Inventory Control with Demand Forecasting in Planting Chem Company Limited

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Abstract

This paper presents a case study of Planting Chem Company Limited on inventory control. Inventory control system is one of the most important system for business and has an essential role to monitor the goods condition on supply chain distribution from warehouse to retail with consumer demand. At the present, inventory controlling become the most challenging problem in supply chain management. Companies want to provide a high customer service level and get enough inventories to fulfill customer demand while customer demand is extremely fluctuating all the time, and it will be problem in inventory control. Therefore, demand forecasting become the essential part of inventory control and increase efficiency of inventory management. The purpose of this research is dealing with developing inventory control systems with minimal cost. The result of research is useful system for controlling inventory base on customer demand. This inventory control system will minimize supply chain cost, product inventory level can be maintained in time and amount of inventory that must be fulfilled without stock out.

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Chapter 1

Introduction

A case study of Planting Chem Company Limited on inventory control. Inventory control is important for a business type of manufacturing company which encourages for production and stock in future inventory, so demand forecasting is available to increase performance for controlling inventory.

1.1 Background

Making profit is the most significant part for business, so business owner should consider business operation to make benefit because there are many competitors in the world at present. Business owners should be very active and improve their business activities constantly to increase competitive ability.

Inventory management is considered to be one of the most important parts for business because inventory is an important part of supply chain management in every organization. Moreover, inventory management is the main activity to create a business strategy of capital management because one of the vital problems related to inventory management is the inventory accuracy problem where an actual stock level does not match with the stock level shown in the system, this may cause stock out or overstock problem. The stockout of products and raw material is one of the reasons which affect business operation. In the other hand, overstock makes the company hold higher inventory and cost.

Also business owners should control orders and stock quantities in each time affecting core business strategy as good service performance makes customer satisfaction better by lower capital in business operation. Consequently, inventory management has an important role to satisfy customers as well as to have appropriate inventory in order to respond customer demand without any risk.

1.2 Problems Statement

One of the most important things in supply chain management is inventory management. Unfortunately, the company does not have planning in inventory management and affects to lack of optimization in inventory which occurs both shortage and excess in inventory. In shortage inventory, it results from inaccurate records and poor forecasting in the inventory system and makes product delays to customers, so the company loses a lot of customers. In the case of excess inventory, the company have a lot of product and have not been sold because of inaccurate demand projection. It results in additional costs to the company in storage costs and loses money on the product.

1.3 Objectives

1) To reduce the amount of stock and the problem which product is not enough to meet demand
2) To reduce the amount of excess stock
3) To improve efficient storage in warehouse by ABC-XYZ analysis
4) To develop inventory control system from supplier to warehouse with optimize quantity and minimal cost

1.4 Benefits

The benefit of this research is the increasing inventory management efficiency of the company. Companies utilize stock control to preserve a fitting level of materials on hand to meet client requests without tying up as well much capital in stock and consider demand variables to provide plans in inventory control. In addition, the company can balance both planning and forecasting which can prepare unforeseen events, so the company always able to serve customers and increase ability in competition.

1.5 Scope of Work

This study is relates to inventory management of agriculture products at Planting Chem Company Limited in order to increase and improve controlling inventory systems and manage inventory. Applying with other company should consider other factors together in order to protect mistakes.

1.5.1. Study each product information of Planting Chem Company Limited. which is in the chemical agriculture production field.

- Checking and collecting stock information
    - Check and collect stock information from 2009 until 2019 of Planting Chem Company Limited which provides agriculture production.

1.5.2. Determination of Future Demand

- Using time-series method on big data of demand data in the past of organization for demand forecasting to calculate and predict future demand for responding customer demand which will happen in the near future.

1.5.3. Determination of Safety Stock

- Safety Stock is defined as the difference between the amount stocked to satisfy demand during a certain time interval and the mean expected demand for that period.
- To get the accurate safety stock level for managing inventory system.

1.5.4. Determination of Lead Time

- Lead time is of fundamental importance in determining inventory levels.

1.5.5. Determination Reorder Point

- It is a minimum amount of an item which a firm holds in stock, such that, when a stock falls to this amount, the item must be reordered to response to customer need in time and run all process smoothly.

1.5.6. Determination ABC-XYZ Classification

- ABC-XYZ analysis is one of the important processes in inventory management to identify the value of product and manage products follow their value.

Chapter 2

Literature Review

Inventory Management is a essential factor to result in success of company, and an efficient inventory management try to ensure production by maintaining inventory at a satisfactory level and also minimizes cost of inventory by avoiding stockout of product. Therefore, efficiency in Inventory Management cause achievement in running and survival of company. This chapter primarily explain in overview of inventory management system.

2.1 Inventory Management

Inventory management we know as it is very important for almost every type of business whether it is a product or service. The production manager or operation department of operations needs to have responsibility in cost controlling for operation. Furthermore, the capital cost is the most important for the operation which is the expense using raw materials, other waste during the process, and the goods that already finish but waiting for shipping. Also, if the investment on which we spent on the expense is high this will affect to cost of funds, high cost of operation and lead to reducing in the efficiency of productivity.

Inventory management program has an essential role to track the state of the products on the delivery of the supply chain from the central warehouse to market with customer demand. Demand for products on stores is complex, creating issues with inventory management. The issues are unbalanced inventory items in the central warehouse. Several approaches have been developed to address the inventory management mechanism problem at a central warehouse. Reorder Point (ROP) is one approach utilizing stock-flow analysis (Efrilianda, D., & Isnanto, R.,2018). Inventory control is an important factor for the manager to focus on and take care of them because inventory has the highest value of the current assets of production. The problems in inventory control are one of the reasons that can lead to business failure. In the industrial business, if raw materials and various components there is not enough for production needs may cause problems to stop production and cannot deliver the product to customer on-time. The problems can affect customer satisfaction. But if we have a high inventory level to prevent the shortage of materials or finished products, we need to spend a lot of money on holding the inventory level such as holding costs. There have 2 kinds to control better inventory control. First, to control the inventory at the lowest level. Second, improve customer service and manage the production department. Therefore, better inventory control, better performance of a process, and operating expenses.

2.1.1 Definition of inventory

Inventory is products or raw materials that available in the firms due to raw materials or products both received externally and caused by production that has not been used, the two main reasons of inventory are:

1) Improve customer services
2) Reduce various cost

Inventory can classify into 2 characteristics which are:

1) Classified by status in the production process divided into raw materials, work in process, finished goods, spare parts, and consumables.
2) Classified by conditions or features of use divided into on delivery products, speculation products, Regular or cyclical products, safety stock products for unstable demand and lead time, and obsolete, dead, or shrinkage products.

2.1.2 Forms of Inventories

1) Raw materials, which is an unprocessed material we buy to use for producing goods to the customer.
2) Work in Process, which is the materials are in process waiting to be produced in step.
3) Maintenance, which is the supplies or safety stock that stock for repairing the old supplies that expire or broken.
4) Finished goods, which is the factor of production that produce through every process and ready to ship or sold for customers.

2.1.3 Importance factors of inventory control

There many perspectives in processing which can be separate into 3 parts:

1) Raw materials purchased component of inventory control is the beginning materials that use for productivity but the outbound is the one who manages the process of producing the material.
2) Inventory process, after the process is start by using raw materials and other components that order from outbound to be processing during one of the production periods. Inventories are in process will be finished during that time for inventory control waiting to be finishing goods.
3) Finished goods, which keep in the factory waiting for shipping to customers this type of inventory control for services and the final step of the goods

2.1.4 Purpose of inventory control

2.1.4.1 Inventory Management have two main purpose:

1) By having enough inventory for customer and satisfy the need of customer to make more profit
2) To reduce the investment cost in inventory control to be lowest to make capital cost in production to be lower as well

2.1.4.2 Benefit of inventory control as followed:

1) To satisfy customer need that had been estimate in each period by keeping inventory in inventory control
2) Keep production in constant rate to preserve the level of employment to be steady
3) Having safety stock, in case the product is out of stock or delaying in process
4) Help in keeping the process to be managing smoothly and no stop during process and to make customer to be satisfy in receiving product on time

2.1.5 Reason and Importance that should have in Inventory Control

- To reduce cost in transportation and production
- To adjust the balance between the need and provide inventory to keep in inventory control
- To make the production run smoothly without stopping

2.1.6 Importance of inventory control in Different Type

2.1.6.1 Inventory of Products

To prevent mistakes caused by the demand of a product that is more than anticipated, in this case, if the company doesn't have any safety stock this may cause a company to loss profit that should be received and this will make customer less reliable as well. In this condition, the customer may be able to buy a product from other companies so to prevent this company needs to have some safety stock which will be a benefit for our own and customer in the future.

2.1.6.2 Inventory During Process

Inventory during the production process allows the production of each unit of production to continue smoothly without any interruption or without needing to rely on each other for example production from the first stage and forwarding to the second stage if the first one having interrupted the second stage will be interrupted too this lead to the company to have slow working process. So, this condition if the company give the order to the first stage to produce overwork product which call safety stock which can help the second stage work well even if the first one having something interrupted.

2.1.6.3 Raw Materials

To reduce a lack of raw materials due to lateness such as the change in time of sending product or seller lack of material which lead to no production. As this occurs we need to have a safety stock of raw materials to use in an emergency time also as we have safety stock, which can help us to reduce the cost of production and purchase because purchase in large amount can reduce price unit of raw materials Furthermore, safety stock help to reduce money loss when the raw material price grows up in the future.

2.1.7 Inventory Management System

Inventory management system is a policy that related to the products in the warehouse such as a place to store each type of product, system and policy for inventory control, planning and purchasing management, and warehouse management. The goal is to have the availability of raw materials or products in the desired time and quantity, maintaining a balance between the level of product and customer service and cost.

2.1.7.1 Inventory management system that is popularly used widely in the industrial business. With the following:

1) Economic Order Quantity (EOQ) is how to determine the number of products that will be orders each time that leads to the most saving. With the lowest of purchasing cost and holding cost. Therefore, EOQ came to help to see purchasing times, purchasing costs, how much is needed to buy at the time, so it has not come with a high product holding level.

2) Materials Resource Planning (MRP) is a material planning either the parts produced by the factory itself or the parts that were bought from others. The parts produced by itself are called Jobs, while the parts for others called Purchase Orders. The main function of MRP is to calculate the production time and purchase orders, in order to be sufficient for the needs of these materials and in-time according to customers' requirements.

3) Just-in-Time (JIT) is a product arrive in the production process at the desired time and desired quantity. Also, JIT is production or delivery of the desired item in a time if need with the required amount by using a need of the customer to determine the production quantity and raw materials usage. Not only customers but also personnel in other areas that need work-in-process or materials for continuous production by using Pull Method of

Material Flow to control inventory and production in each work station.

2.1.8 The Goal of Inventory Management

Inventory control aims to manage inventory of products so that the organization does not take stock shortage and maximize the cost of delivery of the supply chain at the main warehouse. It is possible to order management of inventory of products to reach customer with approach. Optimizing the security stock will affect a company's logistics costs (Efrilianda, D., & Isnanto, R.,2018). The important goal is to buy and have enough inventory to support continuous production and sales but least problems are required because inventory having its expenses which is the cost that occur from procurement department including cost in keeping inventory.

Inventory control occurs by 4 main types which are seasonal ingredients, safety stock, buying large quantities to get a cheaper price, and speculation. Also determine a safety stock is based on the principle that it must not be given too much or too little by specifying from the lead time of items and must be accurate and efficient.

The purpose of determining inventory needs to be an appropriate level which is to have the lowest expense for inventory and the lowest expense in keeping inventory also the important factor for planning inventory needs to look by maximum not minimum.

2.1.9 Inventory Control System

2.1.9.1 Continuous Inventory System

This inventory system that provides accounting methods for every receive and payment of keeping account under control and knowing the true and right inventory at all times. But this system is a method that has a high cost of document work and require a lot of staff to have duty on it. So in this condition using barcode, laser scan, etc. to help because it is more efficient and accurate than the old system also this method use less staff so we can spread staff to do the other part to reduce time on other process, reducing time of work and easy to control inventory and staff too.

- Advantages of Continuous Inventory System
    - Having safety stock to reduce lack of material or product.
    - Using a fixed amount of order which will easily get volume discount easier.
    - Can check each of inventory independently.

