

**APPLYING INVENTORY CONTROL IN ELECTRICAL INDUSTRY**

**: A CASE STUDY**



**AN INDEPENDENT STUDY SUBMITTED IN PARTIAL  
FULFILLMENT  
OF THE REQUIREMENT FOR THE DEGREE OF  
MASTER OF SCIENCE IN LOGISTICS AND SUPPLY CHAIN  
MANAGEMENT  
INTERNATIONAL COLLEGE  
KING MONGKUT'S INSTITUTE OF TECHNOLOGY LADKRABANG  
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KMITL-2017- IC-M- 002-006**

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เอกสารนี้เป็นเอกสารที่สงวนไว้สำหรับการใช้งานเพื่อการศึกษาเท่านั้น เมื่ออนุญาตให้นำไปใช้ประโยชน์ด้านการค้า  
ไม่ว่ากรณีใดๆ ทั้งสิ้น อีกทั้งห้ามมิให้ดัดแปลงเนื้อหา และต้องอ้างอิงถึงเจ้าของเอกสารทุกครั้งที่มีการนำไปใช้



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### ABSTRACT

In this research, the researcher surveyed the warehouse in electronic company. After the surveyed and conducted in-depth interview with the production manager to analyze the current problem of the company found that the case study company has so many inventories results in much inventory value, sunk cost and had to pay much carrying and maintenance cost. The researcher collected the raw materials data that used to produce the standard transformers include round aluminium wire, flat aluminium wire, transformer oil, high voltage bushing, low voltage bushing, and terminal lug. Then used the ABC analysis method to classify the raw materials into three groups (A,B and C). After that, test variability coefficient in group A and B to find the appropriate method to control the inventories. Then the researcher used the EOQ, ROP, safety stock and the silver meal method to determine the new purchasing method in A and B groups. After comparison results between the new and old method, found that the new purchasing method can reduce the inventories value from 22,292,593 Baht to 16,090,280 Baht.

## ACKNOWLEDGEMENTS

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# CHAPTER 1

## INTRODUCTION

### 1.1 Introduction

Electronic industry is very important to Thai economic system. It continually grows and generates income to the country from export and investment. It also attracts foreign investors to invest in the country. In addition, the strength of Thai entrepreneur is the ability to produce quality product which is internationally acceptable.

However, after the establishment of the ASEAN Economic Community (AEC) in 2015, electronic industry gets the effects from this economic system. Because there are numbers of competitors which makes the market become highly competitive.

Accordingly, the case study company needs to increase competitiveness over the competitors.

### 1.2 Background and Problem Statement

The case study company was established in 1981 with registered capital of 4,000,000 Baht at that time. They produced and sold distribution transformers in both domestic and international markets including ASEAN, South Asia, Middle East, South Africa and Australia. The distribution transformers had capacity about 1kva-40,000kva with the maximum voltage of 36 kV. The company had been certified by ISO 14001 (Environmental Management), ISO/IEC 17025 (Testing

and Calibration Laboratories) and OHSAS 18001 (Occupational Health and Safety)

Inventory is essential to the company. It helps the company operate continuously and smoothly. If the company has too many inventories, the company will have more carrying cost that leads to the problem to the company. On the other hand, if the company has fewer inventories, it may result in lack of inventory. Therefore, it will not be able to supply the demand as well.

At present, the company does not have the appropriate method to order raw materials. The current method of the case study company affects the order quantity which does not relate to the quantity of use. There were many inventories, which result in sunk cost, and lost opportunities in utilizing sunk cost for other benefits. Moreover, the company has to pay more carrying and maintenance cost. Therefore, the case study company has to reduce inventories in order to increase efficiency in inventory management. Accordingly, the researcher will select main materials which use to produce the standard transformers including round aluminum wire, flat aluminum wire, transformer oil, low voltage bushing, high voltage bushing and terminal lug to analyze the problem and determine the order of quantity by the appropriate method.

### **1.3 Objectives of the study**

1. To use ABC Analysis to classify the inventories.
2. To find the appropriate order quantities each time.
3. To reduce the stock of inventories.

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## 1.4 Scope of the study

1. Used data to study was data in 2015
2. ABC analysis is used to classify the inventories.
3. Focus on raw material that used to produce the transformers only.

## 1.5 Research methodology

The researcher is divided the project into seven parts namely:

1. Identifying the problem: identify the problem from interview the personnel and visiting the company.
2. Definition of the problem: After identify the problem of company and knows what is the problem, then find cause of problem and identify the scope, aim and objectives of this project.
3. Literature review: review literatures which involve this project.
4. Data collection: collect and analyze the data which use to solve the problem, such as the data of use and storage raw materials and the historical data of ordering.
5. Problem solving: use appropriate tools to solve the problem.
6. Solution and validation analysis: To examine the results after solve the problem and compare the results between before & after solving.
7. Implementation and recommendations: a company can improve the process efficiently and extend results to other products.

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## CHAPTER 2

### LITERATURE REVIEW

#### 2.1 Supply Chain Management (SCM)

Supply chain management is defined as the link between upstream and downstream value chain entities. The effective supply chain management needs to integrate the value chain entities to create cooperative and collaborative environments that encourage information exchanges, materials and cash flows (Kukalis, 1989).

Supply chain management is a set of methods used to efficiently integrate manufacturers, supplier, customers and logistics to improve the long term performance of the company (Chopra and Meindl, 2001).

Supply chain management is a set of entities involved in upstream and downstream flows of products, services, finances or information from a source to customer (Mentzer, 2002).

#### 2.2 Inventory management

##### 2.2.1 Concept of Inventory management

Inventory is necessary to the business because it is current assets that helps the business produce or sell smoothly. If the business has a lot of inventory, there will be a problem to the business in terms of high holding cost, obsolete goods and lost opportunity in sunk cost which can be used for other benefits. On the other hand, if the business has fewer inventories, the business may be stock out and lost opportunity to sell the goods to customer. This will give an opportunity to the competitors who are ready to serve the customer. Furthermore, there is a possibility to lose a customer, if

the important materials are out-of-stock and the operation in producing or selling are stopped. This also has an effect on the image of the business. Thus, it is the responsibility of entrepreneur to manage the inventory in appropriate level, which is not over abundantly or too few. Because it probably leads to the illiquidity of the business.

### **2.2.2 Definition of Inventory management**

Inventory management is defined as the storage resource uses in current or future for smooth operation of business by way of planning appropriate level of inventory or managing about the list of inventory including collecting, taking notes inventory and controlling the level of inventory to meet the demands of the customer.

### **2.2.3 Definition of Inventory**

According to Chase et al. (2009), the inventory system can be explained as the guidelines of policies and regulations that monitor levels of inventory and help in determining what levels should be maintained, when stock should be ordered and in what sizes should be ordered.

### **2.2.4 Types of Inventory**

The inventory can be categorized into four types as follows.

#### **2.2.4.1 Raw Material Inventory**

Raw Material Inventory is used to produce component, subassemblies, or finished product. It has direct relationship with the supplier. Therefore, the business should choose the right supplier with the quality of raw material and

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also has punctual distribution. Because the raw material inventory is the important factor of the production.

#### **2.2.4.2 Work-in-Process: WIP**

Work-in-Process: WIP is made up from all materials; components, assemblies and subassemblies by passing the initial production process or are waiting to go to the next process to complete cycle time. Managing inventory in this group is important because it helps the production process smoothly.

#### **2.2.4.3 Maintenance/Repair/Operating: MROs**

Maintenance/Repair/Operating: MRO is the necessary items which is used to support and maintain the production process to prevent the shortage of spare parts.

#### **2.2.4.4 Finished Goods Inventory**

Finished Goods are the items that have been passed the final production process, it readies to sell to the customer. Thus, finished goods are the stock of completed goods and they are assets of the business. This type of inventory depends on the customer requirement. If the customer requirement is not constant, it will affect the level of

### **2.2.5 Cost of Inventory**

#### **2.2.5.1 Ordering cost**

Ordering costs are the expenses in placing an order goods with the supplier each time. Examples of ordering costs include cost of preparing a

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purchase order, cost of preparing a purchase requisition, cost of labor, cost of moving the goods to warehouse, telephone bill and so on. There is a contrary relationship between mean and an order quantity each time such that they move in opposite directions.

#### **2.2.5.2 Carrying costs**

Carrying costs are the expenses from holding the inventory. Examples of carrying costs include cost of capital, storage cost, taxes on inventory, insurance cost, warehouse expense, obsolescence, depreciation and other items. The carrying costs will change in the same way with the order of quantity each time.

#### **2.2.5.3 Shortage costs**

Shortage costs are the cost incurred when the demand exceeds the available inventory on hand. The shortage of inventories results in lost profits on sales, lost customer goodwill, failure to deliver services to customers and so on.

#### **2.2.6 Objective of Inventory management**

1. To have sufficient inventory to respond the customer requirement in time and also to create the circulation and maintain the market share.
2. To keep the level of investment in inventory at optimum level.
3. To reduce the carrying costs of inventory.
4. To reduce the ordering costs of inventory.

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5. To reduce the loss of stealing

### **2.2.7 Benefits of Inventory management**

1. It can response the works in Just in Time system, support the smooth production, reduce the variance of demand and supply and reduce the level of inventory.

2. It can meet customer satisfaction in term of readiness in goods and services. The good inventory management will help manage in time distribution of goods to customer according to the order.

3. It can prevent the stock out that may change from the market situation and season. The purpose of the warehouse is holding the materials and goods in appropriate level in order to response the customer requirement and the market.

4. It can achieve economies of scale in the cost of operation and production system.

5. It can create the competitive advantage in business. The warehouse is the important tool to create the competitive advantage in term of time, place and quantity that are ready to service the customer continuously.

## **2.3 Inventory Control**

### **2.3.1 Definition of Inventory Control**

Inventory control is the method to manage inventory efficiently. It intends to monitor the inventory including raw materials, work in progress and finished goods. It helps to provide data of inventory to different units or departments and also helps to

เอกสารนี้ keep inventory at lowest costs. เพื่อการศึกษาเท่านั้น ไม่อนุญาตให้นำไปใช้ประโยชน์ด้านการค้า  
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### 2.3.2 Objective of Inventory Control

1. To prevent fluctuations in demand.
2. To meet customer requirement timely and efficiently.
3. To balance cost of inventory.
4. To smooth in production process.
5. To control the level of stock and stock distribution.

### 2.4 Inventory control techniques

Inventory control has to consider the relation between inventory costs. For example, increasing in holding cost consequently leads to higher order costs as well as shortage costs. Therefore, it is necessary to control the inventory at the lowest total cost.

There are several methods to control the inventories. In this study, the researcher considers some of the important techniques to control the inventories which are listed as follows:

#### 2.4.1 Economic order quantity (EOQ) with constant demand

Economic order quantity (EOQ) is the amount of inventory that the company should place an order with quantity that minimizes cost of the holding costs and the ordering costs where demand is constant. The assumptions are listed as follows:

1. Known the demand clearly and the demand is constant.
2. All goods are delivered at once
3. Lead time (from the beginning of an order placement until receiving goods) is constant.

4. Holding cost and ordering cost are constant.
5. Price per unit of inventory is constant.
6. Stock outs are not permitted.

The EOQ can be expressed as equation 2.1:

$$EOQ = \sqrt{\frac{2CoD}{Ch}} \quad (2.1)$$

The minimum total cost can be expressed as equation 2.2:

$$TC_{min} = \frac{CoD}{Q} + \frac{QCh}{2} \quad (2.2)$$

Where

D = Annual demand requirements per unit

Co = Ordering cost per order (Baht)

Ch = Holding cost per unit (Baht)

Q = Order quantity

TC = Total annual cost (Baht)

The total annual ordering cost can be expressed as equation 2.3 :

$$\text{Annual ordering cost} = \left(\frac{D}{Q}\right)Co$$

(2.3)

The total annual holding cost can be expressed as equation 2.4 :

$$\text{Annual holding cost} = \left(\frac{Q}{2}\right)Ch \quad (2.4)$$

The optimum number of orders per year can be expressed as equation 2.5 :

$$\text{Number of orders per year} = \frac{D}{Q} \quad (2.5)$$

The length of the order cycle can be expressed as equation: 2.6 :

$$\text{Orders cycle time} = \frac{Q}{D} \quad (2.6)$$

#### 2.4.1.1 The method to check the appropriate to use EOQ

From the limitation of economic order quantity (EOQ) that can use when the demand is constant. Peterson and Silver (1979) suggest the method called Peterson-Silver rule to measure the lumpy demand by find the variability coefficient (VC).

The variability coefficient (VC) can be expressed as equation 2.7 :

$$VC = \frac{Est.VarD}{\bar{d}^2} \quad (2.7)$$

$$\bar{d}^2 = \frac{1}{n} \sum_{i=1}^n d_i \quad (2.8)$$

$$Est. Var D = \frac{1}{n} \sum_{i=1}^n d_i^2 \quad (2.9)$$

Where:

$d_i$  = Demand per period

$n$  = Horizon period length

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The result can be summarized as:

If variability coefficient  $< 0.25$ , the demand is not lumpy. Hence, economic order quantity can be used.

If variability coefficient  $> 0.25$ , the demand is lumpy. Hence, dynamic lot sizing model will be used.

## 2.4.2 The Method to Control the Lumpy Demand

After testing the demand by Peterson-Silver rule, the appropriate method to calculate order quantity is needed to be determined. If the variability coefficient  $> 0.25$ , the Economic Order Quantity (EOQ) cannot be used. However, there are other methods that can be used to calculate such as heuristic methods.

### 2.4.2.1 Silver-Meal heuristic (SM)

Silver-Meal heuristic is the method to determine the order quantity by considering a number of periods ahead ( $m$ ) in order to find the order quantity to meet the requirement customer at lowest average cost per period for the  $m$ -period span. The considered costs are the ordering cost and holding cost. When the future demand for the next  $m$  period is  $D_1, D_2, \dots, D_n$ ,  $K(m)$  is the average variable cost per period. The assumptions are that the holding cost happens at the end of period time and the quantity requirement for the period is used at the initial of the period (Silver and Meal, 1973). Therefore, if the order quantity equals  $D_1$  to meet the customer requirement in the period 1, the variable cost can be calculated as the equation 2.10 :

$$K(1) = A \quad (2.10)$$

when  $A = \text{Ordering cost}$

If the order quantity equals  $D_1 + D_2$  in the period 1 and 2 to meet the customer requirement. The variable cost can be calculated as the equation 2.11 :

$$K(2) = \frac{1}{2} (A + h D_2) \quad (2.11)$$

when  $A =$  Ordering cost

$H =$  Holding cost per unit in the 1 period time

Hence, the variable cost in total study period can be calculated as the equation 2.12 :

$$K(m) = \frac{1}{m} (A + h D_2 + 2h D_3 + \dots + (m-1)(h D_m)) \quad (2.12)$$

Recalculate  $K(m)$ ,  $m = 1, 2, 3, \dots, m$  until the variable cost in total period increases, then stop the calculation as the equation 2.13 :

$$K(m+1) > K(m) \quad (2.13)$$

We will order the quantity to meet requirement during the period which the average cost per period begins to increase. Hence, in the period 1, the order can be calculated from the equation 2.14 as below :

$$Q_1 = D_1 + D_2 + \dots + D_m \quad (2.14)$$

After that , we will perform the following steps in the next period  $(m+1)$  until the end of study period

#### 2.4.2.2 Lease Unit Costing (LUC)

Lease Unit Costing (LUC) is the method to determine the order quantity which is similar to the Silve-Meal heuristic. But the average variable

cost per unit will be taken for consideration rather than the average variable cost per period. By specifying, the  $K'(m)$  is average variable cost per unit, if the order covers  $m$  period (Sipper and Bulfin, 1998). Hence, if the order quantity equals  $D_1$  to meet the customer requirement in period 1. The variable cost can be calculated as the equation 2.15 :

$$K'(1) = \frac{A}{D_1} \quad (2.15)$$

when  $A =$  Ordering cost

If the order quantity equals  $D_1 + D_2$  in the period 1 and 2 to meet the customer requirement. The variable cost can be calculated as the equation 2.16 :

$$K'(2) = \frac{(A + hD_2)}{D_1 + D_2} \quad (2.16)$$

when  $A =$  Ordering cost

$H =$  Holding cost per unit in the 1 period time

Hence, the variable cost in the total study period can be calculated as the equation 2.17 :

$$K'(m) = \frac{(A + hD_2 + 2hD_3 + \dots + (m-1)hD_m)}{D_1 + D_2 + \dots + D_m}$$

(2.17)

Recalculate  $K'(m)$ ,  $m = 1, 2, 3, \dots, m$  until the variable cost in total period increases then stop the calculation as the equation 2.18 :

$$K'(m+1) > (m) \quad (2.18)$$

We will order the quantity to meet requirement during the period which the average cost per period begins to increase. Hence, in the period 1,

the order can be calculated from the equation 2.19 as below:

$$Q_1 = D_1 + D_2 + \dots + D_m \quad (2.19)$$

After that, we will perform the following steps in the next period ( $m+1$ ) until the end of study period, which is similar to the Silver-Meal heuristic. The limitation of Silver-Meal heuristic (SM) and Lease Unit Costing (LUC) is considering the order quantity in one period of time. Therefore, the variable cost per period or per unit will be different in each study time.

