdate quantity (kg)	83,080	40,957	31,429	36,924
Exp shortage quantity (kg)	174,550	44,714	42,935	70,782
Expected total inventory cost (Rp)	1,299,937,342	640,263,174	319,820,759	293,502,491

Appendix 6 The Search of Minimum Expected Inventory Cost of All Products

Review Interval	Expected Total Inventory Cost					
	511B	511	594	521	534IJ87	BP11B
1	1,434,897,029	460,521,599	153,297,584	132,239,091	120,167,938	157,646,154
2	1,250,571,472	785,629,921	142,916,948	99,926,112	81,538,841	117,210,816
3	1,169,666,685	796,328,495	138,465,971	91,598,887	67,483,491	101,464,984
4	1,161,840,926	1,165,270,439	162,767,598	144,084,943	60,952,910	93,179,157
5	1,217,561,919	1,220,392,998	193,885,441	146,669,506	58,439,107	88,809,058
6	1,391,913,290	1,637,376,848	231,411,721	204,796,927	58,753,322	87,036,788
7	1,551,825,971	2,089,558,323	252,866,729	214,557,269	61,390,255	87,326,295
8	1,771,143,255	2,935,846,692	302,906,818	279,657,685	66,108,811	89,405,392
9	2,049,460,899	3,494,757,508	360,610,786	349,521,876	72,799,320	109,445,540
10	2,386,589,439	4,492,074,065	399,742,936	425,303,749	70,396,757	114,271,687
11	2,782,984,184	4,821,304,080	444,690,927	514,705,427	97,822,423	120,817,770
12	3,238,973,938	5,207,106,167	495,981,526	600,083,238	109,843,105	129,090,890
13	3,766,483,210	9,933,001,276	554,221,640	759,238,867	123,981,232	139,124,607
14	4,342,720,168	10,704,556,243	620,174,427	816,712,674	140,290,791	150,981,337
15	4,982,387,301	11,595,406,639	1,090,735,015	883,560,736	158,848,897	164,744,903
16	5,687,515,177	12,620,301,679	1,212,212,277	975,042,460	179,759,872	180,521,529
17	6,460,468,489	19,393,479,453	1,350,384,201	1,749,200,824	203,177,236	198,445,690
18	7,304,533,067	21,219,994,768	1,507,811,565	1,900,619,491	229,265,263	218,681,398
19	8,224,621,702	23,320,915,868	1,687,297,935	2,075,605,401	258,281,911	241,434,263
20	9,226,660,488	33,019,312,069	1,892,315,627	2,277,475,824	290,525,967	266,927,155

Appendix 7 Bounding Phase of Product 511

Iteration	Q	EAC
0	380,467	5,448,282,741
1	680,467	4,562,600,672
2	1,280,467	5,341,919,571

Appendix 8 Bounding Phase of Product 521

Iteration	Q	EAC
0	155,198	640,271,728
1	255,198	762,059,668

Appendix 9 Bounding Phase of Product 534IJ87

Iteration	Q	EAC
0	98,745	321,141,393
1	188,745	380,455,953

Appendix 10 Bounding Phase of Product BP11B

Iteration	Q	EAC
0	74,596	313,793,043
1	144,596	310,795,632
2	284,596	668,411,119

Appendix 11 Interval Halving of Product 511

Iteration	a	b	L	Q_1	Q_m	Q_2	EAC(1)	EAC(m)	EAC(2)
1	380,467	1,280,467	900,000	605,467	830,467	1,055,467	4,630,813,553	4,579,573,857	4,855,901,757
2	605,467	1,055,467	450,000	717,967	830,467	942,967	4,550,083,821	4,579,573,857	4,687,279,077
3	605,467	830,467	225,000	661,717	717,967	774,217	4,573,756,360	4,550,083,821	4,553,573,657
4	661,717	774,217	112,500	689,842	717,967	746,092	4,558,263,118	4,550,083,821	4,548,721,947
5	717,967	774,217	56,250	732,030	746,092	760,155	4,548,590,735	4,548,721,947	4,550,405,170
6	717,967	746,092	28,125	724,998	732,030	739,061	4,549,129,492	4,548,590,735	4,548,457,958
7	732,030	746,092	14,063	735,545	739,061	742,576	4,548,523,455	4,548,457,958	4,548,589,817
8	735,545	742,576	7,031	737,303	739,061	740,819	4,548,490,485	4,548,457,958	4,548,621,837
9	737,303	740,819	3,516	738,182	739,061	739,940	4,548,572,428	4,548,457,958	4,548,539,935
10	738,182	739,940	1,758	738,621	739,061	739,500	4,548,613,372	4,548,457,958	4,548,498,956
11	738,621	739,500	879	738,841	739,061	739,280	4,548,535,643	4,548,457,958	4,548,576,605
12	738,841	739,280	439	738,951	739,061	739,171	4,548,594,976	4,548,457,958	4,548,517,287
13	738,951	739,171	220	739,006	739,061	739,116	4,548,526,462	4,548,457,958	4,548,585,787
14	739,006	739,116	110	739,033	739,061	739,088	4,548,492,209	4,548,457,958	4,548,620,041
15	739,033	739,088	55	739,047	739,061	739,074	4,548,573,253	4,548,457,958	4,548,539,000