2.1.9.2 Periodic Inventory System

This inventory system is an inventory system that provided accounting methods only for a specified period only such as weekly or monthly. Also, this system is suitable for ordering and withdrawing for certain period.

- Advantages of Periodic Inventory System
    - It's takes less time and cost to control than a continuous system.
    - Help reducing cost related to document and reduce cost of purchasing also easy for counting.
    - The cost of keeping data of inventory is lower.

2.1.9.3 ABC-XYZ Analysis in Inventory Classification

ABC Analysis classify by considering the quantity and value of each inventory to reduce the burden of overseeing, counting, and controlling the large inventory which, if controlling all items in the same system will waste more time and money than necessary.

- High-Value Items (A-class) is 10% of all products contribute to 80% of the annual inventory value of the items.
- Medium-Value Items (B-class) is 30% of all products contribute to 15% of the annual inventory value of the items.
- Low-Value Items (C-class) is 50% of all products contribute to 5% of the annual inventory value of the items.

XYZ Analysis classify inventory items according to demand variability into X-class, Y-class, and Z-class. The demand variability is measured by using Coefficient Variation (CV).

- Low-Variation Items (X-class) is a very little variation of the demand variability of each product ($CV \leq 10\%$)
- Medium-Variation Items (Y-class) is some variation of the demand variability of each product ($10\% < CV \leq 50\%$)
- High-Variation Items (Z-class) is high variation of the demand variability of each product ($CV > 50\%$)

ABC Analysis not only make a better control over high-value items to improves inventory stock, and reduces loss and cost but also make more efficient use of stock management resources. Moreover, ABC analysis can provide a less stock outs resulting in improved production efficiency. In XYZ Analysis can improves forecasting accuracy and reduce stockout which improve efficiency of production and customer satisfaction.

Table 2.1 ABC-XYZ Analysis Classification

	A	B	C
X	High value, Low demand variation	Medium value, Low demand variation	Low value, Low demand variation
Y	High value, Medium demand variation	Medium value, Medium demand variation	Low value, Medium demand variation
Z	High value, High demand variation	Medium value, High demand variation	Low value, High demand variation

Whether the products are AX or BX, they are very stable in demand, and need not be stored in large amounts, but AX products are more essential than BX products. Therefore, we've got to take care of AX goods a lot more than BX products. At the other hand, because of the variability in high demand, AZ goods are also very critical but hard to forecast.

We may take an average inventory coverage when the goods are AY or BY to monitor the risk that could be caused by variability in medium demand. The products are relevant but hard to predict whether the products are AZ or BZ, so AZ and BZ products are high stock coverage and high risk for variation in demand.

The risk is small for CX products because of small variability in demand and fairly unimportant products even for CX products. These products need low inventory and managed risk, if the products are CY. The CZ products are hard to forecast and there is a high risk of overstocking, so we only need certain items on request (ABC-XYZ Analyze to Optimize Your Inventory, n.d.).

2.1.10 Inventory Cost

- Setup cost, which is the cost of purchase that involved with the procurement of raw materials process and supplies from outsources. While the cost of installation or operation involves the cost of procurement and operation within the system. Also, for the production system to operate which is related to the cost of time and money
- There are 3 main types of inventor carrying cost which are cost of capital, storage and risk.
- Shortage cost is the cost that occur when there is no stock or inventory to sell or produce for customer this will results to customer canceled orders and unsatisfied to organization, lack of money income or even production will be stop produce.
- Opportunities costs occur by trade off during deciding to operate with the other options.
- Product costs in the storage waiting for orders and shipping.

2.1.11 Decision Rules for Inventory Control

The solution for inventory problems is not to make minimize inventory but have to find the most suitable level should have the inventory maintained, for minimize cost and make highest profit.

From the implementation of having the most inventory available involve with 4 types of decision makings are:

1) How much business should order, also the frequency of ordering.
2) When business should order, and what is the ordering point.
3) If a discount is offered with the condition that have to order in larger quantity, how to decide.
4) Should there be some spare products or not and how much to spare.

In addition, there have decisions making in other area that related for inventory control such as inventory storage, product categories, product count, product evaluation, product organization. Therefore, if business want to minimize ordering cost, business need to order in a larger quantity. If business want to minimize cost of purchasing inventory, business should order a smallest amount.

2.2 Demand Forecasting

The forecasting of demand is usually either qualitative or quantitative. Qualitative schemes include consensus group, Delphi process, historical comparison, and research on the market. We rely on subjective domain expert judgments and lack data-driven decision-making models. Quantitative schemes which include methods of regression and time-series are more systematic and accurate. Regression methods primarily concentrate on the identification of causalities between the independent predictors and the dependent outcome. Conversely, time-series models forecasting potential outcome values based on historical knowledge are excellent at resolving cyclic fluctuations or trend trends resulting from commodity volatility. Time-series in particular can handle the time-lags between the leading predictors and the lagging effect (Wang, C., & Chen, J.,2019).

In certain organizational operations, forecasting is a required pre-requisite. Without a projected forecast, it is not possible to schedule the level of operation to be anticipated and, thus, it is not possible to predict the resources to be built, prepared and managed to achieve this level of activity. It is extremely clear importance to forecast level of future demand for controlling the amount of inventory. Many demand series are affected by the event and seasons of the year which occur annually. The goal of forecasting models takes into account seasonal variation is to create this relation for each time of the year and to use the sensationalizing factors found by this method to produce forecasts (D Lewis, C.,1997). According to agriculture production of company, demand will fluctuate all the time because of seasonal variation which is one of component time-series forecasting, so time-series forecasting is the use of a model to predict future values based on previously observed values. Time-series methods make forecasts based solely on historical patterns in

the data. Time-series methods use time as independent variable to produce demand. In a time-series, measurements are taken at successive points or over successive periods. Time-series models are adequate forecasting tools if demand has shown a consistent pattern in the past that is expected to recur in the future.

From studying the principle of time-series method, it is a simple method to predict future demand and very useful in terms of helping to understand the past behavior for future prediction, so we give the important thing with demand forecasting because demand forecasting is the essential process for most operational activities of an organization. Without an estimate of the future it is impossible to plan for the level of activity which is to be expected and difficult to estimate the needed resources.

In this section, we will calculate future demand of production with time-series methods in moving average which is good for stable demand with no pronounced behavioral patterns. The exponential smoothing forecast process which is an average process that weighs more heavily on the most recent past data than on more distant past data. Therefore, the forecast should respond more aggressively to immediate data adjustments. This is very helpful if the recent adjustments in the data arise from a real shift and the modified exponential smoothing forecast consisting of an exponential smoothing forecast with additional pattern adjustment factor (Bernard W., T.,2002). These three approaches are simple strategies for forecasting demand for supply which have specific advantages and special characteristics. Every approach delivers specific average error to the outcome, so we'll select the benefit of demand forecasting with less average error to use for inventory management in the EOQ model.

2.3 Economic Order Quantity (EOQ)

The quantity of economic order is the optimal order quantity that a business will buy to reduce inventory costs such as storage costs, shortage costs, and order costs. The EOQ is the maximum order quantity of a business that minimizes the overall costs of buying, processing, and keeping inventory and is used as part of a constant inventory management program in which the inventory volume is tracked at all times and a set quantity is requested each time the inventory volume exceeds a certain reorder stage. The EOQ offers a formula for determining the correct reorder point and the optimum rearrangement quantity to ensure immediate product replenishment.

From the analysis of the EOQ theory, we know that the EOQ model is a basic but powerful method for explaining and maximizing the exchange between purchasing and keeping costs, so it can be a valuable resource for small business owners who need to determine how much inventory to keep on hand, how many things to order each time and how much to rearrange to incur the lowest possible costs(Economic Order Quantity (EOQ), n.d.).

2.4 Visual Basic for Application

The programming language of Excel and other Office programs is the visual basic for application to document long processes and collect in programming language terms. The application's outstanding visual basic point is versatile editing capable of handling anything, and Excel VBA is being implemented in this study. Excel VBA is capable of managing Excel to run automatically without any error from the start to the end of the program, even if the job has several processes or complicated instructions, allowing us to save time in every job (Walkenbach, J., n.d.).

- Principle of using VBA with database:
    - Design the table and test formula until gest the beast way to saving time.
    - Using Macro recorder to record using tool on menu instead writing code.
    - VBA code have to create for flexibility which can use for every table structure.
    - Avoid delete order which stop using because deleting data male losing that data.
    - Using VBA for decreasing important process.

- Advantage of Visual Basic for Application:
    - The structure of the Basic programming language is very simple, particularly as to the executable code.
    - VBA is not only a language but primarily an integrated, interactive development environment.
    - VBA provides a comprehensive interactive and context-sensitive online help system.
    - Reduces the formulas burden used in Excel reports.
    - Excel performs the task much faster than you can do it manually.

Chapter 3

Research Methodology

This study will be operated by using the cost of purchasing raw material from 2009 until 2019 of Planting Chem Company Limited in order to classify into ABC-XYZ analysis, forecast future demand, and calculate economic order quantity for solving the problem of inventory which mismatch with demand.

3.1 Tools in Study

3.1.1 ABC-XYZ Classification System for Inventory Management

The researcher classify inventory into a group with the ABC-XYZ classification system by calculating the value of raw material and order from a maximum value to minimum value.

1) Demand information of raw material from 2009 until 2020 with 36 products in total and identify the unit cost of each raw material.

2) Calculate total cost of each raw material.

3) Classify raw material into ABC-XYZ analysis.

3.1.2 Time-Series Forecasting for Future Demand Value

Time-series methods are statistical techniques that make use of historical data accumulated over a period of time. Time-series methods assume that what has occurred in the past will continue to occur in the future. There are many methods to predict the future value of demand in time-series method, so researcher take AX, AY and BX class to predict future demand value with all method, and use the least forecasting error value from all processes to use in forecasting process.

3.1.2.1 Moving Average Method

Moving averages are a simple and common form of smoothing used in analyzing time-series and predicting time-series. Calculating a moving average requires generating a new series where the values in the original time-series consist of the average of the raw observations (Brownlee, J. , n.d.).

- The advantage of moving average method
  - It is good for stable demand with no pronounced behavioral pattern
  - The method is useful to separate out random variation
  - Moving average give constant forecast

- The disadvantage of moving average
    - Moving average do not response to the fluctuation and can computed as followed:

$$\text{MA} = \frac{(D_1 + D_2 + \cdots + D_n)}{D_n}$$

Where:

D = data in period n

n = number of time periods

3.1.2.2 Weight Moving Average Method

A Weighted Moving Average adds more weight to recent data and less weight to past data. This is achieved by multiplying the price of each bar by a weighting factor because WMA would match prices more closely than a corresponding Simple Moving Average because of its unique measurement (What Is the Weighted Moving Average, n.d.).

- Weight moving average is computed as followed:

$$\text{WMA} = W_1D_1 + W_2D_2 + \ldots + W_nD_n$$

Where:

W = the weight for period n, between 0 and 1.0

D = data in period n

3.1.2.3 Exponential Smoothing Method

Exponential smoothing is an averaging method that reacts more strongly to recent changes in demand than to more distant past data.

- The advantage of exponential smoothing
  - Exponential smoothing produce accurate forecast
  - Exponential smoothing gives more significance to recent observations.
- The disadvantage of exponential smoothing
  - Exponential smoothing cannot handle trends well.
- Exponential smoothing is computed as followed:

$F_{t+1} = \alpha \times D_t + (1- \alpha) F_t$

Where:

F_{t+1} = The forecast for the next period

D_t = Actual demand in the present period

F_t = The previously determined forecast for the present period

α = A weighting factor referred to as the smoothing constant

3.1.2.4 Adjust Exponential Smoothing Method

Adjusted exponential smoothing is the exponential smoothing forecast with an adjustment for a trend added to it.

- Adjust exponential smoothing is computed as follow:

$$AF_{t+1} = F_{t+1} + T_{t+1}$$

Where:

$$F_{t+1} = \alpha \times D_t + (1- \alpha) F_t$$

$$T_{t+1} = \beta (F_{t+1} – Ft) + (1- \beta) T_t$$

= Trend factor for the next period

T_t = Trend factor for the current period

β = A smoothing constant for trend

3.1.2.5 Linear Trendline Method

Linear regression is most commonly considered a causal forecasting approach in which a statistical relationship is formed between demand and some other factor influencing demand behavior. However, a minimum square regression line, or linear trend line, can be used to predict demand when demand shows an apparent pattern over time.