### 2.4.2.3 Part Period Balancing (PPB)

Part Period Balancing (PPB) is the method with the attempt to determine the order quantity in order to minimize the sum of variable costs. It is a computation of holding cost per unit by Part Period. It means one part period is equal to one unit of item in the holding inventory for one period. Therefore, If we hold inventory 10 units for one period, it is equal to 10 Part Periods. On the other hand, it is equal to 5 units which are held in inventory for 2 periods. Hence, when defining  $PP_m$  is Part Period for  $m$  period, the formula will be as equation 2.23 :

$$PP_1 = 0 \quad (2.20)$$

$$PP_2 = D_2 \quad (2.21)$$

$$PP_3 = D_2 + 2D_3 \quad (2.22)$$

$$PP_m = D_2 + 2D_3 + \dots + (m-1)D_m \quad (2.23)$$

Thus, the holding cost is equal to  $h(PP_m)$ , and we will select the order horizon  $m$  that makes the holding cost is close to the ordering cost.

Therefore, we will select  $m$  as

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$$A \cong h(PP_m) \quad (2.24)$$

Or

$$PP_m \cong \frac{A}{h} \quad (2.25)$$

Which are also the stopping rule and the  $A/h$  can called “The Economic Part Period Factor”. We can calculate the order size as equation 2.26 :

$$Q_1 = D_1 + D_2 + \dots + D_m \quad (2.26)$$

After that, we will perform the following steps in the next period ( $m+1$ ) until the end of the study period. Moreover, Part Period Balancing (PPB) is also known as Least Total Cost (LTC)

### 2.4.3 Safety Stock and Service level

#### 2.4.3.1 Safety Stock

Safety stock is also known as buffer stock. It is determination the amount of inventory on hand to avoid the probability of a stock out. However, there are unpredictable events such as lead time that is longer than expected or unexpected demand. If there is too much safety stock, the probability of stock out is less. But it results in higher holding cost. On the other hand, if there is too little safety stock, it leads to lost sales opportunity.

#### 2.4.3.2 Service level

There are many methods to determine the amount of safety stock. The extensive method determines the safety stock to meet specific service level. The service level is the probability of the amount of inventory on hand during lead time to meet the expected demand. There is a probability of stock

out will not occur. At the service level of 90 % means that there is a 0.90 probability that demand will be met during lead time. Therefore, the probability that stock out will occur is 10%.

#### 2.4.4 Reorder Point

Reorder Point is the level of inventory that will trigger the placement an order for additional units. There are three factors to determine the reorder point as follows :

1. Demand - The daily quantity of use.
2. Lead time - The number of days during the beginning placement of an order until goods receives.
3. Safety stock - The amount of inventory on hand in the even that there is unpredictable event such as lead time which is too longer than expected or unexpected demand.

##### 2.4.4.1 The Reorder point with constant in both demand and lead time

If the demand is constant and lead time is certainly, they are deterministic model. The reorder point is equal to average demand rate multiplies by lead time as equation 2.27 :

$$\text{Reorder point} = \bar{d} \times LT \quad (2.27)$$

Where

$\bar{d}$  = average daily demand rate

LT = Lead time

#### 2.4.4.2 The Reorder point with uncertain demand and constant Lead time

If the demand during each day is uncertain and independent, stock out may be occurs. Thus the storage safety stock is necessary to reduce the risk of stock out when the demand is unexpected. Moreover, the service level is needed to estimate in order to determine the safety stock. The reorder point with a safety stock to meet specific service level can be calculated as equation (2.28)

$$\begin{aligned} \text{Reorder point} &= (\text{Average demand} \times \text{Lead time}) + \\ \text{Safety Stock} & \\ &= (\bar{d})(LT) + Z\sigma_d \sqrt{LT} \end{aligned} \quad (2.28)$$

Where

$\bar{d}$  = average daily demand rate

LT = lead time

Z = number of standard deviation corresponding to the service level probability

$\sigma_d$  = standard deviation of demand

Service level = 100% - probability of stock out

#### 2.4.4.3 The Reorder point with constant demand and uncertain lead time

This case happens when the demand is constant, but lead time is uncertain. If the lead time is longer than expected and the stock has to be

used before the arrival of shipment, the stock out will occur. According to this case, the reorder point can be calculated as equation 2.29 :

$$\text{Reorder point} = (\bar{d})(LT) + Z d \sigma_{LT} \quad (2.29)$$

Where

$\bar{d}$  = average daily demand rate

$d$  = daily demand

LT = lead time

Z = number of standard deviation corresponding to the service level

probability

$\sigma_{LT}$  = Standard deviation of lead time

#### 2.4.4.4 The Reorder point with uncertain in both demand and lead time

When the both demand and lead time are uncertain. the reorder point can be calculated as equation (2.30) :

$$\text{Reorder point} = (\bar{d})(LT) + Z \sqrt{\overline{LT}} \sigma_d^2 + \bar{d}^2 \sigma_{LT}^2 \quad (2.30)$$

Where

$\bar{d}$  = average daily demand rate

$\overline{LT}$  = average lead time

Z = number of standard deviation corresponding to the service level

probability y

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$\sigma_{LT}$  = standard deviation of lead time

### 2.4.5 ABC analysis

ABC analysis is the one of techniques to classify the inventory based on Pareto principle. This method classifies the inventory into three groups according to its importance or value. The first group is A items. They are the inventory which has the highest in consumption value. The second group is B items. They have a moderate consumption value. They are less important than A items but more important than C items. The third group is C items. They are negligible important and have the least consumption value.

According to Heizer and Render (1966), the rules of classifying the inventory are as follows:

A items: there are 5-15 % of total inventory items, but accounts for 75-80 % of the consumption value.

B items: there are 20-25 % of total inventory items, but accounts for 10-15 % of the consumption value.

C items: there are 60-65 % of total inventory items, but accounts for 5-10 % of the consumption value.

#### 2.4.5.1 The procedure to classify the inventory

According to Lalitaphorn (2000, p. 101-105), the procedure to classify the inventory can be done as follows:

1. Finding the unit cost of inventory and the quantity of use of each inventory per year.

2. Calculating the annual consumption value of each inventory. The annual consumption value can be calculated by annual demand multiply by price per unit.
3. Listing all the inventories in descending value according to the annual consumption value.
4. Adding up the annual consumption value and the number of inventories, and calculating the accumulate value of the annual consumption value and the number of inventories for each item.
5. Creating a curve chart to connect the percentage of the number of items and the annual consumption value. Dividing the chart into A, B and C.

#### **2.4.6 Inventory control policies**

##### **2.4.6.1 Inventory Control Policies of A items**

For inventory control in this group, the company should has a strict and close control, because A items are very important for the company. There are always the checking and reporting the movement of inventory to the chief executive. The placement of the order and the use of inventory have to be recorded accurately. Purchasing department should continually follow up the supplier in shipment of the inventory and should conform to the usage. The stock out avoidance of this group is a priority. The reorder point should be calculated carefully and ordered frequently. The level of safety stock should be low or no safety stock. The company should have accurate forecasting by

using the appropriate methods to control inventory such as Economic Order Quantity (EOQ).

#### **2.4.6.2 Inventory Control Policies of B Items**

There are moderate controls in this group. The administrator has to determine and check on inventory. For example, there is a check every 3-4 months. The purchasing in this group is not often as A items. There are low safety stocks as same as A items. The Economic Order Quantity (EOQ) is mostly used.

#### **2.4.6.3 Inventory Control Policies of C Items**

The items in this group are slow-moving inventory. The inventory control of this group is not strict. There are high safety stock levels. The method to control is uncomplicated. There is either a few records or no record for these items. The checking of inventory is not often. For examples, there is a check of inventory once a year or every six months. The Economic Order Quantity (EOQ) and Reorder point are not necessary in this group. The most popular methods to control this group are the Two-Bin System and Visual Review System.

### **2.5 In-Depth Interview**

#### **2.5.1 The definition of In-Depth Interview**

In-depth interviewing is a qualitative research technique to collect specific information which involves conducting intensive individual interviews with target

respondents to explore in depth a respondent's point of view, perspectives, feeling or experience (Boyce and Neale 2006).

### **2.5.2 The process for Conducting In-Depth Interview**

According to Boyce and Neale (2006), the process to conduct in-depth interviews includes planning, developing instruments, collecting data, analyzing data, and disseminating findings. The detailed steps can be described as below:

#### **1. Plan**

- Identify the involved stakeholders.
- Identify the information that we needed and from whom.
- List stakeholders and identify stakeholder groups by national, facility and beneficiary levels.

#### **2. Develop the instrument**

Develop an interview protocol to ensure consistency and increase the reliability of findings between interviews. The instructions for the interviewer should be included in the protocol as below :

- What to say to the respondents when setting up the interview.
- What to say to the respondents when starting the interview.
- What to say to the respondents in finishing up the interview.
- What the interviewer does during the interview (Take notes or Audiotape).
- Develop interview guidelines that list the questions to be explored during the interview. The questions should not be over 15 questions.

#### **3. Training data collection**

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- Identify and train respondents.
4. Collect data
- Set up interview with respondents.
  - Seek informed agreement of respondents. Re-explain the objective and expected duration of the interview, how the information of this interview will be kept as confidential.
  - If the respondents have agreed, conduct the interview.
5. Analyze data
- Transcribe or review the data information.
  - Analyze all data of the interview.
6. Disseminate findings
- Write the report of the interview.
  - Collect feedback from respondents
  - Revise the interview.
  - Disseminate to respondents and the community as appropriate.

## 2.6 Related research

Nueakruk (2008) studied Economic Order Quantity in Dynamic Flow case study company. The purpose of this study was to decrease the quantity of inventory and the holding costs. The case study company imported the cast steel valve from the overseas and the problem of the case study company was excess inventory. Thus, there were high in inventory values and inventory cost including the ordering cost and the holding cost. Moreover, the case study company did not have the appropriate technique to calculate the order quantity. This study used the Economic Order Quantity model to determine the optimum order quantity. The comparison between

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before and after results revealed that the new purchasing method could reduce the inventory costs around 1,240,987.5 Baht or 2.61 % and could reduce the inventory quantities over 10 %.

Krisana Chaiyasil (2011) studied Inventory Control Analysis of Network Camera Components in an Electronic Assembly Manufactory. The purpose of this study was to find the method to reduce the inventory cost and the inventory quantities. This study mainly focused on class A that was imported from the overseas, because they had the highest value in total inventories. From data collection, it found that the lot sizing policy was inefficient. The inventory quantities were not related to the use of inventories. Hence, this study presented the others method such as EOQ, Silver-Meal, POQ, LUC and LTC to determine the optimum order quantity. The results showed that there was lower in ordering cost comparing with the holding cost, because the case study company has the efficient in purchasing. Thus, to reduce the inventory cost, the case study company should increase the frequency of purchasing with less quantities. As a result, the inventory quantities were reduced. The comparison between the old and the new purchasing methods revealed that the inventory costs decreased by 31% and the inventory quantities decreased by 15%.

Sukanya Homnan (2012) studied The Applications of ABC classification and EOQ model in drugs inventory management case study : tambol health promotion hospital, Chiang Kham district, Phayao province. The purpose of this research was to study and use the Economic Order Quantity (EOQ), ABC analysis and Reorder point to control the drugs inventory. Because the hospital had a lot of drugs inventories causing the high drugs inventory value. It consequently leads to high holding cost. Meanwhile, some drugs were stock out which resulted in an inability to provide service to the customer. The cause of problem was the hospital does not has did not

have the appropriate method to control the drugs inventory. The results indicated that the new method could reduce the inventory cost around 26,540.4 Baht or 27.82% and the drugs inventory value decreased around 125,032.9 Baht or 24.73%



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## CHAPTER 3

### METHODOLOGY

#### 3.1 Company overview

The case study company was established on 24 June 1981. They design and produce the distribution transformers. The maximum production capacity per year is 4,000 MVA. The product range is from 1 kVA – 40,000 kVA with maximum voltage of 36 kV. The company has 11 service centers covering the whole country to serve their customers in case of emergency or normal services. For planning and forecasting demand requirements, the production plan of the company 50 % is made-to-stock and the rest is made-to-order. The planning department uses data from sales department to forecast demand requirements. For purchasing, the company orders some raw materials from the overseas supplier. The overseas supplier has an agent in Thailand. Thus, the company can order through the agent. The raw materials that they order from overseas including round aluminum wire, flat aluminum wire, bushing set and transformer oil. It orders the terminal lug from domestic suppliers. The lead times are 90 days for overseas order except bushing set, lead times are 60 days and 30 days for domestic order.