Appendix 12 Interval Halving of Product 521

Iteration	a	b	L	Q_1	Q_m	Q_2	EAC(1)	EAC(m)	EAC(2)
1	155,198	255,198	100,000	180,198	205,198	230,198	655,430,033	682,094,230	718,012,956
2	155,198	205,198	50,000	167,698	180,198	192,698	646,199,456	655,430,033	667,488,282
3	155,198	180,198	25,000	161,448	167,698	173,948	642,792,652	646,199,456	650,435,867
4	155,198	167,698	12,500	158,323	161,448	164,573	641,413,275	642,792,652	644,386,591
5	155,198	161,448	6,250	156,760	158,323	159,885	640,812,111	641,413,275	642,073,882
6	155,198	158,323	3,125	155,979	156,760	157,541	640,535,958	640,812,111	641,100,056
7	155,198	156,760	1,563	155,588	155,979	156,370	640,404,068	640,535,958	640,667,399
8	155,198	155,979	781	155,393	155,588	155,784	640,324,147	640,404,068	640,470,069
9	155,198	155,588	391	155,295	155,393	155,491	640,304,855	640,324,147	640,371,025
10	155,198	155,393	195	155,246	155,295	155,344	640,281,386	640,304,855	640,314,503
11	155,198	155,295	98	155,222	155,246	155,271	640,276,558	640,281,386	640,286,214
12	155,198	155,246	49	155,210	155,222	155,234	640,274,143	640,276,558	640,278,972
13	155,198	155,222	24	155,204	155,210	155,216	640,266,025	640,274,143	640,268,440
14	155,198	155,210	12	155,201	155,204	155,207	640,268,877	640,266,025	640,263,174
15	155,204	155,210	6	155,205	155,207	155,208	640,271,510	640,263,174	640,268,658

Appendix 13 Interval Halving of Product 534IJ87

Iteration	a	b	L	Q_1	Q_m	Q_2	EAC(1)	EAC(m)	EAC(2)
1	98,745	188,745	90,000	121,245	143,745	166,245	321,930,541	333,753,856	353,673,062
2	98,745	143,745	45,000	109,995	121,245	132,495	319,865,024	321,930,541	326,709,178
3	98,745	121,245	22,500	104,370	109,995	115,620	320,032,262	319,865,024	320,529,876
4	104,370	115,620	11,250	107,182	109,995	112,807	319,841,689	319,865,024	320,098,320
5	104,370	109,995	5,625	105,776	107,182	108,589	319,908,272	319,841,689	319,830,745
6	107,182	109,995	2,813	107,886	108,589	109,292	319,827,149	319,830,745	319,843,415
7	107,182	108,589	1,406	107,534	107,886	108,237	319,829,910	319,827,149	319,824,484
8	107,886	108,589	703	108,061	108,237	108,413	319,830,238	319,824,484	319,827,608
9	108,061	108,413	352	108,149	108,237	108,325	319,822,926	319,824,484	319,826,045
10	108,061	108,237	176	108,105	108,149	108,193	319,831,012	319,822,926	319,823,704
11	108,105	108,193	88	108,127	108,149	108,171	319,831,400	319,822,926	319,823,315
12	108,127	108,171	44	108,138	108,149	108,160	319,831,594	319,822,926	319,823,121
13	108,138	108,160	22	108,144	108,149	108,155	319,827,260	319,822,926	319,827,454
14	108,144	108,155	11	108,147	108,149	108,152	319,822,926	319,822,926	319,820,759
15	108,149	108,155	5	108,151	108,152	108,153	319,826,273	319,820,759	319,824,107

Appendix 14 Interval Halving of Product BP11B

Iteration	a	b	L	Q_1	Q_m	Q_2	EAC(1)	EAC(m)	EAC(2)
1	74,596	284,596	210,000	127,096	179,596	232,096	298,809,961	352,396,723	463,174,971
2	74,596	179,596	105,000	100,846	127,096	153,346	294,104,403	298,809,961	319,039,940
3	74,596	127,096	52,500	87,721	100,846	113,971	299,850,533	294,104,403	294,188,114
4	87,721	113,971	26,250	94,283	100,846	107,408	296,130,795	294,104,403	293,512,649
5	100,846	113,971	13,125	104,127	107,408	110,690	293,640,810	293,512,649	293,705,918
6	104,127	110,690	6,562	105,768	107,408	109,049	293,538,911	293,512,649	293,566,775
7	105,768	109,049	3,281	106,588	107,408	108,229	293,511,056	293,512,649	293,536,078
8	105,768	107,408	1,641	106,178	106,588	106,998	293,521,273	293,511,056	293,508,201
9	106,588	107,408	820	106,793	106,998	107,203	293,513,223	293,508,201	293,510,416
10	106,793	107,203	410	106,896	106,998	107,101	293,510,707	293,508,201	293,512,908
11	106,896	107,101	205	106,947	106,998	107,049	293,513,059	293,508,201	293,510,554
12	106,947	107,049	103	106,973	106,998	107,024	293,510,629	293,508,201	293,512,981
13	106,973	107,024	51	106,985	106,998	107,011	293,509,415	293,508,201	293,514,195
14	106,985	107,011	26	106,992	106,998	107,005	293,512,412	293,508,201	293,511,198
15	106,992	107,005	13	106,995	106,998	107,001	293,513,911	293,508,201	293,502,491

BIOGRAPHY

Nofinda Ghaisani was born in Surabaya, 7th April 1994. She was graduated from TK Jaya Kusuma Surabaya in 1999, SD Negeri Babat Jerawat I Surabaya in 2005, SMP Negeri 26 Surabaya in 2008, and SMA Negeri 6 Surabaya in 2011. She also attended Institut Teknologi Sepuluh Nopember, majoring in Industrial Engineering. During her study, she has got a lot of skills, both hard and soft skills. She likes reading, travelling, and doing new things. She also likes learning new language. She can be found in this email: ghaisani.nofinda@gmail.com.