- Linear trend line is computed as follow:

$$y = a + bx$$

Where:

a = Intercept (at period 0)

b = Slope of the line

x = The time period

y = Forecast for demand for period x

3.1.3 Forecasting Accuracy

3.1.3.1 Forecasting Error

In statistics, a forecast error is the difference between the actual or real and the predicted or forecast value of a time-series or any other phenomenon of interest.

- Forecasting error is computed ad followed:

$$\text{Forecast Error} = \left(\frac{|\text{Actual value} - \text{Forecast value}|}{\text{Actual value}}\right) \times 100\%$$

3.1.3.2 Mean Absolute Deviation (MAD)

$$MAD = \frac{\Sigma| D_t - F_t |}{n}$$

Where:

D_t = Demand in period t

F_t = The forecast for period t

n = The total number of periods

3.1.3.3 Mean Absolute Percent Error (MAPE)

$$MAPE = \left(\frac{\text{Actual value} - \text{Forecast value}}{n}\right) \times 100\%$$

3.2 Economic Order Quantity Process

3.2.1 Economic Order Quantity (EOQ)

Researcher will use the information of raw material and presents the order size that minimizes the sum of carrying costs and holding costs of raw material in 2019 by EOQ theory in order to increase efficiency in inventory management of this case study, so information for finding order size included:

- Demand of raw material in 2019
- Unit cost
- Ordering cost
- Holding cost
- Shortage cost

Formula for calculating EOQ included:

- The Order Quantity Size is computed as follows:

$$Q_{opt} = \sqrt{\frac{2C_O D}{c_c}}$$

- The Annual Ordering Cost is computed as follow:

$$\text{Annual Ordering Cost} = c_o \frac{D}{Q}$$

- The Optimal Shortage Level is computed as follow:

$$S_{opt} = Q_{opt}\left(\frac{C_c}{C_c+C_s}\right)$$

- The Annual Carrying Cost is computed as follow:

Total Carrying Cost = $C_c \left(\frac{Q-S}{2Q}\right)^2$

- The Annual Shortage Cost is computed as follow:

Total Shortage Cost = $C_s \frac{S^2}{2Q}$

Where: D = Annual Demand (Demand of Product in 1 year)

C_o = Ordering Cost

C_c = Carrying Cost

S = Shortage Level

C_s = Shortage Cost

3.3 Safety Stock

A safety stock refers to inventories held by a company as a reserve against any increase in demand during the work-order lead time and/or delay in receipt production of inventories. Safety stock is a rainy-day stock held by a company to guard against stock-out costs.

3.3.1 Determining Safety Stock by using service levels

Service level is the possibility that the amount of inventory on hand during the lead period is adequate to satisfy the anticipated demand and is the possibility that there will not be a stock out. The volatility of supply and demand makes it difficult to determine the quantity of stock needed to satisfy the needs of the customers while avoiding stock-outs. In the retail sector, however, the average level of service is 90 percent, with higher priority products hitting 95 percent, which means that increasing the level of product service will increase the amount of inventory kept as security stock, which will increase the cost of this commodity as shown in Table 3.1. (Robinson, D. (2016). How to Use The Safety Stock Formula: A Step-by-Step Guide. Retrieved 6 April 2020, from http://www.skuvault.com/blog/safety-stock-formula/)

Table 3.1 Determining Safety Stock by using service levels

Service Level	Service Factor	Service Level	Service Factor
50.00%	00.00	95.00%	01.64
55.00%	00.13	96.00%	01.75
60.00%	00.25	97.00%	01.88
65.00%	00.39	98.00%	02.05
70.00%	00.52	99.00%	02.33
75.00%	00.67	99.50%	02.58
80.00%	00.84	99.80%	02.88
85.00%	01.04	99.90%	03.09
90.00%	01.28	99.99%	03.72

Safety stock is computed as follow:

Safety Stock = $Z \times \sigma LT \times d$

Where: Z = number of standard deviations corresponding to the service level

σLT = standard deviation of lead time

d = constant daily demand

3.4 Reorder point with Variable Lead Time

A reorder point is a stock threshold that you do not want to go below. Therefore, the ideal inventory reorder point allows for adequate time to make a new order before the stock reaches this threshold.

- Reorder point is computed as follow:

  ROP = (Average Daily Usage × Average Lead Time) + Safety Stock

3.5 Compare total cost of inventory in 2019 between normal method of company with EOQ

- Normal inventory cost is computed as follow:

  TC = PC

  Where: TC is the Total Cost.

  PC is Purchase Cost.

- Inventory cost with EOQ is computed as follow:

  $TC = TC_o + TC_c + TC_s$

  Where: TC is the Total cost.

  TC_o = Total Ordering Cost

  TC_c = Total Carrying Cost

  TC_s = Total Shortage Cost

Chapter 4

Research Result and Analysis

This chapter review the result and analyst of research which is followed by figure 4.1. The beginning task starts with collecting production data of Planting Chem Company Limited from 2009 until the present. Then, classify production data into ABC-XYZ analysis and use class AX, AY, and BX to forecast in forecasting process of time-series method forecasting like moving average, weight moving average, exponential smoothing, adjust exponential smoothing and linear trend line and use the method which has the least forecasting error value to forecast demand for all product in inventory for using forecasting demand in EOQ process which is dealing with inventory management. In the EOQ process, there is designing a user interface and creating a source code program for creating a program by using Microsoft Excel VBA. The program support EOQ policy to provide quantity at optimal, safety stock and reorder point at each product.

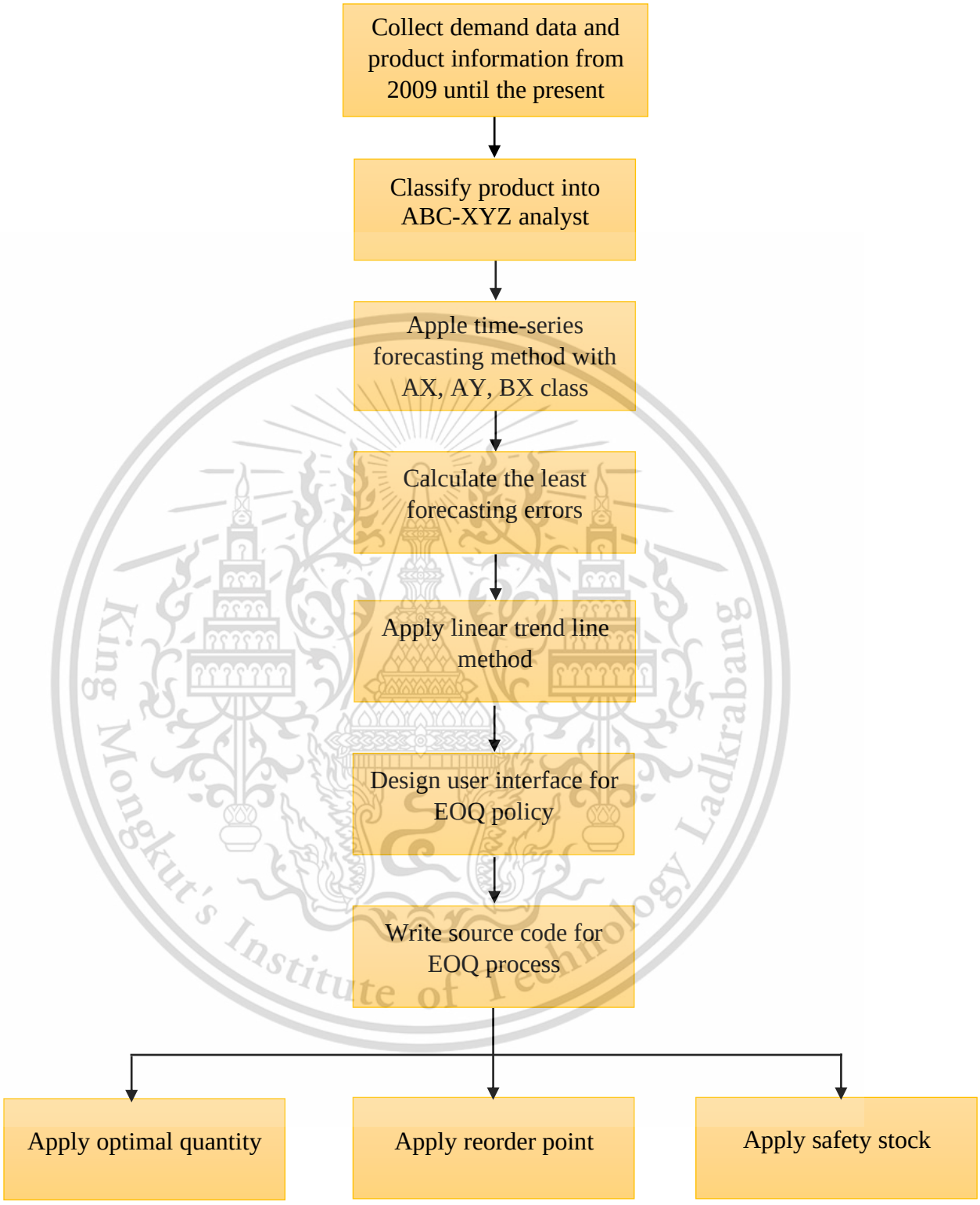


Figure 4.1 The Result and Analyst of Research

4.1 Analyze the Cause of Problems

Researcher collect the inventory data of case study company 36 raw materials and products which is Product name, Unit cost, Demand from 2009 to 2019, and Total cost as shown in Table 4.1

Table 4.1 List of Inventory from 2009 to 2019

Product Name	Unit Cost (Baht)	Demand from 2009 to 2019 (Liter)	Cost (Baht)
Calcium boron cream	100	9,756	975,600
Cyto-Z	55	21,767	1,197,185
EMS	60	17,741	1,064,460
Rice Hormone	43	29,407	1,264,501
Hightouch	38	59,679	2,267,802
Jabbai	85	101,050	8,589,250
KG, Mahoran	129	102,165	13,179,285
Chlorophyll	166	26,598	4,415,268
Planting Rice	43	26,869	1,155,367
Plant Roots	40	23,497	939,880
Abamegtin	115	13,557	1,559,055
Arsel	270	31,823	8,592,210
DDVP	150	58,996	8,849,400
New Toxic	110	77,436	8,517,960
OH	170	21,882	3,719,940
Plantcrovos	110	60,945	6,703,950
Packone	115	29,307	3,370,305
RTG	240	85,589	20,541,360
Rassa	255	7,550	1,925,250
Cabosunfran	190	49,751	9,452,690
Siptid	180	45,929	8,267,220
Airy	195	10,431	2,034,045
Cabendasin	140	22,763	3,186,820
K.A.	160	19,496	3,119,360
Metalecsil	195	38,298	7,468,110
Makla	90	17,807	1,602,630
Mancoset	90	121,302	10,917,180
Copper	80	79,990	6,399,200
Stepcy	180	21,926	3,946,680
Tarna	35	234,960	8,223,600

Valida Mycin	90	8,418	757,620
Builting	145	17,534	2,542,430
Glyphosate	340	1,935,368	658,025,120
Builtaco	165	30,913	5,100,645
Conweat	165	81,222	13,401,630
Paraquat	60	1,339,801	80,388,060
Total	**4,794**	**4,881,523**	**923,661,068**

From Table 4.1, researcher found that the case study company use 36 products from 2009 to 2019 in the total cost of 923,661,068 baht. Therefore, the total cost indicates how much the company has to pay each year on each product which is too high for a small company.

4.1.1 ABC-XYZ Analysis Process

Shows the name of product name, unit price, total cost, ABC classification, coefficient variation (CV), and XYZ classification.

- ABC Analysis

Researcher will use data of raw material to calculate for Total Cost and classify calculated data into A-class, B-class, and C-class. Data for finding ABC analysis included:

  - Unit cost (Price per unit)
  - Annual demand of each product
  - Total cost of each product (unit cost × demand per month)
  - Total cost (sum of total cost of each product)

- XYZ Analysis

Researcher will use data of raw material to calculate for coefficient variation (CV) to measure the dispersion of data in a data series around the mean into X-class, Y-class, and Z-class.