**Figure 3.1:** The product of case study company

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## 3.2 Current status of the company

### 3.2.1 Business process flow of the case study company

The process flow starts from the sales department that receives the order from the customers. Then, the engineering department will design the transformer, and the accounting department will analyze the project costs. After that, the project costs will return to the sales department to bargain with the customers. If it can produce, the sales department will send a purchase order (PO) to the purchasing department. Then, the purchasing department will create bill of materials (BOM) and check the products whether they are available or not. If the products are not available, the purchasing department will inform to the production department to produce the products. The warehouse department will check the raw materials whether they are enough or not. If they are not enough, they will inform to the purchasing department for purchasing plan. After that, the accounting department will bargain with the supplier to purchase raw materials. The shipping department will check the products whether they meet the customer requirements or not. If the customers are not satisfied, they will return the products to the production department to improve. On the other hand, if the customers are satisfied, they will send the products to the customers. The process flow of the company is shown as figure 3.2 :

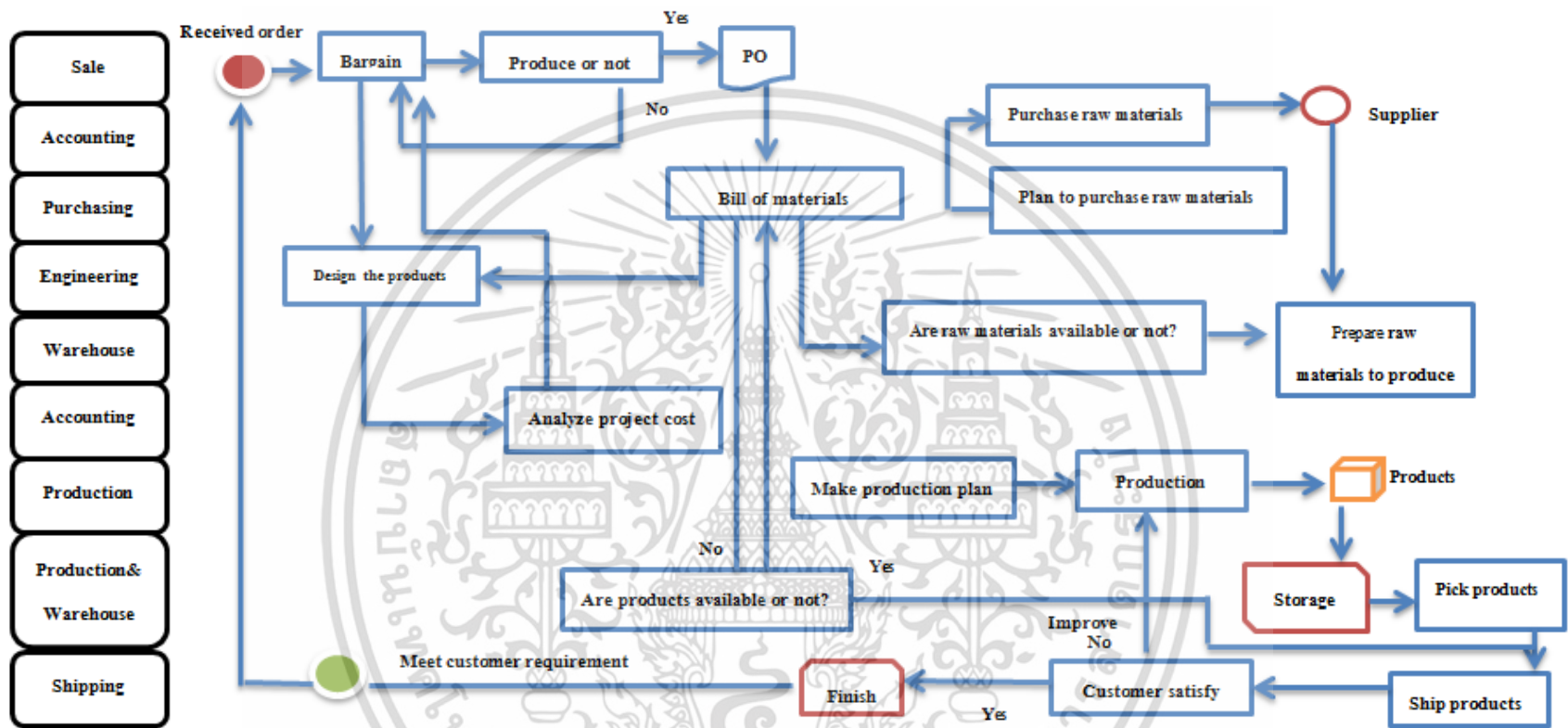
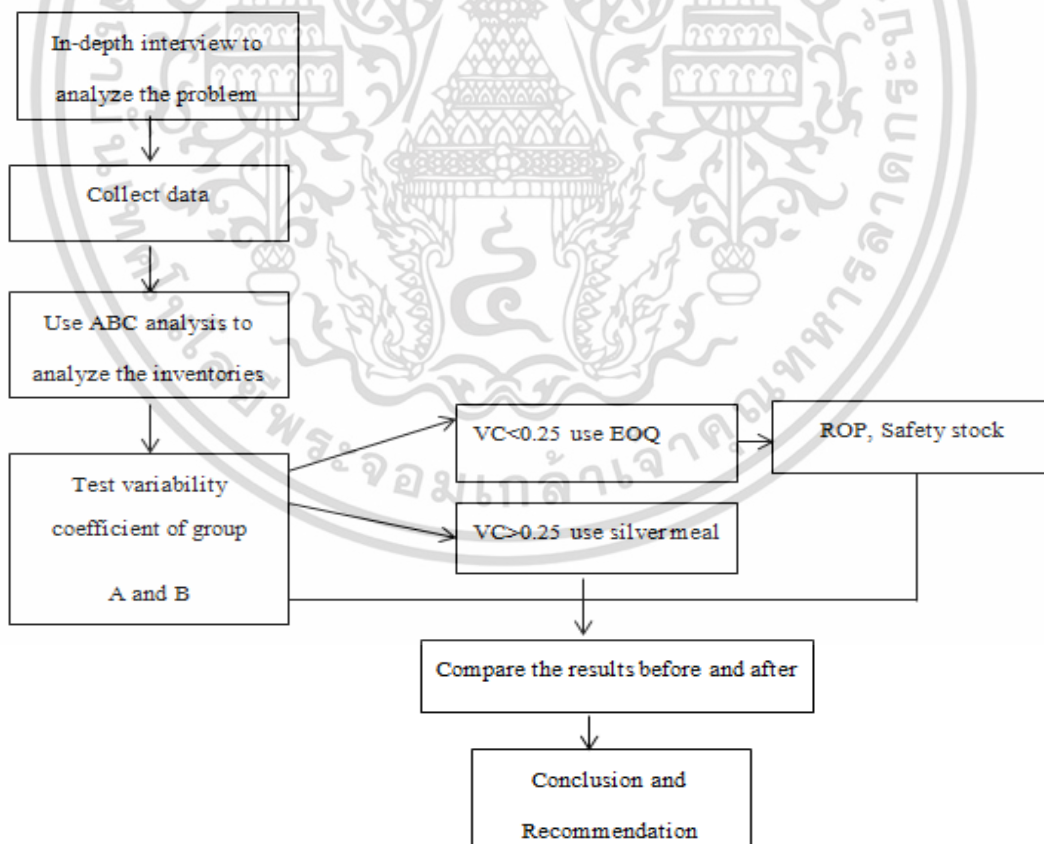


Figure 3.2 The business process flow of the case study company

### 3.3 Methodology

This research focuses on improving the inventory management of the company. Firstly, the researcher conducted in-depth interview with the production manager to analyze the problem of the case study company. The next procedure was collecting inventory data and analyzed the data. Then, the researcher classified the inventory into three groups (A,B and C) by applying ABC analysis method. After that, the test of variability coefficient was conducted for Group A and B in order to find the appropriate method to improve the inventory. It was a comparison the results between the new and the old purchasing. Finally, the researcher concluded and provided the recommendations of this research. The procedures to improve the inventory problem are shown as Figure 3.3 :



**Figure 3.3** The procedure to improve the inventory problem

เอกสารนี้เป็นเอกสารที่สงวนไว้สำหรับการใช้งานเพื่อการศึกษาเท่านั้น ไม่อนุญาตให้นำไปใช้ประโยชน์ด้านการค้า ไม่ว่ากรณีใดๆ ทั้งสิ้น อีกทั้งห้ามมิให้ดัดแปลงเนื้อหา และตั้ง 30 อังอิงถึงเจ้าของเอกสารทุกครั้งที่มีการนำไปใช้

### 3.3.1 In-depth interview

From the in-depth interview (appendix1) with the production manager to analyze the current problems of the company, it could be summarized that the case study company had problems of high inventory level and high inventory costs. The cause of problem was the company did not have the appropriate method to determine the order quantities which the order quantities were not related to the usage. Therefore, the case study company needed to reduce the inventories in order to decrease sunk cost and minimize inventory costs. The raw materials that used to produce the transformer included iron core, copper wire, insulating paper, round aluminium wire, flat aluminium wire, transformer oil, high voltage bushing, low voltage bushing, and terminal lug etc. For the iron core, there was the highest price in the all of raw materials and the case study company had a strict control in this group. Thus, the case study company and the researcher agreed not improve in this group. For selecting the raw materials to improve, the case study company would focus on the raw materials that had a lot inventories, high price and only used to produce the standard transformer. Hence, the case study company selected the raw materials to reduce the inventories including :

1. Round aluminium wire
2. Flat aluminium wire
3. Transformer oil
4. High voltage bushing
5. Low voltage bushing
6. Terminal lug

Accordingly, the researcher collected the inventory data of six groups as

mentioned above from the case study company in terms of the quantity of use, order เอกสารนี้เป็นเอกสารที่สงวนไว้สำหรับการใช้งานเพื่อการศึกษาเท่านั้น ไม่อนุญาตให้นำไปใช้ประโยชน์ด้านการค้า ไม่ว่าจะกรณีใดๆ ทั้งสิ้น อีกทั้งห้ามมิให้ดัดแปลงเนื้อหา และตั้ง 31 บ้างอิงถึงเจ้าของเอกสารทุกครั้งที่มีการนำไปใช้

quantities, quantity of inventory and the material price of each raw material to improve the inventory problem.

### 3.3.2 Collecting data

The inventory data provided by the company showed the raw material data in 2015 including the material price, order quantity, quantity of use and quantity of inventory. Then the researcher calculated the inventory value of each inventory to analyze the inventory problem. The inventory data are shown in Table below :

**Table 3.1:** Inventory value of round aluminum wire

Round aluminum wire	Material price (baht)	Order quantity (KG)	Quantity of use (KG)	Inventory (KG)	Inventory value (baht)
2/EI/AIW/0.70 mm.	130	6,018	4,509	1,509	196,170
2/EI/AIW/0.90 mm.	130	12,033	8,130	3,903	507,390
2/EI/AIW/1.40 mm.	130	36,417	27,703	8,714	1,132,820
2/EI/AIW/1.70 mm.	130	22,564	14,047	8,517	1,107,210
2/EI/AIW/1.90 mm.	130	18,338	11,953	6,385	830,050
2/EI/AIW/2.00 mm.	130	13,496	9,711	3,785	492,050
2/EI/AIW/2.10 mm.	130	4,788	3,218	1,570	204,100
2/EI/AIW/2.20 mm.	130	11	0	11	1,430

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ไม่ว่ากรณีใดๆ ทั้งสิ้น อีกทั้งห้ามมิให้ดัดแปลงเนื้อหา และต้องอ้างอิงถึงเจ้าของเอกสารทุกครั้งที่มีการนำไปใช้

**Table 3.1:** Inventory value of round aluminum wire (Continued)

<b>Round aluminum wire</b>	<b>Material price (baht)</b>	<b>Order quantity (KG)</b>	<b>Quantity of use (KG)</b>	<b>Inventory (KG)</b>	<b>Inventory value (baht)</b>
2/EI/AIW/2.30 mm.	130	15,299	10,965	4,334	563,420
2/EI/AIW/2.40 mm.	130	2,645	563	2,082	270,660
2/EI/AIW/2.50 mm.	130	2,904	120	2,784	361,920
2/EI/AIW/2.60 mm.	130	13,899	8,345	5,554	722,020
2/EI/AIW/2.70 mm.	130	1,472	415	1,057	137,410
2/EI/AIW/2.90 mm.	130	6,260	4,274	1,986	258,180
2/EI/AIW/3.20 mm.	130	19,901	16,146	3,755	488,150
2/EI/AIW/3.90 mm.	130	3,457	1,823	1,634	212,420
			<b>Total</b>	<b>57,580</b>	<b>7,485,400</b>

According to Table 3.1, it shows that there is a high level of inventory. This group has the highest inventories from the other groups. There are about 57,580 kg of inventories with the values of 7,485,400 Baht.

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ไม่ว่ากรณีใดๆ ทั้งสิ้น อีกทั้งห้ามมิให้ดัดแปลงเนื้อหา และต้องอ้างอิงถึงเจ้าของเอกสารทุกครั้งที่มีการนำไปใช้

**Table 3.2:** Inventory value of flat aluminum wire

Flat aluminum wire	Material price (baht)	Order quantity (KG)	Quantity of use (KG)	Inventory (KG)	Inventory value (baht)
3.0×10.0/0.5 mm.	160	14,114	9,533	4,581	732,960
3.0×14.0/0.5 mm.	160	7,562	4,199	3,363	538,032
3.5×14.0/0.5 mm.	160	10,102	6,889	3,213	514,144
4.0×10.0/0.5 mm.	160	8,133	6,181	1,952	312,352
4.0×12.0/0.5 mm.	160	3,402	2,179	1,223	195,664
			<b>Total</b>	<b>14,332</b>	<b>2,293,120</b>

According to Table 3.2, it is found that the price of flat aluminum is low but there are a lot inventories around 14,332 kg with the inventory values of 2,293,120 Baht.

**Table 3.3:** Inventory value of Low voltage bushing

Low voltage Bushing	Material price (baht)	Order quantity (SE)	Quantity of use (SE)	Inventory (SE)	Inventory value (baht)
DT 1/630-AP13	800	12	8	4	3,200
DT 1/1000-AP13	800	16	16	0	0
DT 1/2000-AP13	800	40	40	0	0
DT 1/3150-AP13	800	60	56	4	3,200
DT 1/4500-AP13+Con.Flag	800	208	208	0	0
			<b>Total</b>	<b>8</b>	<b>6,400</b>

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According to Table 3.3, it is found that there were fewer inventories. There were inventories about 8 SE with the inventory values of 6,400 Baht.

**Table 3.4:** Inventory value of High voltage bushing

High voltage Bushing	Material price (baht)	Order quantity (SE)	Quantity of use (SE)	Inventory (SE)	Inventory value (baht)
3N DT 250 DIN 42539	2,000	44	23	21	42,000
250A EN50180	2,000	1,506	1,138	368	736,000
3N DT 630 DIN 42539	2,000	38	38	0	0
DT10 Nf 630 DIN 42532	2,000	91	63	28	56,000
DT20 Nf 630 DIN 42532	2,000	42	21	21	42,000
DT20 Nf 1000 DIN 42533	2,000	30	21	9	18,000
DT10 Nf 1000 DIN 42533	2,000	21	19	2	4,000
DT10 Nf 2000 DIN 42533	2,000	71	43	28	56,000
DT10 Nf 3150 DIN 42533	2,000	8	8	0	0
3KV 6500A	2,000	13	4	9	18,000
			<b>Total</b>	<b>486</b>	<b>972,000</b>

According to Table 3.4, it is found that in this group of high voltage bushing, there are low inventory around 486 set but the price is high, it costs 2,000 Baht/SET. The order quantities is nearest the quantities of use but there were high inventories in some high voltage bushing such as high voltage bushing 250A EN50180, there were inventories up to 368 sets with the inventories value of 736,000 Baht.

**Table 3.5:** Inventory value of transformer oil

Transformer oil	Material price (baht)	Order quantity (L)	Quantity of use (L)	Inventory (L)	Inventory value (baht)
IEC 296/CLASS II	22	2,711,804	2,458,534	253,270	5,571,940
CLASS I (PEGASUS03)	22	7,524	4,984	2,540	55,880
ENVIROTEMP FR3 FLUID	22	26,671	22,912	3,759	82,698
FLUID TSF451-50ETH	22	7,700	0	7,700	169,400
NYTRO LIBRA	22	5,080	2,105	2,975	65,450
PTT HIVOLT99	22	990	840	150	3,300
NYTRO GEMINI X	22	12,540	11,704	836	18,392
NYTRO IZAR II	22	214,713	178,020	36,693	807,246
SHELL DIALA S3 ZX-I	22	1,239	836	403	8,866
HYPERTRANS HR	22	15,321	13,890	1,431	31,482
ERGON HYVOLT III	22	13,487	11,397	2,090	45,980
SHELL DIALA S4 ZX-I	22	7,050	6,767	283	6,226
			<b>Total</b>	<b>312,130</b>	<b>6,866,860</b>

According to Table 3.5, it is found that the price of transformer oil is low but the inventories were high. There were about 312,130 liters with the value of 6,866,860 Baht. Especially IEC296/CLASS II, there were the highest inventory in this group about 253,270 liters with the value of 5,571,940 Baht.