  - The coefficient variation (CV) computed as follows:

$$\text{CV for population} = \frac{\sigma}{\mu} \times 100\%$$

Table 4.2 Calculated ABC-XYZ Analysis Classification

Product Name	Unit Price (Baht)	Total Cost (Baht)	% of Total Cost	ABC Analysis	Coefficient Variation (CV)	XYZ Analysis
Glyphosate	340	658,025,120	71.24	A	1.91%	X
Paraquat	60	80,388,060	8.70	A	21.73%	Y
RTG	240	20,541,360	2.22	A	5.33%	X
Conweat	165	13,401,630	1.45	A	29.98%	Y
KG Mahoran	129	13,179,285	1.43	A	57.13%	Z
Mancoset	90	10,917,180	1.18	B	13.43%	Y
Cabosunfran	190	9,452,690	1.02	B	26.92%	Y
Arsel	270	8,592,210	0.93	B	64.33%	Z
New Toxic	110	8,517,960	0.92	B	53.20%	Z
DDVP	150	8,849,400	0.96	B	4.35%	X
Jabbai	85	8,589,250	0.93	B	20.69%	Y
Tarna	35	8,223,600	0.89	B	39.28%	Y
Siptid	180	8,267,220	0.90	B	34.13%	Y
Metalecsil	195	7,468,110	0.81	B	14.43%	Y
Plantcrovos	110	6,703,950	0.73	B	37.90%	Y
Copper	80	6,399,200	0.69	B	17.87%	Y
Builtaco	165	5,100,645	0.55	B	72.85%	Z
Chlorophyll	166	4,415,268	0.48	B	44.93%	Y
OH	170	3,719,940	0.40	B	57.06%	Z
Rassa	255	1,925,250	0.21	C	11.60%	Y
Stepcy	180	3,946,680	0.43	C	47.76%	Y
Packone	115	3,370,305	0.36	C	66.59%	Z
K.A.	160	3,119,360	0.34	C	18.13%	Y
Cabendasin	140	3,186,820	0.35	C	10.42%	Y
Builting	145	2,542,430	0.28	C	6.87%	X
Hightouch	38	2,267,802	0.25	C	82.83%	Z
Airy	195	2,034,045	0.22	C	73.77%	Z
Makla	90	1,602,630	0.17	C	33.18%	Y
Abamegtin	115	1,559,055	0.17	C	74.10%	Z
Rice Hormone	43	1,264,501	0.14	C	70.61%	Z
Cyto-Z	55	1,197,185	0.13	C	36.86%	Y
Planting Rice	43	1,155,367	0.13	C	66.86%	Z
EMS	60	1,064,460	0.12	C	43.45%	Y
Calcium boron cream	100	975,600	0.11	C	58.71%	Z
Plant Roots	40	939,880	0.10	C	24.07%	Y
Valida Mycin	90	757,620	0.08	C	17.23%	Y
Total	**4,794**	**923,661,068**	**100%**			

From Table 4.2, Researcher chooses Glyphosate, Paraquat, RTG, Conweat, and DDVP because these products are in AX, AY, and BX class. Glyphosate, Paraquat, RTG, and Conweat are in A-items of ABC Analysis which means they are most valuable of all products. And DDVP is in B-items of ABC Analysis but DDVP is X-items in XYZ Analysis that means DDVP has a low variation of demand and future demand can reliably forecast.

4.1.2 Classification of ABC-XYZ Analysis

Table 4.3 A-Class Product Classification

Product	Unit Cost (baht)	Demand from 2009-2019	Cost	% of Cost	ABC class	XYZ class
Glyphosate	340	1,935,368	658,025,120	71.24	A	X
Paraquat	60	1,339,801	80,388,060	8.70	A	Y
RTG	240	85,589	20,541,360	2.22	A	X
Conweat	165	81,222	13,401,630	1.45	A	Y
KG Mahoran	129	102,165	13,179,285	1.43	A	Z
Total	**934**	**3,544,145**	**785,535,455**	**85.05%**		

From Table 4.3, A-class which have 5 products and the total cost of products in A-Class is 785,535,455 baht and it's 85.05% of total cost which is 923,661,068 baht.

Table 4.4 B-Class Product Classification

Product	Unit Cost (baht)	Demand from 2009-2019	Cost	% of Cost	ABC class	XYZ class
Mancoset	90	121,302	10,917,180	1.18	B	Y
Cabosunfran	190	49,751	9,452,690	1.02	B	Y
Arsel	270	31,823	8,592,210	0.93	B	Z
New Toxic	110	77,436	8,517,960	0.92	B	Z
DDVP	150	58,996	8,849,400	0.96	B	X
Jabbai	85	101,050	8,589,250	0.93	B	Y
Tarna	35	234,960	8,223,600	0.89	B	Y
Siptid	180	45,929	8,267,220	0.90	B	Y
Metalecsil	195	38,298	7,468,110	0.81	B	Y
Plantcrovos	110	60,945	6,703,950	0.73	B	Y
Copper	80	79,990	6,399,200	0.69	B	Y
Builtaco	165	30,913	5,100,645	0.55	B	Z
Chlorophyll	166	26,598	4,415,268	0.48	B	Y
O.H.	170	21,882	3,719,940	0.40	B	Z
Total	**1,996**	**979,873**	**105,216,623**	**11.39%**		

From Table 4.4, B-class which have 14 products and the total cost of products in B-class is 105,216,623 baht and it's 11.39% of total cost which is 923,661,068 baht.

Table 4.5 C-Class Product Classification

Product	Unit Cost (baht)	Demand from 2009-2019	Cost	% of Cost	ABC class	XYZ class
Rassa	255	7,550	1,925,250	0.21	C	Y
Stepcy	180	21,926	3,946,680	0.43	C	Y
Packone	115	29,307	3,370,305	0.36	C	Z
K.A.	160	19,496	3,119,360	0.34	C	Y
Cabendasin	140	22,763	3,186,820	0.35	C	Y
Builting	145	17,534	2,542,430	0.28	C	X
Hightouch	38	59,679	2,267,802	0.25	C	Z
Airy	195	10,431	2,034,045	0.22	C	Z
Makla	90	17,807	1,602,630	0.17	C	Y
Abamegtin	115	13,557	1,559,055	0.17	C	Z
Rice Hormone	43	29,407	1,264,501	0.14	C	Z
Cyto-Z	55	21,767	1,197,185	0.13	C	Y
Planting Rice	43	26,869	1,155,367	0.13	C	Z
EMS	60	17,741	1,064,460	0.12	C	Y

Calcium boron cream	100	9,756	975,600	0.11	C	Z
Plant Roots	40	23,497	939,880	0.10	C	Y
Valida Mycin	90	8,418	757,620	0.08	C	Y
Total	**1,864**	**357,505**	**32,908,990**	**3.56%**		

From table 4.5, C-Class which have 17 products and the total cost of products in C-Class is 32,908,990 baht and it's 3.56% of total cost which is 923,661,068 baht.

4.2 Forecasting Process

From classify customer demand by using ABC-XYZ analysis, researcher choose 5 products that have high value and low variation of demand which are AX-class, AY-class, and BX-class which include Glyphosate, Paraquat, RTG, Conweat, and DDVP respectively. In the forecasting method, researcher use 5 different methods are Moving Average, Weight Moving Average, Exponential Smoothing, Exponential Smoothing with Trend Adjustment, and Linear Trendline.

4.2.1 Forecasting of Glyphosate

Table 4.6 Forecasting Glyphosate with Moving Average

Year	Actual Demand	Moving Average (3 years)	Moving Average (4 years)	Moving Average (5 years)	Forecast Error (3years)	Forecast Error (4years)	Forecast Error (5years)
2009	175,931						
2010	175,651						
2011	178,172						
2012	182,088	176,584.67			3.02		
2013	171,424	178,637.00	177,960.50		4.21	3.81	
2014	176,116	177,228.00	176,833.75	176,653.20	0.63	0.41	0.31
2015	178,940	176,542.67	176,950.00	176,690.20	1.34	1.11	1.26
2016	174,820	175,493.33	177,142.00	177,348.00	0.39	1.33	1.45
2017	175,540	176,625.33	175,325.00	176,677.60	0.62	0.12	0.65
2018	169,036	176,433.33	176,354.00	175,368.00	4.38	4.33	3.75
2019	177,650	173,132.00	174,584.00	174,890.40	2.54	1.73	1.55
2020		174,075.33	174,261.50	175,197.20			
AVG					2.14%	1.83%	1.49%

Table 4.7 Forecasting Glyphosate with Weight Moving Average

Year	Actual Demand	Weight Moving Average (3 years)	Weight Moving Average (4 years)	Weight Moving Average (5 years)	Forecast Error (3years)	Forecast Error (4years)	Forecast Error (5years)
2009	175,931						
2010	175,651						
2011	178,172						
2012	182,088	170,950.04			6.12		
2013	171,424	172,232.06	176,491.00		0.47	2.96	
2014	176,116	172,854.48	177,161.50	140,995.40	1.85	0.59	19.94
2015	178,940	172,410.92	178,231.80	141,480.60	3.65	0.40	20.93
2016	174,820	168,966.60	177,835.60	142,581.60	3.35	1.72	18.44
2017	175,540	171,459.40	174,128.80	142,419.60	2.32	0.80	18.87
2018	169,036	171,757.80	176,740.00	139,204.80	1.61	4.56	17.65
2019	177,650	168,808.12	176,698.80	140,945.20	4.98	0.54	20.66
2020		168,681.30	174,309.90	141,428.30			
AVG					3.04%	1.65%	19.42%

Table 4.8 Forecasting Glyphosate with Exponential Smoothing

Year	Actual Demand	Alpha (0.3)	Alpha (0.5)	Alpha (0.7)	Forecast Error (α = 0.3)	Forecast Error (α =0.5)	Forecast Error (α =0.7)
2009	175,931						
2010	175,651	175,931.00	175,931.00	175,931.00			
2011	178,172	175,847.00	175,791.00	175,735.00			
2012	182,088	176,544.50	176,981.50	177,440.90	3.04		
2013	171,424	178,207.55	179,534.75	180,693.87	3.96	4.73	
2014	176,116	176,172.49	175,479.38	174,204.96	0.03	0.36	1.09
2015	178,940	176,155.54	175,797.69	175,542.69	1.56	1.76	1.90
2016	174,820	176,990.88	177,368.84	177,920.81	1.24	1.46	1.77
2017	175,540	176,339.61	176,094.42	175,750.24	0.46	0.32	0.12
2018	169,036	176,099.73	175,817.21	175,603.07	4.18	4.01	3.89
2019	177,650	173,980.61	172,426.61	171,006.12	2.07	2.94	3.74
2020		175,081.43	175,038.30	175,656.84			
AVG					2.07%	2.22%	2.08%

Table 4.9 Forecasting Glyphosate with Exponential Smoothing with Trend Adjustment (Alpha=0.7, Beta=0.3)

Year	Actual Demand	Forecast	Trend	FIT	Forecast Error
2009	175,931	175931.00	0.00	175,931.00	0.00
2010	175,651	175931.00	0.00	175,931.00	0.16
2011	178,172	175735.00	-58.80	175,676.20	1.37
2012	182,088	177423.26	465.32	177,888.58	2.56
2013	171,424	180828.17	1,347.20	182,175.37	5.49
2014	176,116	174649.41	-910.59	173,738.82	0.83
2015	178,940	175402.85	-411.38	174,991.46	1.98
2016	174,820	177755.44	417.81	178,173.25	1.68
2017	175,540	175825.97	-286.37	175,539.60	0.16
2018	169,036	175539.88	-286.29	175,253.59	3.85
2019	177,650	170901.28	-1,591.98	169,309.29	3.80
2020		175147.79	159.56	175,307.35	
AVG					1.99%

Table 4.10 Forecasting Glyphosate with Linear Trendline

Year	Actual Demand	Forecast	Forecast Error
2009	175,931	177,432.99	0.85
2010	175,651	177,134.98	0.84
2011	178,172	176,836.97	0.75
2012	182,088	176,538.96	3.05
2013	171,424	176,240.95	2.81
2014	176,116	175,942.94	0.10
2015	178,940	175,644.93	1.84
2016	174,820	175,346.92	0.30
2017	175,540	175,048.91	0.28
2018	169,036	174,750.9	3.38
2019	177,650	174,452.89	1.80
2020		174,154.88	
AVG			1.46%

4.2.2 Forecasting of Paraquat

Table 4.11 Forecasting for Paraquat with Moving Average

Year	Actual Demand	Moving Average (3years)	Moving Average (4years)	Moving Average (5years)	Forecast Error (3years)	Forecast Error (4years)	Forecast Error (5years)
2009	136,339						
2010	133,019						
2011	139,046						
2012	138,019	136,134.67			1.37		
2013	135,102	136,694.67	136,605.75		1.18	1.11	
2014	133,210	137,389.00	136,296.50	136,305.00	3.14	2.32	2.32
2015	138,591	135,443.67	136,344.25	135,679.20	2.27	1.62	2.10
2016	129,332	135,634.33	136,230.50	136,793.60	4.87	5.33	5.77
2017	83,200	133,711.00	134,058.75	134,850.80	60.71	61.13	62.08
2018	56,113	117,041.00	121,083.25	123,887.00	108.58	115.78	120.78
2019	78,820	89,548.33	101,809.00	108,089.20	13.61	29.17	37.13
2020		72,711.00	86,866.25	97,211.20			
AVG					24.47%	30.92%	38.36%

Table 4.12 Forecasting for Paraquat with Weight Moving Average

Year	Actual Demand	Weight Moving Average (3 years)	Weight Moving Average (4 years)	Weight Moving Average (5 years)	Forecast Error (3years)	Forecast Error (4years)	Forecast Error (5years)
2009	136,339						
2010	133,019						
2011	139,046						
2012	138,019	131,713.02			4.57		
2013	135,102	131,686.53	135,833.05		2.53	0.54	
2014	133,210	133,896.04	135,681.25	108,700.05	0.52	1.86	18.40
2015	138,591	132,185.80	137,854.50	108,234.30	4.62	0.53	21.90
2016	129,332	131,074.47	136,451.15	110,322.45	1.35	5.50	14.70
2017	122,210	130,168.74	134,769.25	108,945.15	6.51	10.28	10.85
2018	56,113	128,870.80	133,692.60	107,119.00	129.66	138.26	90.90
2019	78,820	110,868.21	129,232.25	102,851.55	40.66	63.96	30.49
2020		91,338.30	113,686.95	100,270.45			
AVG					23.80%	31.56%	31.21%

Table 4.13 Forecasting for Paraquat with Exponential Smoothing

Year	Actual Demand	Alpha (0.3)	Alpha (0.5)	Alpha (0.7)	Forecast Error (α = 0.3)	Forecast Error (α =0.5)	Forecast Error (α =0.7)
2009	136,339						
2010	133,019	136,339.00	136,339.00	136,339.00			
2011	139,046	135,343.00	134,679.00	134,015.00			
2012	138,019	136,453.90	136,862.50	137,536.70	1.13		
2013	135,102	136,923.43	137,440.75	137,874.31	1.35	1.73	
2014	133,210	136377.00	136,271.38	135,933.69	2.38	2.30	2.04
2015	138,591	135,426.90	134,740.69	134,027.11	2.28	2.78	3.29
2016	129332	136,376.13	136,665.84	137,221.83	5.45	5.67	6.10
2017	122,210	134,262.89	132,998.92	131,698.95	9.86	8.83	7.76
2018	56,113	130,647.02	127,604.46	125,056.68	132.83	127.41	122.87
2019	78,820	108,286.82	91,858.73	76,796.11	37.38	16.54	2.57
2020		99,446.77	85,339.37	78,212.83			
AVG					24.08%	23.61%	24.11%

Table 4.14 Forecasting for Paraquat with Exponential Smoothing with Trend Adjustment (Alpha=0.7, Beta=0.3)

Year	Actual Demand	Forecast	Trend	FIT	Forecast Error
2009	136,339	136,339.00	0.00	136,339.00	0.00
2010	133,019	136,339.00	0.00	136,339.00	2.50
2011	139,046	134,015.00	-697.20	133,317.80	3.62
2012	138,019	137,327.54	505.72	137,833.26	0.50
2013	135,102	137,963.28	544.73	138,508.01	2.12
2014	133,210	136,123.80	-170.53	135,953.27	2.19
2015	138,591	134,032.98	-746.62	133,286.36	3.29
2016	129,332	136,999.61	367.35	137,366.96	5.93
2017	122,210	131,742.49	-1,319.99	130,422.50	7.80
2018	56,113	124,673.75	-3,044.61	121,629.14	122.18
2019	78,820	75,767.84	-16,803.00	58,964.84	3.87
2020		72,863.45	-12,633.42	60,230.03	
AVG					14.00%

Table 4.15 Forecasting for Paraquat with Linear Trendline

Year	Actual Demand	Forecast	Forecast Error
2009	136,339	151,782.50	11.33
2010	133,019	145786.00	9.60
2011	139,046	139,789.50	0.53
2012	138,019	133,793.00	3.06
2013	135,102	127,796.50	5.41
2014	133,210	121,800.00	8.57
2015	138,591	115,803.50	16.44
2016	129,332	109,807.00	15.10
2017	122,210	103,810.50	15.06
2018	56,113	97,814.00	74.32
2019	78,820	91,817.50	16.49
2020		85,821.00	
AVG			15.99%

4.2.3 Forecasting of RTG

Table 4.16 Forecasting for RTG with Moving Average

Year	Actual Demand	Moving Average (3years)	Moving Average (4years)	Moving Average (5years)	Forecast Error (3years)	Forecast Error (4years)	Forecast Error (5years)
2009	7,507						
2010	7,719						
2011	7,812						
2012	7,129	7,679.33			7.72		
2013	7,982	7,553.33	7,541.75		5.37	5.52	
2014	7,862	7,641.00	7,660.50	7,629.80	2.81	2.56	2.95
2015	8,258	7,657.67	7,696.25	7,700.80	7.27	6.80	6.75
2016	8,262	8,034.00	7,807.75	7,808.60	2.76	5.50	5.49
2017	8,352	8,127.33	8,091.00	7,898.60	2.69	3.13	5.43
2018	7,046	8,290.67	8,183.50	8,143.20	17.66	16.14	15.57
2019	7,660	7,886.67	7,979.50	7,956.00	2.96	4.17	3.86
2020		7,686.00	7,830.00	7,915.60			
AVG					6.16%	6.26%	6.68%

Table 4.17 Forecasting for RTG with Weight Moving Average

Year	Actual Demand	Weight Moving Average (3 years)	Weight Moving Average (4 years)	Weight Moving Average (5 years)	Forecast Error (3years)	Forecast Error (4years)	Forecast Error (5years)
2009	7,507						
2010	7,719						
2011	7,812						
2012	7,129	7,397.24			3.76		
2013	7,982	7,415.03	7,597.45		7.10	4.82	
2014	7,862	7,401.64	7,671.55	6,083.35	5.86	2.42	22.62
2015	8,258	7,295.64	7,635.10	6,155.10	11.65	7.54	25.47
2016	8,262	7,753.46	7,551.30	6,154.80	6.16	8.60	25.50
2017	8,352	7,812.94	8,001.40	6,060.20	6.45	4.20	27.44
2018	7,046	8,027.44	8,065.30	6,421.70	13.93	14.47	8.86
2019	7,660	7,834.42	8,212.70	6,392.50	2.28	7.22	16.55
2020		7,592.00	8,076.50	6,526.10			
AVG					7.15%	7.04%	21.07%

Table 4.18 Forecasting for RTG with Exponential Smoothing

Year	Actual Demand	Alpha (0.3)	Alpha (0.5)	Alpha (0.7)	Forecast Error (α = 0.3)	Forecast Error (α =0.5)	Forecast Error (α =0.7)
2009	7,507						
2010	7,719	7,507.00	7,507.00	7,507.00			
2011	7,812	7,570.60	7,613.00	7,655.40			
2012	7,129	7,643.02	7,712.50	7,765.02	7.21		
2013	7,982	7,488.81	7,420.75	7,319.81	6.18	7.03	
2014	7,862	7,636.77	7,701.38	7,783.34	2.86	2.04	1.00
2015	8,258	7,704.34	7,781.69	7,838.40	6.70	5.77	5.08
2016	8,262	7,870.44	8,019.84	8,132.12	4.74	2.93	1.57
2017	8,352	7,987.91	8,140.92	8,223.04	4.36	2.53	1.54
2018	7,046	8,097.13	8,246.46	8,313.31	14.92	17.04	17.99
2019	7,660	7,781.79	7,646.23	7,426.19	1.59	0.18	3.05
2020		7,745.26	7,653.12	7,589.86			
AVG					6.07%	5.36%	5.04%

Table 4.19 Forecasting for RTG with Exponential Smoothing with Trend Adjustment (Alpha=0.7, Beta=0.3)

Year	Actual Demand	Forecast	Trend	FIT	Forecast Error
2009	7,507	7,507.00	0.00	7,507.00	0.00
2010	7,719	7,507.00	0.00	7,507.00	2.75
2011	7,812	7,655.40	44.52	7,699.92	2.00
2012	7,129	7,778.38	68.06	7,846.43	9.11
2013	7,982	7,344.23	-82.60	7,261.63	7.99
2014	7,862	7,765.89	68.67	7,834.56	1.22
2015	8,258	7,853.77	74.44	7,928.21	4.90
2016	8,262	8,159.06	143.69	8,302.75	1.25
2017	8,352	8,274.23	135.13	8,409.36	0.93
2018	7,046	8,369.21	123.09	8,492.30	18.78
2019	7,660	7,479.89	-180.63	7,299.26	2.35
2020		7,551.78	-104.88	7,446.90	
AVG					4.66%

Table 4.20 Forecasting for RTG with Linear Trendline

Year	Actual Demand	Forecast	Forecast Error
2009	7,507	7,679.22	2.29
2010	7,719	7,699.54	0.25
2011	7,812	7,719.85	1.18
2012	7,129	7,740.17	8.57
2013	7,982	7,760.49	2.78
2014	7,862	7,780.81	1.03
2015	8,258	7,801.13	5.53
2016	8,262	7,821.44	5.33
2017	8,352	7,841.76	6.11
2018	7,046	7,862.08	11.58
2019	7,660	7,882.40	2.90
2020		7,902.72	
AVG			4.32%

4.2.4 Forecasting of Conweat

Table 4.21 Forecasting for Conweat with Moving Average

Year	Actual Demand	Moving Average (3years)	Moving Average (4years)	Moving Average (5years)	Forecast Error (3years)	Forecast Error (4years)	Forecast Error (5years)
2009	9,506						
2010	9,056						
2011	9,616						
2012	8,646	9,392.67			8.64		
2013	8,716	9,106.00	9,206.00		4.47	5.62	
2014	8,264	8,992.67	9,008.50	9,108.00	8.82	9.01	10.21
2015	7,044	8,542.00	8,810.50	8,859.60	21.27	25.08	25.78
2016	7,314	8,008.00	8,167.50	8,457.20	9.49	11.67	15.63
2017	6,864	7,540.67	7,834.50	7,996.80	9.86	14.14	16.50
2018	2,676	7,074.00	7,371.50	7,640.40	164.35	175.47	185.52
2019	3,520	5,618.00	5,974.50	6,432.40	59.60	69.73	82.74
2020		4,353.33	5,093.50	5,483.60			
AVG					35.81%	44.39%	56.06%

Table 4.22 Forecasting for Conweat with Weight Moving Average

Year	Actual Demand	Weight Moving Average (3 years)	Weight Moving Average (4 years)	Weight Moving Average (5 years)	Forecast Error (3years)	Forecast Error (4years)	Forecast Error (5years)
2009	9,506						
2010	9,056						
2011	9,616						
2012	8,646	9,104.52			5.30		
2013	8,716	8,882.62	9,344.50		1.91	7.21	
2014	8,264	8,883.52	9,145.50	7,443.30	7.50	10.67	9.93
2015	7,044	8,342.68	9,122.40	7,259.20	18.44	29.51	3.06
2016	7,314	8,034.68	8,529.60	7,212.60	9.85	16.62	1.39
2017	6,864	7,488.58	8,259.50	6,745.90	9.10	20.33	1.72
2018	2,675	6,883.08	7,685.50	6,552.50	157.31	187.31	144.95
2019	3,520	6,170.95	6,879.55	5,922.75	75.31	95.44	68.26
2020		4,832.9	6,293.45	5,276.55			
AVG					35.59%	52.44%	38.22%