**Table 3.6:** Inventory value of terminal lug

<b>Terminal lug</b>	<b>Material price (baht)</b>	<b>Order quantity (KG)</b>	<b>Quantity of use (KG)</b>	<b>Inventor y (KG)</b>	<b>Inventory value (baht)</b>
Size M20	3,200	4,170	3,094	1,076	3,443,200
Size 2000 A MEA.	3,200	12	12	0	0
Size M42	3,200	24	16	8	25,600
Size 3150 A MEA.	3,200	12	8	4	12,800
Compress type	3,200	77	53	24	76,800
Size 250 A	3,200	702	641	61	195,200
Size 630 A	3,200	355	229	126	403,200
Size 1000 A	3,200	92	79	13	41,600
Size 2000 A	3,200	211	163	48	153,600
Size 3150 A	3,200	310	271	39	124,800
Size 4500 A	3,200	85	68	17	54,400
Size 300 A PEA.No.1	3,200	10,724	9,634	1,090	3,488,000
Size M30	3,200	1,170	1,018	152	486,400
			<b>Total</b>	<b>2,658</b>	<b>8,505,600</b>

According to Table 3.6, it is found that there are the highest inventory value. The price of terminal lug is the most expensive in raw materials. There are inventories about 2,658 kg with the inventory values of 8,505,600 Baht. Especially size 300 A PEA.No.1 and size M20, there were inventories about 1,090 kg and 1,076 kg with the value 3,488,000 Baht and 3,443,200 Baht respectively.

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ไม่ว่ากรณีใดๆ ทั้งสิ้น อีกทั้งห้ามมิให้ดัดแปลงเนื้อหา และตั้ง 37 อ้างอิงถึงเจ้าของเอกสารทุกครั้งที่มีการนำไปใช้

### 3.3.3 Using ABC analysis to analyze the inventories

After collecting data, the researcher used the ABC analysis method to classify the inventories of the case study company into three groups: A, B and C according to its value or importance. The rules to classify the inventory are as the following rules:

A items: there are 5-15 % of total inventory items and accounts for 75-80 % of the consumption value.

B items: there are 20-25 % of total inventory items and accounts for 10-15 % of the consumption value.

C items: there are 60-65 % of total inventory items and accounts for 5-10 % of the consumption value.

The result of classifying the inventories by the ABC analysis method is shown in Table 3.8-3.12 respectively.

**Table 3.7:** The summarize of result a model ABC analysis

CLASS	The amount of inventory	Inventory value	Accumulative value (%)
A	5	102,335,170	77.28 %
B	12	20,864,155	15.76 %
C	44	9,228,097	6.97%
Total	61	132,427,422	100.00%

According to Table 3.7 can be summarized that there are 5 items in A group with the accumulative value of 77.28 %, 12 items in B group with the accumulative value of 15.76% and 44 items in C group with the accumulative value of 6.44%. Then the researcher will chose A and B groups to test variability coefficient to find the appropriate method to improve the inventory.



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**Table 3.8:** Results a Model ABC analysis

No	Raw materials	Annual demand	Price per unit (BATH)	The annual consumption value	%of item value	Accumulative value (%)	CLAS S
35	Transformer oil IEC 296/CLASS II	2,458,534.00	22.00	54,087,748.00	40.84	40.84	A
33	Terminal lug 300 A PEA.No.1	9,634.00	3,200.00	30,828,800.00	23.28	64.12	A
22	Terminal lug M20	3,094.00	3,200.00	9,900,800.00	7.48	71.60	A
42	Transformer oil NYTRO IZAR II	178,020.00	22.00	3,916,440.00	2.96	74.56	A
3	Round aluminium2/EI/AIW/1.40 mm.	27,702.94	130.00	3,601,382.20	2.72	77.28	A
34	Terminal lug M30	1,018.00	3,200.00	3,257,600.00	2.46	2.46	B
15	High Voltage bushing 250A EN50180	1,138.00	2,000.00	2,276,000.00	1.72	4.18	B
4	Round aluminium2/EI/AIW/3.20 mm.	16,146.32	130.00	2,099,021.60	1.59	5.76	B
27	Round aluminium2/EI/AIW/1.70 mm.	16,112.05	130.00	2,094,566.50	1.58	7.35	B
53	Terminal lug 250 A	622.00	3,200.00	1,990,400.00	1.50	8.85	B
5	Round aluminium2/EI/AIW/1.90 mm.	11,952.74	130.00	1,553,856.20	1.17	10.02	B
17	Flat aluminium 3.0*10.0/0.5 mm.	9,533.00	160.00	1,525,280.00	1.15	11.17	B
9	Round aluminium2/EI/AIW/2.30 mm.	10,965.05	130.00	1,425,456.50	1.08	12.25	B

**Table 3.9: Results a Model ABC analysis (CONT)**

No	Raw materials	Annual demand	Price per unit (BATH)	The annual consumption value	%of item value	Accumulative value (%)	CLAS S
6	Round aluminium2/EI/AIW/2.00 mm.	9,710.57	130.00	1,262,374.10	0.95	13.20	B
12	Round aluminium2/EI/AIW/2.60 mm.	9,389.03	130.00	1,220,573.90	0.92	14.12	B
19	Flat aluminium 3.5*14.0/0.5 mm.	6,888.60	160.00	1,102,176.00	0.83	14.96	B
2	Round aluminium2/EI/AIW/0.90 mm.	8,129.62	130.00	1,056,850.60	0.80	15.76	B
20	Flat aluminium4.0*10.0/0.5 mm.	6,180.80	160.00	988,928.00	0.75	0.75	C
31	Terminal con.,Bar 3150 A	271.00	3,200.00	867,200.00	0.65	1.40	C
28	Terminal con.,Bar 630 A	229.00	3,200.00	732,800.00	0.55	1.95	C
18	Flat aluminium 3.0*14.0/0.5 mm.	4,199.30	160.00	671,888.00	0.51	2.46	C
1	Round aluminium 2/EI/AIW/0.70 mm.	4,509.18	130.00	586,193.40	0.44	2.90	C
30	Round aluminium2/EI/AIW/2.90 mm.	4,274.41	130.00	555,673.30	0.42	3.32	C
14	Terminal con.,Bar 2000 A	163.00	3,200.00	521,600.00	0.39	3.72	C
37	Transformer oil ENVIROTEMP FR3 FLUID	22,912.00	22.00	504,064.00	0.38	4.10	C
7	Round aluminium2/EI/AIW/2.10 mm.	3,217.57	130.00	418,284.10	0.32	4.41	C

**Table 3.10:** Results a Model ABC analysis (CONT)

No	Raw materials	Annual demand	Price per unit (BATH)	The annual consumption value	%of item value	Accumulative value (%)	CLAS S
21	Flat aluminium 4.0*12.0/0.5 mm.	2,179.10	160.00	348,656.00	0.26	4.68	C
44	Transformer oil HYPERTRANS HR	13,890.00	22.00	305,580.00	0.23	4.91	C
41	Transformer oil NYTRO GEMINI X	11,704.00	22.00	257,488.00	0.19	5.10	C
29	Terminal con.,Bar 1000 A	79.00	3,200.00	252,800.00	0.19	5.29	C
45	Transformer oil ERGON HYVOLT III	11,397.00	22.00	250,734.00	0.19	5.48	C
16	Round aluminium2/EI/AIW/3.90 mm.	1,823.04	130.00	236,995.20	0.18	5.66	C
32	Terminal con.,Bar 4500 A	68.00	3,200.00	217,600.00	0.16	5.83	C
26	Terminal con.,Bar 6500A	53.00	3,200.00	169,600.00	0.13	5.96	C
51	Low Voltage bushing DT1/4500-AP13	208.00	800.00	166,400.00	0.13	6.08	C
46	Transformer oil SHELL DIALA S4 ZX-I	6,767.00	22.00	148,874.00	0.11	6.19	C
55	High Voltage bushingDT10 Nf630 DIN42532	63.00	2,000.00	126,000.00	0.10	6.29	C
36	Transformer oil CLASS I (PEGASUS03)	4,984.00	22.00	109,648.00	0.08	6.37	C
59	HV bushing DT10 Nf 2000 DIN 42533	43.00	2,000.00	86,000.00	0.06	6.44	C

**Table 3.11:** Results a Model ABC analysis (CONT)

No	Raw materials	Annual demand	Price per unit (BATH)	The annual consumption value	%of item value	Accumulative value (%)	CLAS S
54	High Voltage bushing 3N DT 630 DIN 42539	38.00	2,000.00	76,000.00	0.06	6.49	C
10	Round aluminium2/EI/AIW/2.40 mm.	562.89	130.00	73,175.70	0.06	6.55	C
13	Round aluminium2/EI/AIW/2.70 mm.	415.08	130.00	53,960.40	0.04	6.59	C
24	Terminal con.,Bar M42	16.00	3,200.00	51,200.00	0.04	6.63	C
39	Transformer oil NYTRO LIBRA	2,105.00	22.00	46,310.00	0.03	6.66	C
52	High Voltage bushing 3N DT 250 DIN 42539	23.00	2,000.00	46,000.00	0.03	6.70	C
50	Low Voltage bushing DT 1/3150-AP13	56.00	800.00	44,800.00	0.03	6.73	C
56	High Voltage bushingDT20 Nf630DIN 42532	21.00	2,000.00	42,000.00	0.03	6.76	C
57	High Voltage bushingDT20Nf1000 2533	21.00	2,000.00	42,000.00	0.03	6.80	C
23	Terminal con.,Bar 2000 A MEA.	12.00	3,200.00	38,400.00	0.03	6.82	C
58	High Voltage bushingDT10 Nf1000 42533	19.00	2,000.00	38,000.00	0.03	6.85	C
49	Low Voltage bushing DT 1/2000-AP13	40.00	800.00	32,000.00	0.02	6.88	C
25	Terminal con.,Bar 3150 A MEA.	8.00	3,200.00	25,600.00	0.02	6.90	C

**Table 3.12:** Results a Model ABC analysis (CONT)

No	Raw materials	Annual demand	Price per unit (BATH)	The annual consumption value	%of item value	Accumulative value (%)	CLAS S
40	Transformer oil PTT HIVOLT99	840.00	22.00	18,480.00	0.01	6.91	C
43	Transformer oil SHELL DIALA S3 ZX-I	836.00	22.00	18,392.00	0.01	6.92	C
60	High Voltage bushingDT10Nf 3150 42533	8.00	2,000.00	16,000.00	0.01	6.94	C
11	Round aluminium2/EI/AIW/2.50 mm.	119.79	130.00	15,572.70	0.01	6.95	C
48	Low Voltage bushing DT 1/1000-AP13	16.00	800.00	12,800.00	0.01	6.96	C
61	High Voltage bushing 3KV 6500A	4.00	2,000.00	8,000.00	0.01	6.96	C
47	Low Voltage bushing DT 1/630-AP13	8.00	800.00	6,400.00	0.00	6.97	C
8	Round aluminium2/EI/AIW/2.20 mm.	0	130.00	0	0.0	6.97	C
38	Transformer oil FLUID TSF451-50ETH	0	22.00	0	0.0	6.97	C
				132,427,422.40			

### 3.3.4 Test variability coefficient of group A and B

After inventory classification, the variability coefficient (VC) of group A and B were tested to find the appropriate method to determine the inventories.

The variability coefficient (VC) can be calculated as equation 2.7 :

$$VC = \frac{Est.VarD}{\bar{d}^2} \quad (2.7)$$

$$\bar{d}^2 = \frac{1}{n} \sum_{i=1}^n d_i \quad (2.8)$$

$$Est. Var D = \frac{1}{n} \sum_{i=1}^n d_i^2 \quad (2.9)$$

Where:

$d_i$  = Demand per period

$n$  = Horizon period length

If raw material has the variability coefficient less than 0.25, the researcher will use the economic order quantity model (EOQ).

If raw material has the variability coefficient more than 0.25, the researcher will use the silver-meal heuristic method.

### 3.3.5 Find the economic order quantity model (EOQ)

After the variability coefficient (VC) of group A and B testing, the economic order quantity model (EOQ) was applied to the raw material that had the variability coefficient less than 0.25. Because the demand was constant. Thus, economic order

quantity model (EOQ) was the appropriate method to determine the order quantity.

The mentioned equation in Chapter 2 is exemplified as follows:

The EOQ can be calculated as equation 2.1 :

$$EOQ = \sqrt{\frac{2CoD}{Ch}} \quad (2.1)$$

Where

D = Annual demand requirements per unit

Co = Ordering cost per order (Baht)

Ch = Holding cost per unit (Baht)

Q = Order quantity

TC = Total annual cost (Baht)

- Find the minimum total cost

The minimum total cost can be calculated as equation 2.2 :

$$TC_{min} = \frac{CoD}{Q} + \frac{QCc}{2} \quad (2.2)$$

- Find the total annual ordering cost

The total annual ordering cost can be expressed as equation 2.3 :

$$\text{Annual ordering cost} = \left(\frac{D}{Q}\right)Co \quad (2.3)$$

- Find total annual ordering cost

The total annual holding cost can be expressed as equation 2.4 :

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$$\text{Annual holding cost} = \left(\frac{Q}{2}\right)Ch$$

(2.4)

- Find the optimum number of order per year

The optimum number of order per year (N) can be calculated as equation 2.5 :

$$N = \frac{D}{Q} \quad (2.5)$$

- Find Reorder point and Safety stock

The reorder point was computed when the demand was not constant but lead time was certain. However, the supplier was reliable and had on time delivery. Thus, the reorder point can be calculated as equation 2.28 :

Reorder point = (Average demand × Lead time) + Safety Stock

$$ROP = (\bar{d})(LT) + Z\sigma_d \sqrt{LT} \quad (2.28)$$

Where

$\bar{d}$  = average demand

LT = lead time

Z = number of standard deviation corresponding to the service level probability

$\sigma_d$  = standard deviation of demand

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### 3.3.6 Using Silver meal method

In case of the raw material that has the variability coefficient more than 0.25, it shows that, the demand is not constant. Therefore, the economic order quantity model (EOQ) can not be used because this method is appropriate with the constant demand. Accordingly, the silver meal method will be used to determine the order quantities due to this method appropriate with the lumpy demand. Therefore, the variable cost can be found as the equation 2.10 :

$$K(1) = A \quad (2.10)$$

when  $A =$  Ordering cost

If the quantity order equal  $D^1 + D^2$  in the period 1 and 2 to meet the customer requirement, the variable cost can be found as the equation 2.11 :

$$K(2) = \frac{1}{2} (A + hD_2) \quad (2.11)$$

when  $A =$  Ordering cost

$H =$  Holding cost per unit in the 1 period time

Thus, the variable cost in total study period can be calculated as the equation 2.12

$$K(m) = \frac{1}{m} (A + hD_2 + 2hD_3 + \dots + (m-1)(hD_m)) \quad (2.12)$$

Recalculate  $K(m)$ ,  $m = 1, 2, 3, \dots, m$  until the variable cost in total period increases then stop the calculation as the equation 2.13 :

$$K(m+1) > K(m) \quad (2.13)$$

We will order the quantity to meet requirement in the period which the average cost per period begin increasing. Thus, in the period 1 the order quantity can be calculated from the equation 2.14 as below :

$$Q = D + D + \dots + D \quad (2.14)$$

### 3.3.7 Compare the results before and after

After determining the minimum order quantity of the raw materials by the economic order quantity model (EOQ) and silver meal method, the comparison between the new and old purchasing methods were evaluated whether the new purchasing method could reduce the inventory or not. The results of the new purchasing are shown in the chapter 4

## CHAPTER 4

### RESULTS

In this research study, the researcher collected the data and reviewed other literatures. Then, six groups of the raw materials data that used to produce the standard transformers in 2015 were classified by the using ABC analysis method. According to Chapter 3, it is found that there are 5 items in A group with the accumulative value of 77.28 %, 12 items in B group with the accumulative value of 15.76% and 43 items in C group with the accumulative value of 6.97% respectively. The researcher tested the variability coefficient for A and B groups to find the appropriate methods by using the EOQ or Silver-Meal method to solve the problem. The results of the analysis are shown as follows:

#### 4.1 Variability coefficient test in A and B groups

For the test variability coefficient, the researcher used the transformer oil IEC 296/CLASS II of A group as an example for calculation.

**Table 4.1:** the demand of transformer oil IEC 296/CLASS II

Month	Demand (Liters)
January	184,396
February	153,341
March	123,233
April	245,655
May	150,264
June	167,910
July	270,974

**Table 4.1:** the demand of transformer oil IEC 296/CLASS II (Continued)

Month	Demand (Liters)
August	222,474
September	290,411
October	202,363
November	224,013
December	223,500
<b>Total</b>	<b>2,458,534</b>

The variability coefficient (VC) can be calculated as equation 4.3:

$$\bar{d}^2 = \frac{1}{n} \sum_{i=1}^n d_i \quad (4.1)$$

$$= \left( \frac{2,458,534}{2} \right)^2$$

$$= 41,974,926,591.36$$

$$\text{Est. Var D} = \frac{1}{n} \sum_{i=1}^n d_i^2 \quad (4.2)$$

$$= \frac{184,396 + 153,341 + 123,233 + 245,665 + 150,264 + 167,910 + 270,974 + 222,474 + 290,411 + 202,363 + 224,013 + 223,500}{12} - 41,974,926,591.36$$

$$= 44,347,177,701.50$$

$$\text{VC} = \frac{\text{Est.VarD}}{\bar{d}^2} \quad (4.3)$$

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$$= \frac{44,347,177,701.50}{41,974,926,591.36} = 0.06$$

From calculation of the variability coefficient, it found that the transformer oil IEC 296/CLASS II has the VC equal to 0.06, which is less than 0.25. Therefore, The EOQ model is appropriate to use with this raw material.

After calculating the variability coefficient in A and B groups, it can be summarized that all raw materials in A group have the variability coefficient equal or less than 0.25. Hence, the EOQ model can be applied. In B group, there are 9 raw materials that have the variability coefficient equal or less than 0.25. Hence, the EOQ model can be used. However, there are 4 raw materials that have the variability coefficient more than 0.25. Thereby, the Silver-Meal method is used for this group. From the examples given above, the results of variability coefficient test in A and B groups are shown as table 4.2:

**Table 4.2:** Variability test in A and B groups

No	Raw materials	Group	Total demand	$\bar{d}^2$	Est.Var D	VC	Method
1.	Transformer oil IEC 296/CLASS II	A	2,458,534.00	41,974,926,591.36	44,347,177,701.50	0.06	EOQ
2.	Terminal lug 300 A PEA.No.1	A	9,634.00	644,541.36	55,160.47	0.09	EOQ
3.	Terminal lug M20	A	3,094.00	66,478.03	16,277.97	0.24	EOQ
4.	Transformer oil NYTRO IZAR II	A	178,020.00	220,077,225.00	55,591,378.17	0.25	EOQ
5.	Round aluminium2/EI/AIW/1.40 mm.	A	27,702.94	5,329,533.92	1,298,691.32	0.24	EOQ
6.	Terminal lug M30	B	1,018.00	7,196.69	1,758.14	0.24	EOQ
7.	High voltage bushing 250A EN50180	B	1,138.00	8,993.36	1,059.14	0.12	EOQ
8.	Round aluminium2/EI/AIW/3.20 mm.	B	16,146.32	1,810,442.01	448,201.03	0.25	EOQ
9.	Round aluminium2/EI/AIW/1.70 mm.	B	16,112.05	1,802,764.97	788,229.81	0.32	Silver-Meal
10.	Terminal lug 250 A	B	641.00	2,686.69	1,964.47	0.64	Silver-Meal
11.	Round aluminium2/EI/AIW/1.90 mm.	B	11,952.74	992,138.84	228,195.50	0.23	EOQ
12.	Flat aluminium 3.0×10.0/0.5 mm.	B	9,533.00	631,097.84	141,240.98	0.22	EOQ
13.	Round aluminium2/EI/AIW/2.30 mm.	B	10,965.05	834,946.68	206,594.22	0.25	EOQ
14.	Round aluminium2/EI/AIW/2.00 mm.	B	9,710.57	654,827.57	162,918.98	0.25	EOQ
15.	Round aluminium2/EI/AIW/2.60 mm.	B	9,389.03	612,179.75	440,683.99	0.49	Silver-Meal
16.	Flat aluminium 3.5×14.0/0.5 mm.	B	6,888.60	329,533.40	217,219.01	0.41	Silver-Meal
17.	Round aluminium2/EI/AIW/0.90 mm.	B	8,129.62	458,963.34	105,408.07	0.23	EOQ

## 4.2 The holding cost and ordering cost calculation

### 4.2.1 The holding cost

The concept of holding cost is introduced in the Chapter 2. Using the data from the company, the depreciation and the parameters involved in the calculation of the holding cost is given as follows:

$$\text{- Depreciation of warehouse} = \frac{\text{Cost}}{\text{Usefullife}} \quad (4.4)$$

$$= \frac{20,000,000}{10} \\ = 2,000,000 \text{ Baht/year}$$

$$\text{- Depreciation of forklift (2 forklifts)} = \frac{1,500,000 \times 2}{5} \\ = 600,000 \text{ Baht/year}$$

$$\text{Cost of labors 10 people} = 400 \times 10 \times 365 = 1,400,000 \text{ Baht/year}$$

$$\text{Cost of gasoline 2 forklift} = 500 \times 2 \times 365 = 365,000 \text{ Baht/year}$$

$$\text{Cost of electricity} = 200 \times 365 = 73,000 \text{ Baht/year}$$

$$\text{Cost of water} = 10 \times 365 = 3,650 \text{ Baht/year}$$

$$\text{The area of warehouse} = 2,200 \text{ m}^2$$

$$\text{Therefore, the holding cost / area} = 2,000,000 + 600,000 + 1,400,000$$

$$+ 365,000 + 73,000 + 3650 / 2,200$$

$$= 2,018.93 \text{ Baht/ m}^2 \text{ /year}$$

For the calculation of the holding cost of raw materials, the round aluminum wire was used as an example. The result showed that the area for holding 1 square meter can

hold the 720 round aluminum wires. The holding cost per area is 2,018.93 Baht/  $m^2$  /year.

$$\text{Hence, the holding cost of round aluminum wire} = \frac{2,018.93}{720} = 2.81 \text{ Baht/year.}$$

Accordingly, the holding cost of the other raw materials is shown in the table 4.3:

**Table 4.3:** the holding cost of raw materials

No	Raw materials	The area for holding 1 square meter	The holding cost per year (Baht)
1.	Round aluminum wire (kg)	720	2.81
2.	Flat aluminum wire (kg)	800	2.52
3.	Terminal lug (ea)	5,000	0.41
4.	Transformer oil (liter)	7,000	0.29
5.	HV bushing	60	33.65

#### 4.2.2 The ordering cost

The ordering cost can be calculated as follows :

Cost of buying department salary

- Cost of buying officer = 11,000 Baht/month
- Amount of working day = 26 days

Work hours per day = 8 hours

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Therefore, the cost =  $(11,000/26/8) = 52.88$  Baht

Cost of paper = 2 Baht

Cost of telephone and fax = 3 Baht

Accordingly, the ordering cost =  $52.88+2+3 = 57.88$  Baht/time

### 4.3 Economic order quantity calculation

In case of the raw material has the variability coefficient equal or less than 0.25, it implies that the demand is constant. Hence, the EOQ is used to determine the order quantities.

The EOQ can be calculated as equation 4.5:

$$EOQ = \sqrt{\frac{2CoD}{Ch}} \quad (4.5)$$

Where

D = Annual demand requirements per unit

Co = Ordering cost per order (Baht)

Ch = Holding cost per unit (Baht)

Q = Order quantity

TC = Total annual cost (Baht)

For example of the EOQ calculation, the terminal lug 300 A PEA.No.1 was used as an example for calculation as follows:

Terminal lug 300 A PEA.No.1

D = 9,637

Co = 57.88 Baht

Ch = 0.41 Baht

$$EOQ = \sqrt{\frac{2 \times 57.88 \times 9,637}{0.41}}$$

≈ 1,650 each

The minimum total cost can be calculated as equation 4.6:

$$TC_{min} = \frac{CoD}{Q} + \frac{QCc}{2} \quad (4.6)$$

$$= \frac{57.88 \times 9,637}{1,650} + \frac{1,650 \times 0.41}{2}$$
$$= 676.30 \text{ Baht}$$

The optimum number of order per year (N) can be calculated as equation 4.7:

$$N = \frac{D}{Q} \quad (4.7)$$

$$= \frac{9,637}{1,650} = 6 \text{ times}$$

Reorder point and Safety stock can be calculated as equation 4.8:

$$ROP = (\bar{d})(LT) + Z\sigma_d \sqrt{LT} \quad (4.8)$$

Where

$\bar{d}$  = average demand

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$Z$  = number of standard deviation corresponding to the service level probability

$\sigma_d$  = standard deviation of demand

For example of the ROP calculation, the terminal lug 300 A PEA.No.1 was used as an example for calculation as follows:

$$\begin{aligned} \text{ROP} &= 26.39 \times 30 + 1.65 \times \sqrt{30} \\ &= 5,212.22 \end{aligned}$$



**Table 4.4:** Economic Order Quantity (EOQ) calculation

No	Raw materials	Demand	Holding cost	Ordering cost	Q	N	Cost of holding	Cost of ordering	Total cost
1	Terminal lug 300 A PEA.No.1	9,634	0.41	57.88	1,650	6	338.25	338.05	676.30
2	Terminal lug size M30	1,018	0.41	57.88	537	2	110.09	109.72	219.81
3	Terminal lug size M20	3,094	0.41	57.88	935	4	191.68	191.53	646
4	High voltage bushing 250A EN50180	1,138	57.88	33.65	63	19	1,045.51	1,059.98	2,105.49
5	Transformer oil IEC 296/CLASS II	2,458,534	0.29	57.88	31,327	79	4,542.42	4,542.41	9,084.82
6	Transformer oil NYTRO IZAR II	178,020	0.29	57.88	8,430	22	1,222.35	1,222.28	2,444.63
7	Round aluminium2/EI/AIW/1.40 mm.	27,703	2.81	57.88	1,069	26	1,501.95	1,499.95	3,001.90
8	Round aluminium2/EI/AIW/3.20 mm.	16,146	2.81	57.88	816	20	1,146.48	1,145.26	16,320
9	Round aluminium2/EI/AIW/1.90 mm.	11,953	2.81	57.88	702	18	986.31	985.53	1971.84
10	Round aluminium2/EI/AIW/2.30 mm.	10,965	2.81	57.88	673	17	945.57	943.02	1888.59
11	Round aluminium2/EI/AIW/2.00 mm.	9,711	2.81	57.88	633	16	889.37	887.95	1777.32
12	Round aluminium2/EI/AIW/0.90 mm.	8,130	2.81	57.88	579	15	813.50	812.72	1626.21
13	Flat aluminium 3.0×10.0/0.5 mm.	9,533	2.52	57.88	662	15	834.12	833.49	1667.61

**Table 4.5:** The reorder point and safety stock

No	Raw materials	$\bar{d}$	LT	$\bar{d} \times LT$	Z	$\sigma_d$	$\sqrt{LT}$	SS	ROP
1	Terminal lug 300 APEA.No.1	26.39	30	791.84	1.65	245.31	5.48	2,210.22	3,002.05
2	Terminal lug size M30	2.79	30	83.67	1.65	36.40	5.48	327.93	411.60
3	Terminal lug size M20	8.48	30	254.30	1.65	133.26	5.48	1,200.66	1,454.96
4	High voltage bushing 250A EN50180	3.12	90	280.60	1.65	17.03	9.49	1,234.82	1,515.42
5	Transformer oil IEC 296/CLASS II	6,735.71	60	404,142.58	1.65	50,871.51	7.75	648,210.61	1,052,353.19
6	Transformer oil NYTRO IZAR II	487.73	60	29,263.56	1.65	7,787.50	7.75	99,229.21	128,492.77
7	Round aluminium2/EI/AIW/1.40 mm.	75.90	60	4,553.91	1.65	1,190.27	7.75	15,166.62	19,720.53
8	Round aluminium2/EI/AIW/3.20 mm.	44.24	60	2,654.19	1.65	699.25	7.75	8,909.89	11,564.08
9	Round aluminium2/EI/AIW/1.90 mm.	32.75	60	1,964.83	1.65	498.94	7.75	6,357.54	8,322.38
10	Round aluminium2/EI/AIW/2.30 mm.	30.04	60	1,802.47	1.65	474.74	7.75	6,049.16	7,851.63
11	Round aluminium2/EI/AIW/2.00 mm.	26.60	60	1,596.26	1.65	421.58	7.75	5,371.82	6,968.08
12	Round aluminium2/EI/AIW/0.90 mm.	22.27	60	1,336.38	1.65	339.10	7.75	4,320.89	5,657.26
13	Flat aluminium 3.0×10.0/0.5 mm.	26.12	60	1,567.07	1.65	392.53	7.75	5,001.68	6,568.75

#### 4.4 Silver-Meal method calculation

In case of the raw material that the variability coefficient more than 0.25, it shows the demand is not constant. Accordingly, the silver meal method is used to determine the order quantities. For the example of Silver-Meal method calculation, the Terminal lug 250 A was used as an example for calculation as follows:

**Table 4.6:** the demand of Terminal lug 250 A

Month	Demand
January	28
February	24
March	9
April	36
May	21
June	47
July	128
August	138
September	102
October	65
November	25
December	49
<b>Total</b>	<b>641</b>

**Start determine January is T= 1**

**- The order policy for 1 month use**

Hence, the order of quantities = 28 pieces

Total cost = ordering cost + holding cost

$$= 57.88+0 = 57.88 \text{ Baht}$$

Total cost in T period =  $57.88/1 = 57.88$

**- The order policy for 2 months use**

Hence, the order of quantities =  $28+24 = 52$  pieces. (By hold 24 pieces for 1 month)

Total cost = ordering cost + holding cost

$$= 57.88 + (24 \times 0.41) = 67.72 \text{ Baht}$$

Total cost in T period =  $67.72/2 = 33.86 \text{ Baht}$

**- The order policy for 3 month use.**

Hence, the order of quantities =  $28+24+9 = 61$  pieces. (By hold 24 pieces for 1 month and 9 pieces for 2 months)

Total cost = ordering cost + holding cost

$$= 57.88 + (24 \times 0.41) + (9 \times 0.41 \times 2) = 75.1 \text{ Baht}$$

Total cost in T period =  $75.1/3 = 25.03$

**- The order policy for 4 month use**

Hence, the order of quantities =  $28+24+9+36 = 97$  pieces. (By hold 24 pieces for 1 month, 9 pieces for 2 months and 36 pieces for 3 months)

Total cost = ordering cost + holding cost

$$= 57.88 + (24 \times 0.41) + (9 \times 0.41 \times 2) + (36 \times 0.41 \times 3) = 119.38$$

Baht

$$\text{Total cost in T period} = 119.38/4 = 29.84 \text{ Baht}$$

From the calculation, found that the order policy for 3 months use has the lowest cost.