Table 4.23 Forecasting for Conweat with Exponential Smoothing

Year	Actual Demand	Alpha (0.3)	Alpha (0.5)	Alpha (0.7)	Forecast Error (α = 0.3)	Forecast Error (α =0.5)	Forecast Error (α =0.7)
2009	9,506						
2010	9,056	9,506.00	9,506.00	9,506.00			
2011	9,616	9,371.00	9,281.00	9,191.00			
2012	8,646	9,444.50	9,448.50	9,488.50	9.24		
2013	8,716	9,204.95	9,047.25	8,898.75	5.61	3.80	
2014	8,264	9,058.27	8,881.63	8,770.83	9.61	7.47	6.13
2015	7,044	8,819.99	8,572.81	8,416.05	25.21	21.70	19.48
2016	7,314	8,287.19	7,808.41	7,455.61	13.31	6.76	1.94
2017	6,864	7,995.23	7,561.20	7,356.48	16.48	10.16	7.17
2018	2,675	7,655.86	7,212.60	7,011.75	186.20	169.63	162.12
2019	3,520	6,161.60	4,943.80	3,976.02	75.05	40.45	12.96
2020		5,369.12	4,231.90	3,656.81			
AVG					42.59%	37.14%	34.97%

Table 4.24 Forecasting for Conweat with Exponential Smoothing with Trend Adjustment (Alpha=0.7, Beta=0.3)

Year	Actual Demand	Forecast	Trend	FIT	Forecast Error
2009	9,506	9,506.00	0	9,506.00	0.00
2010	9,056	9,506.00	0	9,506.00	4.97
2011	9,616	9,191.00	-94.50	9,096.50	4.42
2012	8,646	9,460.15	14.60	9,474.75	9.42
2013	8,716	8,894.62	-159.44	8,735.18	2.05
2014	8,264	8,721.75	-163.47	8,558.28	5.54
2015	7,044	8,352.29	-225.27	8,127.02	18.57
2016	7,314	7,368.90	-452.70	6,916.20	0.75
2017	6,864	7,194.66	-369.17	6,825.50	4.82
2018	2,675	6,852.45	-361.08	6,491.37	156.17
2019	3,520	3,819.91	-1,162.52	2,657.39	8.52
2020		3,261.22	-981.37	2,279.85	
AVG					19.57%

Table 4.25 Forecasting for Conweat with Linear Trendline

Year	Actual Demand	Forecast	Forecast Error
2009	9,506	1,0476.40	10.21
2010	9,056	9,857.80	8.85
2011	9,616	9,239.20	3.92
2012	8,646	8,620.60	0.29
2013	8,716	8,002.00	8.19
2014	8,264	7,383.40	10.66
2015	7,044	6,764.80	3.96
2016	7,314	6,146.20	15.97
2017	6,864	5,527.60	19.47
2018	2,675	4,909.00	83.51
2019	3,520	4,290.40	21.89
2020		3,671.80	
AVG			16.99%

4.2.5 Forecasting of DDVP

Table 4.26 Forecasting for DDVP with Moving Average

Year	Actual Demand	Moving Average (3years)	Moving Average (4years)	Moving Average (5years)	Forecast Error (3years)	Forecast Error (4years)	Forecast Error (5years)
2009	4,910						
2010	5,360						
2011	5,104						
2012	5,196	5,124. 67			1.37		
2013	5,510	5,220.00	5,142.50		5.26	6.67	
2014	5,271	5,270.00	5,292.50	5,216.00	0.02	0.41	1.04
2015	5,440	5,325.67	5,270.25	5,288.20	2.10	3.12	2.79
2016	5,271	5,407.00	5,354.25	5,304.20	2.58	1.58	0.63
2017	5,672	5,327.33	5,373.00	5,337.60	6.08	5.27	5.90
2018	5,540	5,461.00	5,413.50	5,432.80	1.43	2.28	1.94
2019	5,720	5,494.33	5,480.75	5,438.80	3.95	4.18	4.92
2020		5,644.00	5,550.75	5,528.60			
AVG					2.85%	3.36%	2.87%

Table 4.27 Forecasting for DDVP with Weight Moving Average

Year	Actual Demand	Weight Moving Average (3 years)	Weight Moving Average (4 years)	Weight Moving Average (5 years)	Forecast Error (3years)	Forecast Error (4years)	Forecast Error (5years)
2009	4,910						
2010	5,360						
2011	5,104						
2012	5,196	4,930.68			5.11		
2013	5,510	5,094.52	5,088.40		7.54	7.65	
2014	5,271	5,047.50	5,266.10	4,081.70	4.24	0.09	22.56
2015	5,440	5,147.07	5,200.85	4,223.45	5.38	4.40	22.36
2016	5,271	5,261.10	5,313.65	4,167.35	0.19	0.81	20.94
2017	5,672	5,163.57	5,415.85	4,243.05	8.96	4.52	25.19
2018	5,540	5,265.54	5,341.75	4,349.35	4.95	3.58	21.49
2019	5,720	5,278.90	5,429.10	4,284.10	7.71	5.09	25.10
2020		5,470.40	5,454.10	4,360.40			
AVG					5.51%	3.73%	22.94%

Table 4.28 Forecasting for DDVP with Exponential Smoothing

Year	Actual Demand	Alpha (0.3)	Alpha (0.5)	Alpha (0.7)	Forecast Error (α = 0.3)	Forecast Error (α =0.5)	Forecast Error (α =0.7)
2009	4,910						
2010	5,360	4,910.00	4,910.00	4,910.00			
2011	5,104	5,045.00	5,135.00	5,225.00			
2012	5,196	5,062.70	5,119.50	5,140.30	2.57		
2013	5,510	5,102.69	5,157.75	5,179.29	7.39	6.39	
2014	5,271	5,224.88	5,333.88	5,410.79	0.87	1.19	2.65
2015	5,440	5,238.72	5,302.44	5,312.94	3.70	2.53	2.34
2016	5,271	5,299.10	5,371.22	5,401.88	0.53	1.90	2.48
2017	5,672	5,290.67	5,321.11	5,310.26	6.72	6.19	6.38
2018	5,540	5,405.07	5,496.55	5,563.48	2.44	0.78	0.42
2019	5,720	5,445.55	5,518.28	5,547.04	4.80	3.53	3.02
2020		5,527.88	5,619.14	5,668.11			
AVG					3.63%	3.22%	2.88%

Table 4.29 Forecasting for DDVP with Exponential Smoothing with Trend Adjustment (Alpha=0.7, Beta=0.3)

Year	Actual Demand	Forecast	Trend	FIT	Forecast Error
2009	4,910	4,910.00	0	4,910.00	0.00
2010	5,360	4,910.00	0	4,910.00	8.40
2011	5,104	5,225.00	94.50	5,319.50	2.37
2012	5,196	5,168.65	49.25	5,217.89	0.53
2013	5,510	5,202.57	44.65	5,247.22	5.58
2014	5,271	5,431.16	99.83	5,530.99	3.04
2015	5,440	5,348.99	45.23	5,394.23	1.67
2016	5,271	5,426.27	54.84	5,481.11	2.95
2017	5,672	5,334.03	10.72	5,344.75	5.96
2018	5,540	5,573.83	79.44	5,653.27	0.61
2019	5,720	5,573.98	55.66	5,629.64	2.55
2020		5,692.89	74.63	5,767.52	
AVG					3.06%

Table 4.30 Forecasting for DDVP with Linear Trendline

Year	Actual Demand	Forecast	Forecast Error
2009	4,910	2,337.90	47.62
2010	5,360	3,488.40	34.92
2011	5,104	4,638.90	9.11
2012	5,196	5,789.40	11.42
2013	5,510	6,939.90	25.95
2014	5,271	8,090.40	53.49
2015	5,440	9,240.90	69.87
2016	5,271	10,391.40	97.14
2017	5,672	11,541.90	103.49
2018	5,540	12,692.40	129.10
2019	5,720	13,842.90	142.01
2020		14,993.40	
AVG			65.83%

From researcher use 5 different forecasting methods which are Moving Average, Weight Moving Average, Exponential Smoothing, Exponential Smoothing with Trend Adjustment, and Linear Trendline with 5 products include Glyphosate, Paraquat, RTG, Conweat, and DDVP. We can conclude that the Linear Trendline forecasting method has the lowest forecasting error, so we use a linear trendline to forecast all 36 products as shown in Table 4.31.

4.2.6 Forecasting all products with Linear Trendline Method

Table 4.31 Forecasting all products with Linear Trendline Method

Product Name	Unit Cost (Baht)	Actual Demand 2562	Forecasting Demand 2562 (Linear Trendline)	Forecasting Error (%)
Glyphosate	340	177,650	174,452.89	1.80
Paraquat	60	78,820	91,817.50	16.49
RTG	240	7,660	7,882.40	2.90
Conweat	165	3,520	4,290.40	21.89
KG, Mahoran	129	8,120	12,902.45	58.90
Mancoset	90	8,178	9,093.20	11.19
Cabosunfran	190	4,540	3,909.18	13.89
Arsel	270	1,440	1,5280	6.11
New Toxic	110	3,984	1,931.20	51.53
DDVP	150	5,720	13,842.90	142.01
Jabbai	85	9,436	9,766.03	3.50
Tarna	35	25,515	26,802.60	5.05
Siptid	180	3,228	3,793.99	17.53
Metalecsil	195	4,500	3,970.10	11.78
Plantcrovos	110	5,124	6,814.39	32.99
Copper	80	4,344	5,823.55	34.06
Builtaco	165	6,716	4,997.11	25.59
Chlorophyll	166	3,204	3572.37	11.50
OH	170	250	1,290.42	416.17
Rassa	255	533	623.65	17.01
Stepcy	180	1,480	1,905.80	28.77
Packone	115	2,340	1,296.54	44.59
K.A.	160	1,095	1,374.40	25.52
Cabendasin	140	1,804	2,115.20	17.25
Builting	145	1,524	1,607.70	5.49
Hightouch	38	1,320	-387.60	129.36
Airy	195	2,325	1,699.83	26.89
Makla	90	576	1,126.30	95.54
Abamegtin	115	480	34.77	92.76
Rice Hormone	43	2,220	650.17	70.71
Cyto-Z	55	1,600	2,042.99	27.69
Planting Rice	43	1,206	1,092.34	9.42
EMS	60	1,464	869.18	40.63
Calcium boron cream	100	525	413.20	21.29
Plant Roots	40	1,842	1,988.50	7.95
Valida Mycin	90	621	643.14	3.57
Total	**4,794**	**384,904**	**421,328.79**	

From Table 4.31, after researcher use the Linear Trendline forecasting method with all 36 products, the annual actual demand in 2562 is 384,904 liters but the annual forecasting demand in 2562 is increased to 421,328.79 liters, this because of the high variation of demand that make inaccurate forecasting. This is why researchers use forecasting methods only for AX, AY, and BX in ABC-XYZ analysis which are Glyphosate, Paraquat, RTG, Conweat, and DDVP because these products have a low variation of demand that will make better forecasting accuracy. For BY and BZ class (includes Mancoset, Cabosunfran, Arsel, New Toxic, Jabbai, Tarna, Siptid, Metalecsil, Plantcrovos, Copper, Builtaco, Chlorophyll, and O.H.) we and take an average inventory stock (if the inventory cost is not much high). And for C-class products (CX, CY, and CZ class), these products can make overstocking and need to have some products only for an order.

4.3 Analyst of Economic Order Quantity (EOQ)

Finding order size of the EOQ method will have to consider ordering cost, holding cost, and shortage cost.

4.3.1 Ordering cost

Ordering cot is dealing with the expense which occurs during order activity in a case study of the company in 2019 include wage of an employee who works in process by calculating wage rate during work time and information of working time and wage rate following:

Table 4.32 Calculating Purchasing Department

Employee	Activity	Work time per days	Wage rate per months	Wage rate per year	Calculating wage rate per year
1	Plan, Premise order, and Contract supplier	6 hours	18,000	162,000	$18{,}000 \times 12 \times \frac{6}{8}$
2	Collect PR and PO	4 hours	13,000	78,000	$13{,}000 \times 12 \times \frac{4}{8}$

Total Cost of Purchasing Department = 240,000 baht

Table 4.33 Calculating Accounting Department

Employee	Activity	Work time per days	Wage rate per months	Wage rate per year	Calculating wage rate per year
1	Check order into accounting system and collect document	5 hours	18,000	135,000	$18{,}000 \times 12 \times \frac{5}{8}$
2	Check dept document and tax document	5 hours	18,000	135,000	$18{,}000 \times 12 \times \frac{5}{8}$

Total Cost of Accounting Department = 270,000 baht

Table 4.34 Calculating Inventory and Quality Control Department

Employee	Activity	Work time per days	Wage rate per months	Wage rate per year	Calculating wage rate per year
1	Check product list and keep in inventory	6 hours	18,000	162,000	$18{,}000 \times 12 \times \frac{6}{8}$
2	Check Quality	8 hours	22,000	264,000	$22{,}000 \times 12$

Total cost of inventory and quality Control Department = 426,000 baht

Table 4.35 Calculating Equipment

List	Activity	Work time per days	Working rate	Wage rate per year	Calculating wage rate per year
Telephone	Contract with supplier	1 minute	3 per minutes	51,840	$(60 \times 3) \times 24 \times 12$
Internet	Contract suppler and send PO (500 baths per machine)	Whole days	3 machines	18,000	$(500 \times 3) \times 12$
Paper	Create PR, PO and inspection list (5 papers per one time)	Whole days	0.18 per papers	2,397	$(5 \times 2{,}663) \times 0.18$
Ink	Use to print	Whole days	0.25 per one print	3,329	$(5 \times 2{,}663) \times 0.25$
Pen, Pencil, Eraser and Liquid	Write PR and PO (6 persons)	Whole days	100 per person	600	100×6

Total Cost of Equipment = 76,166 baht

Table 4.36 Calculating Officer Equipment and Repair Fee

List	Activities	Work time per days	Working rate	Wage rate per year	Calculating wage rate per year
Computers	Print PR and PO and check order list (5 machines with 25,000 per machine for 5 years)	Whole days	Depreciate 5,000 per machine	25,000	5000×5
Fax machine	Sent and receipt document (18,000 baht per machine)	Whole days	Depreciate 3,600 baht	3,600	3600×1
Printer	Print all document (22,000 baht per machine)	Whole days	Depreciate 4,400 baht	4,400	4400×1
Repair fee	Repair fee	In problem case	Repair 1,000 baht for computer per year 1,000 baht for fax machine per year 2,000 baht for printer per year	8,000	$(5 \times 1000) + (1 \times 1000) + (1 \times 2000)$

Total Cost of Officer Equipment and Repair Fee = 41,000 baht

Table 4.37 Total Ordering Cost in each Department

List	Total cost (Baht)
Cost of Purchasing	240,000
Cost of Accounting	270,000
Cost of Inventory and Quality Control Department	426,000
Cost of Equipment	76,166
Cost of Officer Equipment and Repair Fee	41,000
Total Cost	1,053,166
Total Purchase Order	2,663
Ordering Cost	395

4.3.2 Carrying Cost

Carrying cost is an expense which occurs because it is available of stock and remains for readying to use which depends on the quantity of stock on hand and the time of keeping stock in inventory. It is usually expressed on a per-unit basis for some period of time. In the case study of the company, the researcher collects information on inventory carrying cost as shown in Table 4.38.

Table 4.38 Inventory Carrying Cost

List	Percentage (%)
Stock Cost	5
Tax Fee	3
Insurance Cost	1
Rent inventory Cost	0
Transportation Cost	3
Controlling Cost	3
Depreciated Cost	4
Shortage Cost	2
Total Cost	21

4.3.3 Shortage Cost

Shortage cost is an expense which happens because it is not enough stock for produce or sell products and make customer cancel order which affect to lose revenue and profit. This cost is affected by the quantity of stock which is if there is enough stock, it will not occur shortage cost, but if there is low or not enough stock, it will occur shortage cost. In the case study of a company, there is no enough information of shortage cost because some information do not keep and company does not consider this factor, but there is a problem about a shortage of stock in some time , so researcher assign value of shortage cost for each category of raw material by product code no. 1 and no.2 are 30 baht per liter, product code no.3 is 50 baht per liter and product code no.4 is 70 baht per liter.

4.3.4 Safety Stock

Safety stock is an important basic factor in inventory management because it is useful in terms of having enough goods for customers until the arrival of an order or already produce a product. Safety stock is dealing with economics order quantity which makes to know order size.

4.3.5 Reorder Point with Variable Lead Time

Raw material purchasing process has time to be an important factor that is able to identify that quantity of purchasing new raw material when it decreases in some level of inventory, so reorder point is the point for making the decision to buy new raw material. Reorders point direct variation with average lead time and safety stock while each ordering raw material may affect overstock in inventory and do not have enough place to keep stock. In some time, the company has a problem with over-stock in some raw material with low demand of customers. Researcher use reorder point with variable lead time in order to prevent the problem because company uses the same supplier for all raw material and there is average lead time with 4 days and standard deviation of lead time is 2 days.

Table 4.39 Summarize of Economic Order Quantity (EOQ)

Product list	Unit cost (Baht)	Demand	EOQ	Number of orders	Safety Stock	Reorder Point	Maximum Inventory	Total Cost
Glyphosate	340	174,453	1,389	126	3,422	6,096	688	74,152
RTG	240	7,882	351	22	155	275	131	12,162
Paraquat	60	91,818	2,399	38	1,801	3,208	2,033	27,925
Conweat	165	4,290	313	14	84	150	209	9,042
KG	129	12,902	613	21	253	451	322	12,674
DDVP	150	13,843	589	23	272	484	287	13,807
Mancoset	90	9,093	617	15	178	318	447	10,054
Cabosunfran	190	3,909	278	14	77	137	119	7,932
Jabbai	85	9,766	657	15	192	341	412	9,546
Tarna	35	26,803	1,697	16	526	937	1,480	11,676
Siptid	180	3,794	282	13	74	133	125	7,677
Metalecsil	195	3,970	277	14	78	139	152	8,781
Plantcrovos	110	6,814	483	14	134	238	273	8,726
Copper	80	5,824	523	11	114	203	392	7,686
Chlorophyll	166	3,572	285	13	70	125	132	7,253
Arsel	270	1,528	146	10	30	53	50	5,568
New Toxic	110	1,931	257	8	38	67	145	4,645
Builtaco	165	4,997	338	15	98	175	226	9,759
OH	170	1,290	169	8	25	45	77	4,393
Builting	145	1,608	204	8	32	56	142	5,277
Rassa	255	624	96	7	12	22	34	3,494
Stepcy	180	1,906	200	10	37	67	114	5,920
K.A	160	1,374	180	8	27	48	107	4,826
Cabendasin	140	2,116	238	9	41	74	150	5,711
Makla	90	1,126	217	5	22	39	157	3,538
Cyto-Z	55	2,043	374	5	40	71	270	3,717
EMS	60	869	233	4	17	30	164	2,506
Plant Roots	40	1,989	433	5	39	70	338	3,236
Valida Mycin	90	643	164	4	13	22	119	2,674
Packone	115	1,297	206	6	25	45	114	3,865
Airy	195	1,700	181	9	33	59	100	5,746
Abamegtin	115	35	34	1	1	1	19	635
Rice Hormone	43	651	238	3	13	23	183	1,904
Planting Rice	43	1,093	309	4	21	38	238	2,468
Calcium boron cream	100	414	125	4	8	14	73	2,079
Total	**4,756**	**407,967**	**15,095**	**502**	**8,002**	**14,254**	**10,022**	**311,054**

Figure 4.2 Graph of Unit Cost, EOQ, Number of Orders, and Maximum Inventory

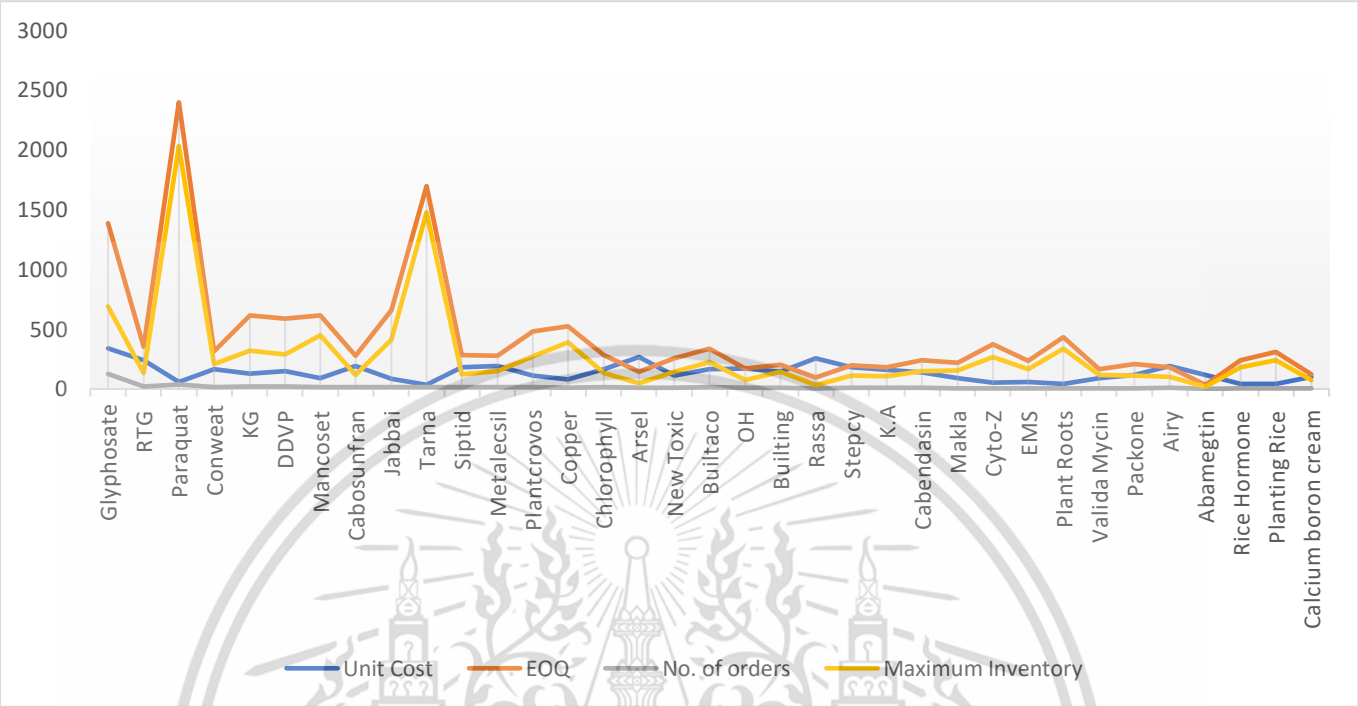
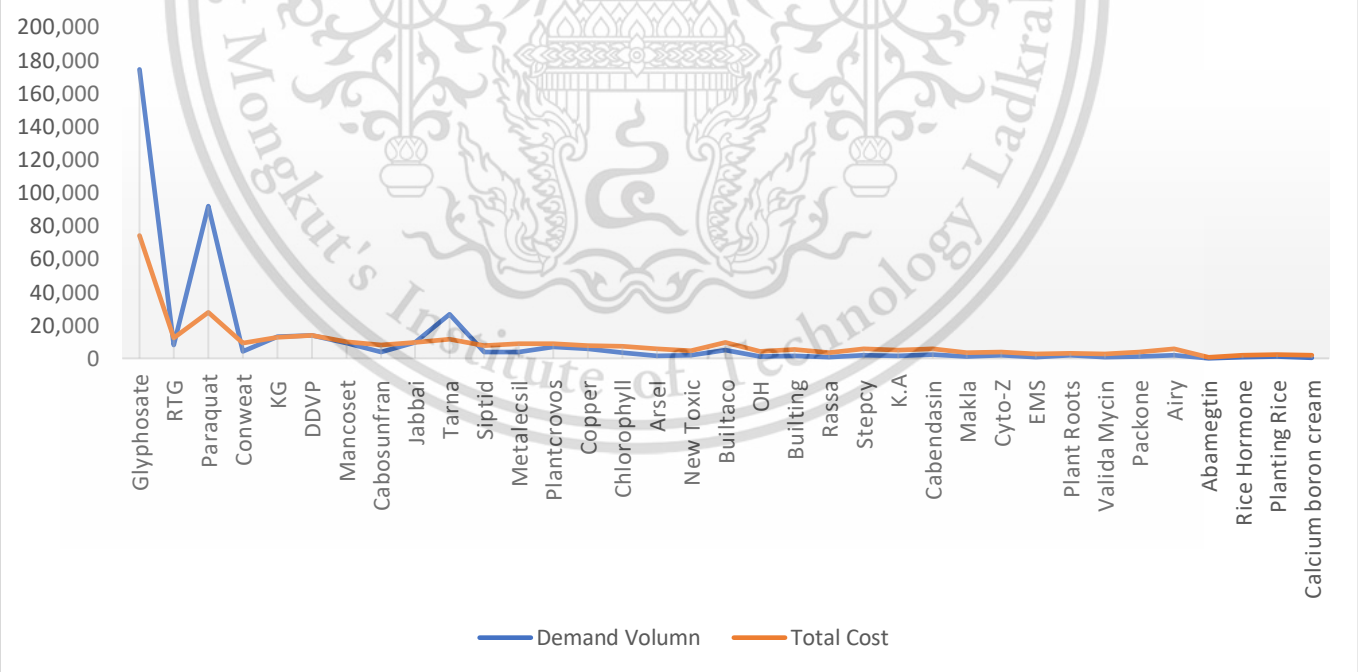