Therefore, the first policy is to order 61 pieces of raw materials to use for 3 months (January, February and March).

**Start determine April is T= 1**

**- The order policy for 1 month use**

Hence, the order of quantities = 36 pieces

Total cost = ordering cost + holding cost

$$= 57.88 + 0 = 57.88 \text{ Baht}$$

$$\text{Total cost in T period} = 57.88/1 = 57.88$$

**- The order policy for 2 months use**

Hence, the order of quantities = 36+21 = 57 pieces. (By hold 21 pieces for 1 month)

Total cost = ordering cost + holding cost

$$= 57.88 + (21 \times 0.41) = 66.49 \text{ Baht}$$

$$\text{Total cost in T period} = 66.49/2 = 33.25 \text{ Baht}$$

**- The order policy for 3 months use**

Hence, the order of quantities = 36+21+47 = 104 pieces. (By hold 21 pieces for 1 month and 47 pieces for 2 months)

Total cost = ordering cost + holding cost

$$= 57.88 + (21 \times 0.41) + (47 \times 0.41 \times 2) = 105.3 \text{ Baht}$$

$$\text{Total cost in T period} = 105.03/3 = 35.01 \text{ Baht}$$

From the calculation, it shows that order policy with 2 months use has the lowest cost. Therefore, the second policy is to order 57 pieces of raw materials to use for 2 months (April and May).

**Start determine June is T= 1**

**- The order policy for 1 month use**

Hence, the order of quantities = 47 pieces

Total cost = ordering cost + holding cost

$$= 57.88 + 0 = 57.88 \text{ Baht}$$

$$\text{Total cost in T period} = 57.88/1 = 57.88$$

**- The order policy for 2 month use**

Hence, the order of quantities = 47+127 = 174 pieces. (By hold 127 pieces for 1 month)

Total cost = ordering cost + holding cost

$$= 57.88 + (127 \times 0.41) = 109.95 \text{ Baht}$$

$$\text{Total cost in T period} = 109.95/2 = 54.98 \text{ Baht}$$

**- The order policy for 3 month use**

Hence, the order of quantities = 47+127+138 = 312 pieces. (By hold 127 pieces for 1 month and 138 pieces for 2 months)

Total cost = ordering cost + holding cost

$$= 57.88 + (127 \times 0.41) + (138 \times 0.41 \times 2) = 223.11 \text{ Baht}$$

$$\text{Total cost in T period} = 223.11 / 3 = 74.37 \text{ Baht}$$

From the calculation, it shows that the order policy for 2 months use has the lowest cost. Therefore, the third policy is to order 174 pieces of raw materials to use for 2 months (June and July)

**Start determine August is T= 1**

**- The order policy for 1 month use**

Hence, the order of quantities = 138 pieces

Total cost = ordering cost + holding cost

$$= 57.88 + 0 = 57.88 \text{ Baht}$$

$$\text{Total cost in T period} = 57.88 / 1 = 57.88$$

**- The order policy for 2 month use**

Hence, the order of quantities = 138+102 = 240 pieces. (By hold 102 pieces for 1 month)

Total cost = ordering cost + holding cost

$$= 57.88 + (102 \times 0.41) = 99.7 \text{ Baht}$$

$$\text{Total cost in T period} = 99.7 / 2 = 49.85 \text{ Baht}$$

**- The order policy for 3 month use**

Hence, the order of quantities = 138+102+65 = 305 pieces. (By hold 102 pieces for 1 month and 65 pieces for 2 months)

Total cost = ordering cost + holding cost

$$= 57.88 + (102 \times 0.41) + (65 \times 0.41 \times 2) = 153 \text{ Baht}$$

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ไม่ว่ากรณีใดๆ ทั้งสิ้น อีกทั้งห้ามมิให้ตัดแปลงเนื้อหา และตั้ง 65 อ้างอิงถึงเจ้าของเอกสารทุกครั้งที่มีการนำไปใช้

$$\text{Total cost in T period} = 153/3 = 51 \text{ Baht}$$

From the calculation, it shows that the order policy for 2 months use has the lowest cost. Therefore, the fourth policy is to order 240 pieces of raw materials to use for 2 months (August and September).

**Start determine October is T= 1**

**- The order policy for 1 month use**

Hence, the order of quantities = 65 pieces

Total cost = ordering cost + holding cost

$$= 57.88 + 0 = 57.88 \text{ Baht}$$

$$\text{Total cost in T period} = 57.88/1 = 57.88$$

**- The order policy for 2 month use**

Hence, the order of quantities = 65+25 = 90 pieces. (By hold 25 pieces for 1 month)

Total cost = ordering cost + holding cost

$$= 57.88 + (25 \times 0.41) = 68.13 \text{ Baht}$$

$$\text{Total cost in T period} = 68.13/2 = 34.07 \text{ Baht}$$

**- The order policy for 3 month use**

Hence, the order of quantities = 65 + 25 + 19 = 109 pieces. (By hold 25 pieces for 1 month and 19 pieces for 2 months)

Total cost = ordering cost + holding cost

$$= 57.88 + (25 \times 0.41) + (19 \times 0.41 \times 2) = 83.71 \text{ Baht}$$

$$\text{Total cost in T period} = 83.71/3 = 27.90 \text{ Baht}$$

From the calculation, it shows that the order policy for 3 months use has the lowest cost. Therefore, the last policy is to order 109 pieces of raw materials to use for 3 months (October, November and December).

**Table 4.7:** the Silver-Meal policy of Terminal lug 250 A

Months	Demand	The order of quantities	Ordering cost	Holding cost	Total cost
January	28	28+24+9 = 61	57.88	=(24×0.41)+(9×0.41×2)	75.10
February	24				
March	9				
April	36	36+21 = 57	57.88	= 21×0.41	66.49
May	21				
June	47	47+127 = 174	57.88	=127×0.41	109.95
July	127				
August	138	138+102 =240	57.88	=102×0.41	99.70
September	102				
October	65	65+25+19=109	57.88	=(25×0.41)+(19×0.41×2)	83.10
November	25				
December	19				
<b>Total</b>	<b>641</b>				<b>434.34</b>

According to the table 4.7, it can be summarized that there are 5 times to order raw materials, the first order is order 61 pieces to use for 3 months (January, February and March). The second order is order 57 pieces to use for 2 months (April and May). The third order is order 174 pieces to use for 2 months (June and July). The fourth is order 240 pieces to use for 2 months (August and September). The last order is order

109 pieces to use for 3 months (October, November and December). The total cost is 434.34 Baht.

**Table 4.8:** the Silver-Meal policy of round aluminium wire 2/EI/AIW/1.70 mm.

Months	Demand	The order of quantities	Ordering cost	Holding cost	Total cost
January	545	545	57.88	0	57.88
February	1,324	1,324	57.88	0	57.88
March	2,284	2,284	57.88	0	57.88
April	409	409	57.88	0	57.88
May	1,394	1,394	57.88	0	57.88
June	1,233	1,233	57.88	0	57.88
July	968	968	57.88	0	57.88
August	2,061	2,061	57.88	0	57.88
September	263	263	57.88	0	57.88
October	525	525	57.88	0	57.88
November	2,091	2,091	57.88	0	57.88
December	950	950	57.88	0	57.88
<b>Total</b>	<b>14,047</b>				<b>694.56</b>

According to the table 4.8, it can be summarized that the company has to order the raw materials every month with the quantity equal to the demand each month.

**Table 4.9:** the Silver-Meal policy of flat aluminium wire 3.5×14.0/0.5 mm.

Months	Demand	The order of quantities	Ordering cost	Holding cost	Total cost
January	250	→ 250	57.88	0	57.88
February	1,204	→ 1,204	57.88	0	57.88
March	259	→ 259	57.88	0	57.88
April	1,095	→ 1,095	57.88	0	57.88
May	106	→ 106	57.88	0	57.88
June	400	→ 400	57.88	0	57.88
July	366	→ 366	57.88	0	57.88
August	806	→ 806	57.88	0	57.88
September	555	→ 555	57.88	0	57.88
October	646	→ 646	57.88	0	57.88
November	275	→ 275	57.88	0	57.88
December	927	→ 927	57.88	0	57.88
<b>Total</b>	<b>6,889</b>				<b>694.56</b>

According to the table 4.9, it can be summarized that the company has to order the raw materials every month with the quantity equal to the demand each month.

**Table 4.10:** the Silver-Meal policy of round aluminium wire 2/EI/AIW/2.60 mm.

Months	Demand	The order of quantities	Ordering cost	Holding cost	Total cost
January	377	→	57.88	0	57.88
February	1,674	→	57.88	0	57.88
March	1,074	→	57.88	0	57.88
April	527	→	57.88	0	57.88
May	620	→	57.88	0	57.88
June	1,246	→	57.88	0	57.88
July	103	→	57.88	0	57.88
August	1,310	→	57.88	0	57.88
September	408	→	57.88	0	57.88
October	511	→	57.88	0	57.88
November	104	→	57.88	0	57.88
December	390	→	57.88	0	57.88
<b>Total</b>	<b>8,345</b>				<b>694.56</b>

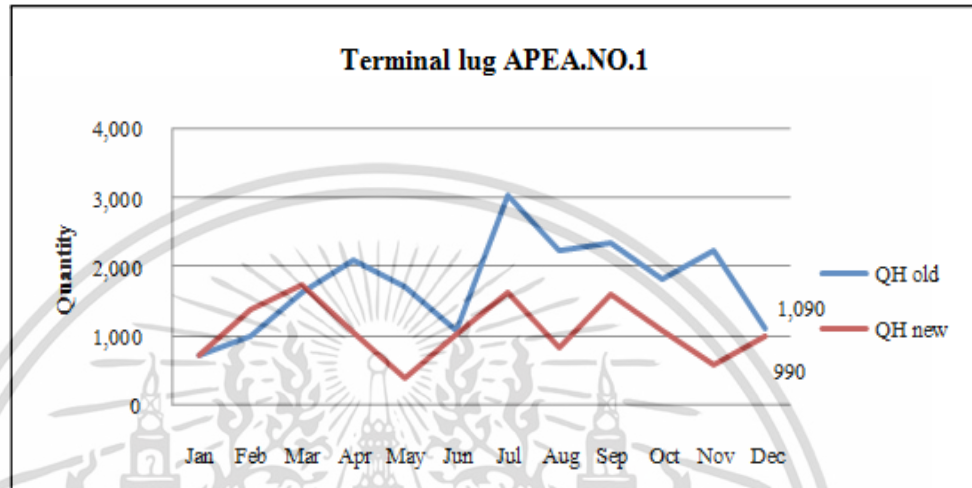
According to the table 4.8, it can be summarized that the company has to order the raw materials every month with the quantity equal to the demand each month.

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ไม่ว่ากรณีใดๆ ทั้งสิ้น อีกทั้งห้ามมิให้ดัดแปลงเนื้อหา และต้องอ้างอิงถึงเจ้าของเอกสารทุกครั้งที่มีการนำไปใช้

## 4.5 The comparison results of new and old method

### 4.5.1 The comparison results EOQ model with the old method

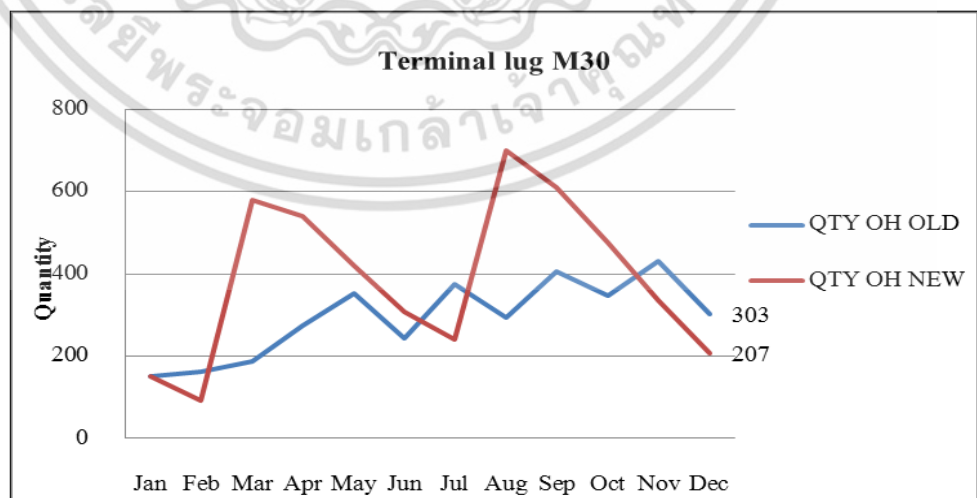
#### - Terminal lug 300 A PEA.No.1



**Figure 4.1:** The comparison graph of terminal lug 300 A PEA.No.1

From Figure 4.1, show that the EOQ method can decrease the inventories from 1,090 ea to 990 ea with the inventory value 320,000 Baht.

#### - Terminal lug M30

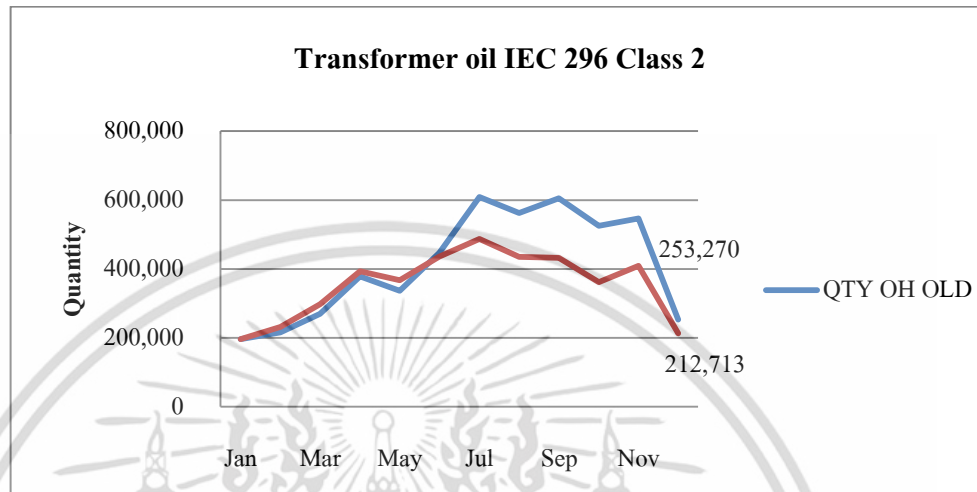


**Figure 4.2:** The comparison graph of terminal lug M30

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From Figure 4.2, show that the EOQ method can decrease the inventories from 303 ea to 207 ea with the inventory value 307,200 Baht.

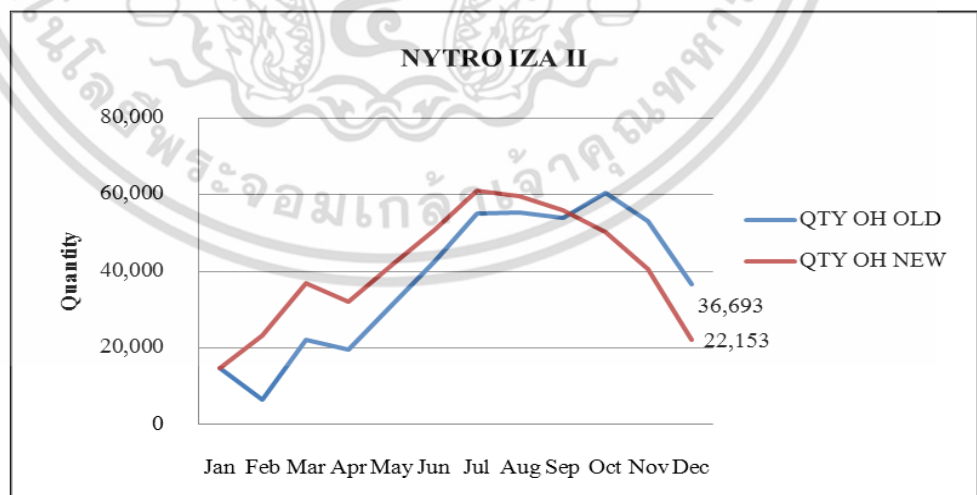
**- Transformer oil IEC 296 Class 2**



**Figure 4.3:** The comparison graph of transformer oil IEC 296 Class 2

From Figure 4.3, show that the EOQ method can decrease the inventories from 253,270 L to 212,713 L with the inventory value 892,254 Baht.

**- NYTRO IZAR II**

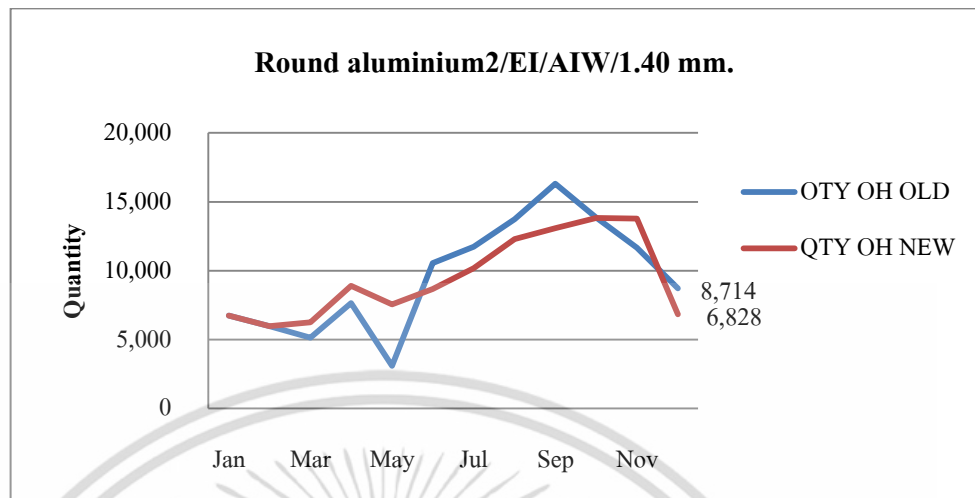


**Figure 4.4:** The comparison graph of NYTRO IZAR II

From Figure 4.4, show that the EOQ method can decrease the inventories from

36,693 L to 22,153 L with the inventory value 319,880 Baht.

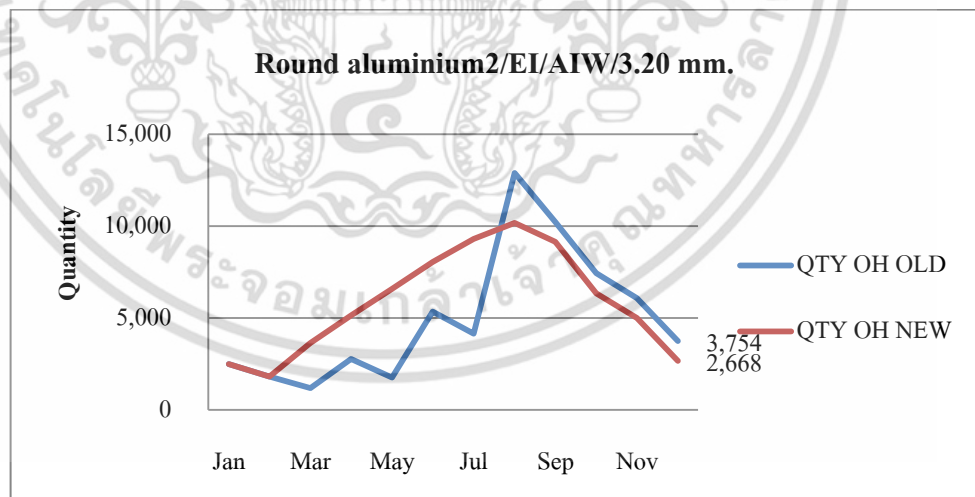
**- Round aluminium2/EI/AIW/1.40 mm**



**Figure 4.5:** The comparison graph of round aluminium2/EI/AIW/1.40 mm

From Figure 4.5, show that the EOQ method can decrease the inventories from 8,714 Kg to 6,828 Kg with the inventory value 245,262 Baht.

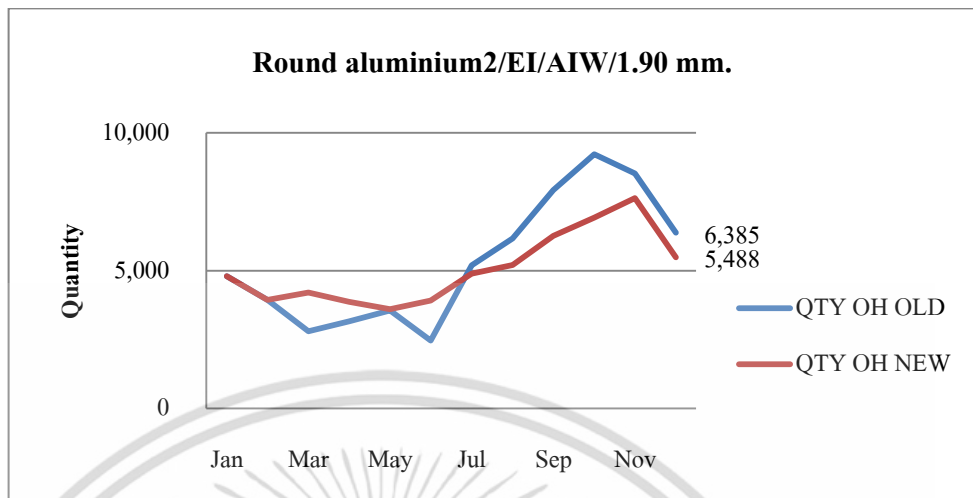
**- Round aluminium2/EI/AIW/3.20 mm.**



**Figure 4.6:** The comparison graph of round aluminium2/EI/AIW/3.20 mm.

From Figure 4.6, show that the EOQ method can decrease the inventories from 3,754 Kg to 2,668 Kg with the inventory value 141,180 Baht.

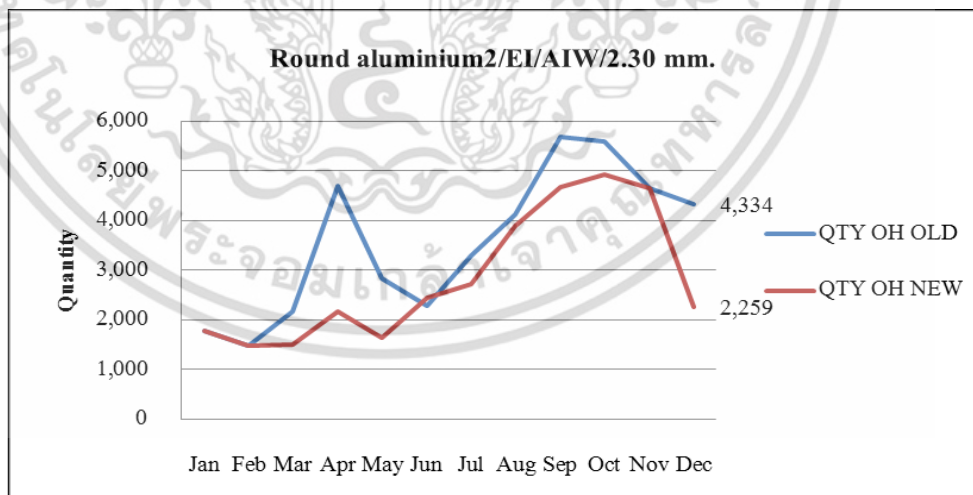
**- Round aluminium2/EI/AIW/1.90 mm.**



**Figure 4.7:** The comparison graph of round aluminium2/EI/AIW/1.90 mm.

From Figure 4.7, show that the EOQ method can decrease the inventories from 6,385 Kg to 5,488 Kg with the inventory value 116,610 Baht.

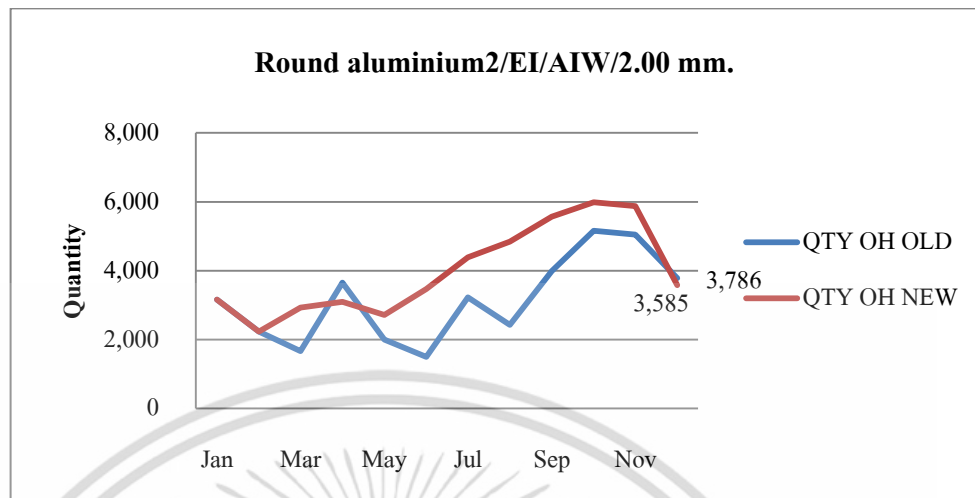
**- Round aluminium2/EI/AIW/2.30 mm**



**Figure 4.8:** The comparison graph of round aluminium2/EI/AIW/2.30 mm.

From Figure 4.8, show that the EOQ method can decrease the inventories from 4,334 Kg to 2,259 Kg with the inventory value 269,750 Baht.

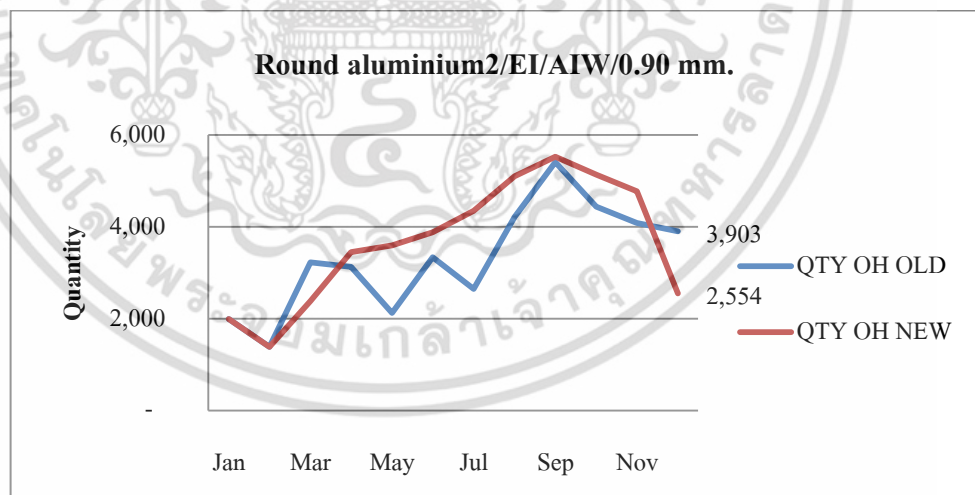
**- Round aluminium2/EI/AIW/2.00 mm.**



**Figure 4.9:** The comparison graph of round aluminium2/EI/AIW/2.20 mm.

From Figure 4.9, show that the EOQ method can decrease the inventories from 3,786 Kg to 3,585 Kg with the inventory value 26,130 Baht.

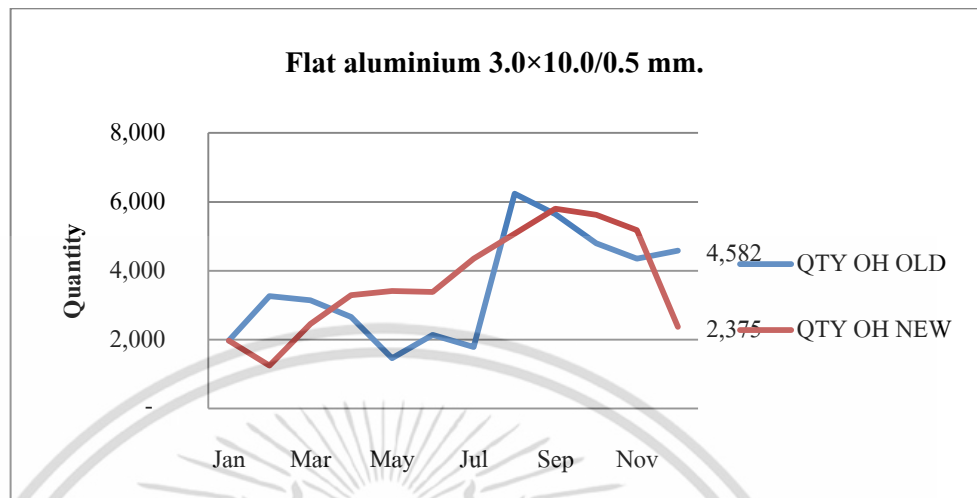
**- Round aluminium 2/EI/AIW/0.90 mm.**



**Figure 4.10:** The comparison graph of round aluminium2/EI/AIW/0.90 mm.

From Figure 4.10, show that the EOQ method can decrease the inventories from 3,903 Kg to 2,554 Kg with the inventory value 175,370 Baht.

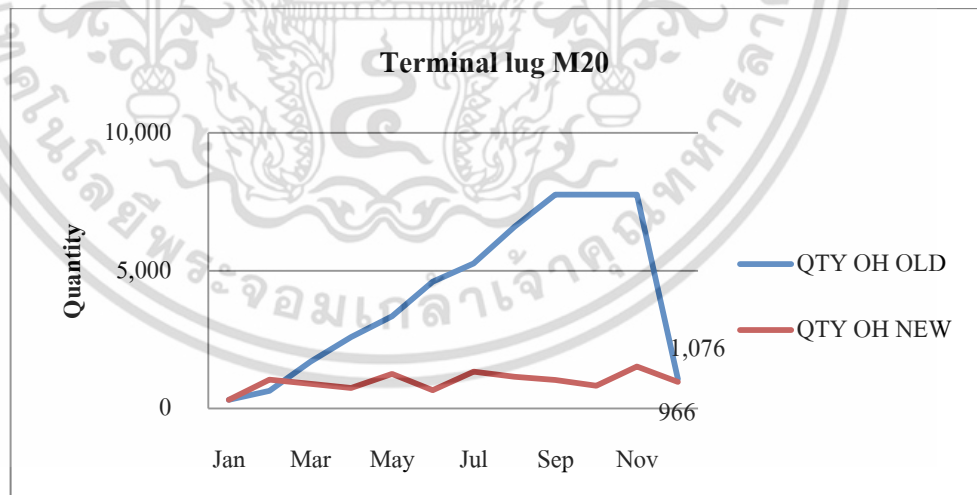
**- Flat aluminium 3.0×10.0/0.5 mm.**



**Figure 4.11:** The comparison graph of flat aluminium 3.0×10.0/0.5 mm.

From Figure 4.11, show that the EOQ method can decrease the inventories from 4,582 Kg to 2,375 Kg with the inventory value 353,120 Baht.

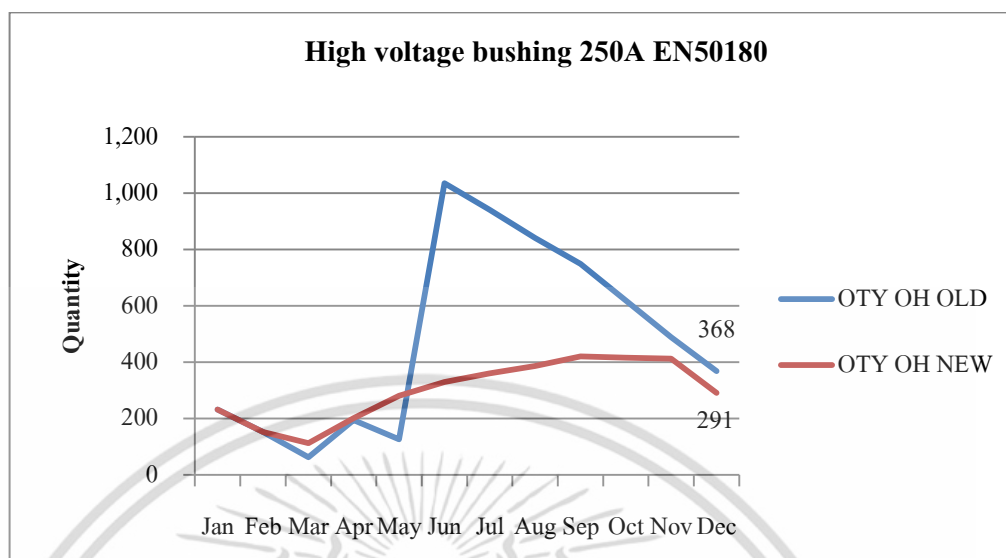
**- Terminal lug M20**



**Figure 4.12:** The comparison graph of terminal lug M20

From Figure 4.12, show that the EOQ method can decrease the inventories from 1,076 ea to 966 ea with the inventory value 352,000 Baht.

## - High voltage bushing 250A EN50180



**Figure 4.13: The comparison graph of high voltage bushing 250A EN50180**

From Figure 4.13, show that the EOQ method can decrease the inventories from 368 ea to 291 ea with the inventory value 154,000 Baht.

### 4.5.2 The comparison results Silver-Meal method with the old method

**Table 4.11: The comparison results Silver-Meal method with the old method**

Raw materials	Old inventories quantities	New inventories quantities	inventories value
Round aluminium2/EI/AIW/1.70 mm.	8,444	0	1,013,280
Terminal lug 250 A	80	0	256,000
Round aluminium2/EI/AIW/2.60 mm.	5,554	0	722,020
Flat aluminium 3.5×14.0/0.5 mm.	4,141	0	662,520
<b>Total</b>			<b>3,438,800</b>

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## CHAPTER 5

### CONCLUSION

#### 5.1 Conclusion

Chapter 1 explains the main problem of the case study company which had so many inventories. Because the order quantity did not relate to the quantity used, it resulted in high inventory value, sunk cost, high carrying and maintenance cost. Therefore, the current method which used to determine the order quantity of the case study company affected to high inventory level. The researcher used the new method to control the order quantity and reduce the inventory level. Chapter 2 explains the tools, theories and related research that related to the research to apply in this case study.

Chapter 3 explains the overview, the current status of the case study company and the procedure to the improve inventory problem. Firstly, the researcher conducted an in-depth interview with the production manager to analyze the problem. Then, the researcher collected and analyzed the inventory data. The next step was to classify the inventory into three groups (A,B and C) by using ABC analysis method. From classification of inventory, it found that there were 5 items in A group with the accumulative value of 77.28 %, 12 items in B group with the accumulative value of 15.76% and 44 items in C group with the accumulative value of 6.97% respectively. After that, group A and B were tested variability coefficient to find the appropriate method to improve the inventory. If raw material has the variability coefficient less than 0.25, using EOQ method, ROP and safety stock to control the inventories will be appropriate. If raw material has the variability coefficient more than 0.25, it will be suitable to use the silver-meal heuristic method.

เอกสารนี้เป็นเอกสารที่สงวนไว้สำหรับการใช้งานเพื่อการศึกษาเท่านั้น ไม่อนุญาตให้นำไปใช้ประโยชน์ด้านการค้า  
ไม่ว่ากรณีใดๆ ทั้งสิ้น อีกทั้งห้ามมิให้ดัดแปลงเนื้อหา และตั้ง 78 อ้างอิงถึงเจ้าของเอกสารทุกครั้งที่มีการนำไปใช้

Chapter 4 shows about the results of variability coefficient test for A and B groups, and also the calculation of EOQ, ROP, safety stock and the silver meal method. After testing the variability coefficient for A and B groups, it found that there were 13 raw materials that had the variability coefficient less than 0.25. Therefore, these groups used the EOQ, ROP, safety stock to control inventories. In contrary, there were 4 raw materials that had the variability coefficient more than 0.25, and showed that the demand was not constant. Therefore, it was not appropriate to use EOQ method. Accordingly, these groups used the silver meal method to determine the order quantities. After the calculation of EOQ, ROP, safety stock and the silver meal method, the researcher compared the new results in the purchasing of the case study company in 2015, and found that the new purchasing method could reduce the inventories value from 22,292,593 Baht to 16,090,280 Baht as shown in the table below:

**Table 5.1:** The comparison results new and old purchasing

<b>Raw materials</b>	<b>Old inventories quantities</b>	<b>New inventories quantities</b>	<b>Old inventories value</b>	<b>New inventories value</b>
Transformer oil IEC 296/CLASS II	253,270	212,713	5,571,940	4,679,686
Terminal lug 300 A PEA.No.1	1,090	990	3,488,000	3,168,000
Terminal lug M20	1,076	966	3,443,200	3,091,200
Transformer oil NYTRO IZAR II	36,693	22,153	807,246	487,366
Roundaluminium2/EI/AIW/1.40 mm.	8,714	6,828	1,132,820	887,640
Terminal lug M30	303	207	969,600	662,400
HV bushing 250A EN50180	368	291	736,000	582,000

เอกสารนี้เป็นเอกสารที่สงวนไว้สำหรับการใช้งานเพื่อการศึกษาเท่านั้น ไม่อนุญาตให้นำไปใช้ประโยชน์ด้านการค้าไม่ว่ากรณีใดๆ ทั้งสิ้น อีกทั้งห้ามมิให้ดัดแปลงเนื้อหา และตั้ง 79 ว่าจะถึงเจ้าของเอกสารทุกครั้งที่มีการนำไปใช้

**Table 5.1:** The comparison results new and old purchasing (Continued)

<b>Raw materials</b>	<b>Old inventories quantities</b>	<b>New inventories quantities</b>	<b>Old inventories value</b>	<b>New inventories value</b>
Round aluminium2/EI/AIW/3.20 mm.	3,754	2,668	488,020	346,840
Round aluminium2/EI/AIW/1.70 mm.	8,444	-	1,013,280	-
Terminal lug 250 A	80	-	256,000	-
Roundaluminium2/EI/AIW/1.90 mm.	6,385	5,488	830,050	713,440
Flat aluminium 3.0×10.0/0.5 mm.	4,582	2,375	733,120	380,000
Round aluminium2/EI/AIW/2.30 mm.	4,334	2,259	563,396.60	293,637.50
Round aluminium2/EI/AIW/2.00 mm.	3,786	3,585	492,180	466,050
Round aluminium2/EI/AIW/2.60 mm.	5,554	-	722,020	-
Flat aluminium 3.5×14.0/0.5 mm.	4,141	-	538,330	-
Round aluminium2/EI/AIW/0.90 mm.	3,903	2,554	507,390	332,020
<b>Total</b>			<b>22,292,593</b>	<b>16,090,280</b>

## 5.2 Problem and Barrier

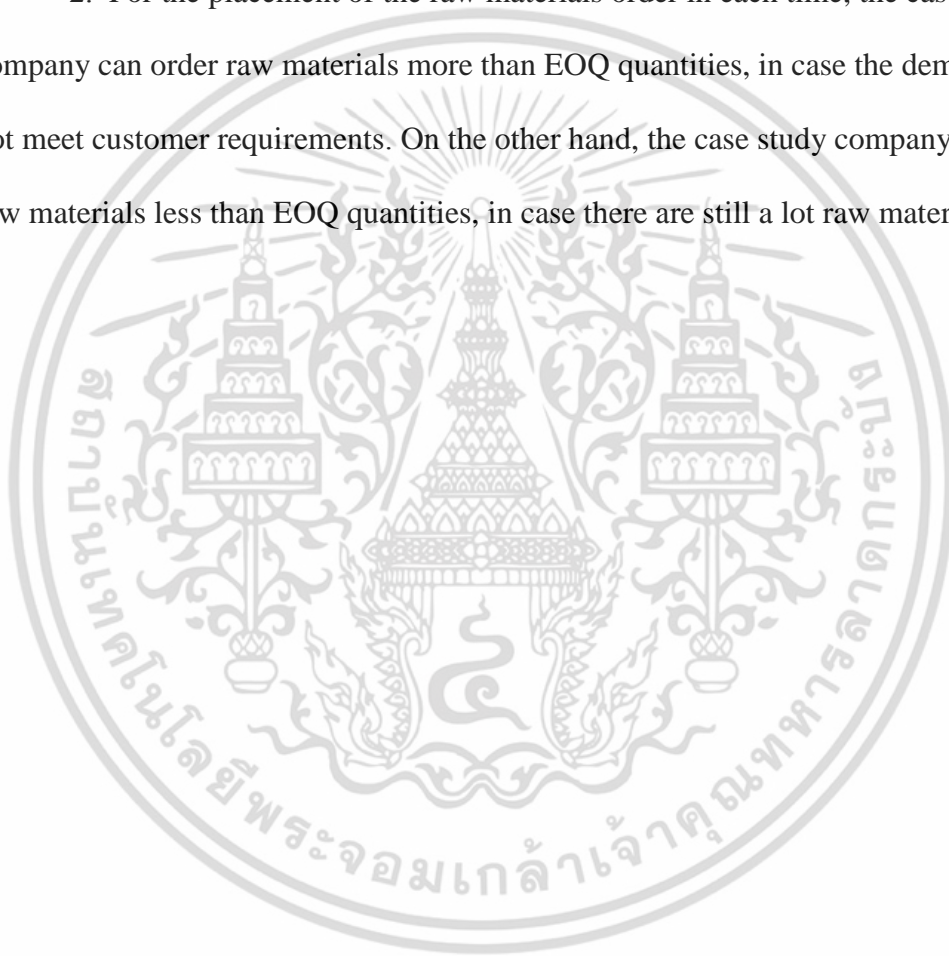
For collection data of this research, the researcher has to get the permission and approval from the executive or parent company. Due to the data is the secret of the case study company. Hence it is difficult to access the information.

เอกสารนี้เป็นเอกสารที่สงวนไว้สำหรับการใช้งานเพื่อการศึกษาเท่านั้น ไม่อนุญาตให้นำไปใช้ประโยชน์ด้านการค้าไม่ว่ากรณีใดๆ ทั้งสิ้น อีกทั้งห้ามมิให้ดัดแปลงเนื้อหา และตั้ง 80 อ้างอิงถึงเจ้าของเอกสารทุกครั้งที่มีการนำไปใช้

### 5.3 Recommendation

1. In this research, the researcher controlled inventories in A and B groups only, there were a lot of raw materials in the other groups. Therefore, the case study company can extend the control to other raw materials in order to increase efficiency inventory management.

2. For the placement of the raw materials order in each time, the case study company can order raw materials more than EOQ quantities, in case the demand may not meet customer requirements. On the other hand, the case study company can order raw materials less than EOQ quantities, in case there are still a lot raw materials.



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## APPENDIX

### In-depth Interview

In this research, the researcher conducted an in-depth interview with the production manager of the case study company and determined the questions for collecting the data to analyze the problem as table below:

<b>Questions</b>	<b>1. Could you briefly describe the company overview?</b>
<b>Answers</b>	- The company was established on 24 June 1981 with registered capital of 4,000,000 Baht (at that time). The main product of the company is the distribution transformers; the maximum production capacity per year is 4,000 MVA. The product range is from 1 kVA – 40,000 kVA with maximum voltage of 36 kV. We are able to produce all type of standardize (special requirement) transformer such as IEC, VDE&DIN (Germany Standard), ANSI (American Standard), JIS (Japan Standard), and special design for petro chemical, refinery industry. We are doing the business in both domestic and international markets such as ASEAN, South Asia, Middle East, South Africa and Australia. We have 10 service station centers around the country to serve our customers. For the production plan of the company, 50 percent is made-to-stock and the rest is made-to-order.
<b>Questions</b>	<b>2. What is the problem of the company?</b>
<b>Answers</b>	From surveyed the warehouse of the company found that, we have high inventory level. There were the inventories more than the demand. The cause of problem is the company does not has the efficient method to determine the order quantities, it is not related with the quantities of use results in lot inventories and incurred to sunk cost. Therefore the company must have to pay high in inventory cost and lost the area in warehouse.
<b>Questions</b>	<b>3. What is the target in inventory management of the company?</b>
<b>Answers</b>	The company needs to control in inventory levels. Due to in the current, the company has high in inventory levels and had to pay high in inventory cost and lost the area in warehouse as above-mentioned. Therefore, the company has to reduce the inventories and inventory cost in order to increase efficient in inventory management.

เอกสารนี้เป็นเอกสารที่สงวนไว้สำหรับการใช้งานเพื่อการศึกษาเท่านั้น ไม่อนุญาตให้นำไปใช้ประโยชน์ด้านการค้า  
ไม่ว่ากรณีใดๆ ทั้งสิ้น อีกทั้งห้ามมิให้ดัดแปลงเนื้อหา และต้องอ้างอิงถึงเจ้าของเอกสารทุกครั้งที่มีการนำไปใช้

<b>Questions</b>	<b>4. How many raw materials that used to produce the standard transformers of the company?</b>
<b>Answers</b>	<p>There were main raw materials that used to produce the standard transformers include iron core, copper wire, insulating paper, round aluminium wire, flat aluminium wire, transformer oil, high voltage bushing, low voltage bushing, and terminal lug etc. For the iron core , the company has strict control in this group and it is the highest price in the all of raw materials. Therefore, we did not improve in this group. Accordingly, The company needs to focus on the rest raw materials that have lot inventories, high price and only used to produce the standard transformer include round and flat aluminium wire, transformer oil , high and low voltage bushing and terminal lug.</p>



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