Figure 4.3 Graph of Demand Volume and Total Cost



4.4 Total Normal Inventory Cost

From case study of company, the company concern total inventory cost with only purchase cost which is followed:

$TC = P \times Q$

Where: Q = Order Size

Purchase Cost = unit purchase cost times the annual demand

4.4.1 Comparison Inventory Cost Between Normal Method and EQO Method

Table 4.40 Inventory Cost between Normal and EOQ Method in AX categories

Product List	Normal Method(baht)	EOQ Method(baht)
Glyphosate	472,368.00	74,152.00
RTG	84,360.00	12,162.00
Total	**556,728.00**	**86,314.00**

In AX categories, the difference inventory cost of normal and EOQ method is 470,414 baht, so it means EOQ method has less inventory cost than normal method.

Table 4.41 Inventory Cost between Normal and EOQ Method in AY categories

Product List	Normal Method(baht)	EOQ Method(baht)
Paraquat	143,960.00	27,925.00
Conweat	51,605.00	9,042.00
Total	**195,565.00**	**36,967.00**

In AY categories, the difference inventory cost of normal and EOQ method is 158,598 baht, so it means EOQ method has less inventory cost than normal method.

Table 4.42 Inventory Cost between Normal and EOQ Method in AZ categories

Product List	Normal Method(baht)	EOQ Method(baht)
KG	79,129.00	12,674.00
Total	**79,129.00**	**12,674.00**

In AZ categories, the difference inventory cost of normal and EOQ method is 66,455 baht, so it means EOQ method has less inventory cost than normal method.

Table 4.43 Inventory Cost between Normal and EOQ Method in BX categories

Product List	Normal Method(baht)	EOQ Method(baht)
DDVP	88,382.00	13,807.00
Total	**88,382.00**	**13,807.00**

In BX categories, the difference inventory cost of normal and EOQ method is 74,575 baht, so it means EOQ method has less inventory cost than normal method.

Table 4.44 Inventory Cost between Normal and EOQ Method in BY categories

Product List	Normal Method(baht)	EOQ Method(baht)
Mancoset	55,486.00	10,054.00
Cabosunfran	52,860.00	7,932.00
Jabbai	55,882.00	9,546.00
Tarna	59,405.00	11,676.00
Siptid	51,938.00	7,677.00
Metalecsil	53,966.00	8,781.00
Plantcrovos	53,102.00	8,726.00
Copper	41,864.00	7,686.00
Chlorophyll	47,232.00	7,253.00
Total	**471,735.00**	**79,331.00**

In BY categories, the difference inventory cost of normal and EOQ method is 329,404 baht, so it means EOQ method has less inventory cost than normal method.

Table 4.45 Inventory Cost between Normal and EOQ Method in BZ categories

Product List	Normal Method(baht)	EOQ Method(baht)
Arsel	39,396.00	5,568.00
New Toxic	28,269.00	4,645.00
Builtaco	55,694.00	9,759.00
OH	28,727.00	4,393.00
Total	**152,086.00**	**24,365.00**

In BZ categories, the difference inventory cost of normal and EOQ method is 127,721 baht, so it means EOQ method has less inventory cost than normal method.

Table 4.46 Inventory Cost between Normal and EOQ Method in CX categories

Product List	Normal Method(baht)	EOQ Method(baht)
Builting	29,614.00	5,277.00
Total	**29,614.00**	**5,277.00**

In CX categories, the difference inventory cost of normal and EOQ method is 24,337 baht, so it means EOQ method has less inventory cost than normal method.

Table 4.47 Inventory Cost between Normal and EOQ Method in CY categories

Product List	Normal Method(baht)	EOQ Method(baht)
Rassa	24,459.00	3,494.00
Stepcy	35,924.00	5,920.00
K.A.	28,762.00	4,826.00
Cabendasin	33,377.00	5,711.00
Makla	19,528.00	3,538.00
Cyto-Z	20,560.00	3,717.00
EMS	14,007.00	2,506.00
Plant Roots	17,298.00	3,236.00
Valida Mycin	14,756.00	2,674.00
Total	**208,671.00**	**35,622.00**

In CY categories, the difference inventory cost of normal and EOQ method is 173,049 baht, so it means EOQ method has less inventory cost than normal method.

Table 4.48 Inventory Cost between Normal and EOQ Method in CZ categories

Product List	Normal Method(baht)	EOQ Method(baht)
Packone	23,683.00	3,865.00
Airy	35,312.00	5,746.00
Abamegtin	3,878.00	635.00
Rice Hormone	10,255.00	1,904.00
Planting Rice	13,293.00	2,468.00
Calcium boron cream	12,468.00	2,079.00
Total	**98,889.00**	**16,697.00**

In CZ categories, the difference inventory cost of normal and EOQ method is 82,192 baht, so it means EOQ method has less inventory cost than normal method.

Table 4.49 Inventory Cost Between Normal and EOQ

Calculating Method	Inventory Cost
Normal	1,880,799.00
EOQ	311,054.00
Difference	**1,569,745.00**

Inventory cost of normal method in the company is 1,880,799 baht which do not have plan of controlling inventory cost while inventory cost of EOQ method have value only 311,054 baht which have cost less than normal method, so EOQ method can save 1,569,745 baht of inventory cost.

Chapter 5

Conclusions

The result of increasing the efficiency of inventory management study of appropriate order quantity by economic order quantity model in a case study of agriculture product manufacturing company is studied by comparing the inventory cost of the normal method and economic order quantity method which is used demand information from 2009 until 2019. It is founded that A-class has 5 products and the total cost of products in A-Class is 785,535,455 baht and it has a value at 85.05 percent of the total cost. AX class of ABC-XYZ analysis has 2 lists and the value of a stock is 73.46 percent in total which is 678,566,4880 baht, AY class also has 2 lists which the value of a stock is 10.15 percent with 93,789,690 baht and AZ class has only 1 list and the value of stock is 1.43 percent with 13,179,285 baht. In addition, B-class has 14 products and the total cost of products in B-class is 105,216,623 baht and it has a value at 11.39 percent of the total cost. BX class has only 1 list in which the value of a stock is 0.96 percent with 8,849,400 baht, BY class has 9 lists and the value of a stock is 7.63 percent with 70,436,468 and BZ class has 4 list which the value of a stock is 2.8 percent with 25,930,755 baht. In contrast, C-Class has 17 products and the total cost of products in C-Class is 32,908,990 baht and it has a value at 3.56 percent of the total cost. CX class has on 1 list with 0.28 percent of the stock value at 2,542,430 baht while CY class has 9 lists with 1.93 percent of the stock value at 17,739,885 baht and CZ class has 7 lists with 1.35 percent of a stock value at 12,626,675 baht.

As a result, researchers take all stock for time-series forecasting to forecast demand in 2019 for studying and find appropriate order quantity with minimizes total inventory costs to control inventory management with safety stock and reorder point and cause both positive effect and advantage to a company. Researcher founded that the linear trend line method is the most efficient way to forecast demand because there is the lowest forecasting error value in all methods in time-series forecasting. The normal inventory cost of AX class provides 556,728 baht in total cost, AY class is 195,565 baht and AZ class is 79,129 baht, while EOQ has inventory cost only 86,314 baht of AX class, 36,967 of AY class and 12,674 of AZ class. Moreover, the normal inventory cost of BX class provides 88,382baht in total cost, BY is 471,735 baht and BZ is 152,086 baht whereas EOQ has inventory cost only 13,807 baht of BX class, 79,331 baht of BY class and 24,365 baht of BZ class respectively. Furthermore, the normal inventory cost of CX class provides 29,614 baht in total cost, CY class is 208,671 baht and CZ class is 98,889 baht while EOQ has inventory cost only 5,277 baht of CX class, 35,622 baht of CZ class and 16,697 of CZ class, so The normal inventory cost has a value at 1,880,799 baht while EOQ provides inventory cost at 311,054 baht, so the normal inventory cost has inventory cost more than EOQ method with 1,569,745 baht.

Form comparing inventory cost between normal method and EOQ method, it is founded that the EOQ method has less inventory cost because it provides the optimal order size that minimizes total inventory costs. The reduced inventory cost of using the EOQ model will affect to appropriate order size and inventory cost depend on the number of order meanwhile stock of EOQ model will have appropriate stock in inventory of each list, so the EOQ model is better than the normal method in this company case study because it

can present both safety stock and reorder point which can plan the inventory system to improve competitive ability and increase efficiency in controlling inventory cost.

Researchers try to create a mini program to use and apply for finding order size, safety stock and reorder point, and visual basic application in Excel is used program in this study. However, researcher has to use the time for studying program, so it makes slowly in other processes.

Form this study, researcher use time-series forecasting with is the classic and old method in forecasting, but there is an advance method in forecasting term with less error at the present, so it should take modern method in order to get a minimum error in forecasting and it will provide more accurate in EOQ model and increase more efficient in inventory control.

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Appendix A

ABC-XYZ Classification in Microsoft Excel

In the ABC-XYZ Analysis process, researcher use Microsoft Excel to calculate for classifying ABC and XYZ classes. In ABC analysis, researcher has to calculate for the cost of each product in each period (Unit Cost × Demand in each period, as shown in Figure 6.1) and sort from highest cost to lowest cost, then calculate in percentage (%) for ABC classification as shows in Figure 6.2 (A-class = 80%, B-class = 15%, and C-class = 5%). For XYZ analysis, researcher use coefficient variation of demand in each product to classify XYZ analysis as shows in Figure 6.3.

Figure 6.1 Calculate for cost of each products in each period

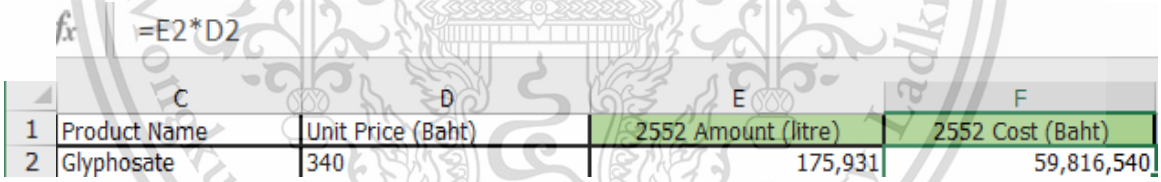


Figure 6.2 ABC classification from percentage of Total Cost

=SUM(F2,H2,J2,L2,N2,P2,R2,T2,V2,X2,Z2)

	AA	AB	AC
1	Total Cost (Baht)	% Total cost	% ABC
2	658,025,120	71.24%	
3	80,388,060	8.70%	
4	20,541,360	2.22%	85.05%
5	13,401,630	1.45%	
6	13,179,285	1.43%	
7	10,917,180	1.18%	
8	9,452,690	1.02%	
9	8,592,210	0.93%	
10	8,517,960	0.92%	
11	8,849,400	0.96%	
12	8,589,250	0.93%	
13	8,223,600	0.89%	11.39%
14	8,267,220	0.90%	
15	7,468,110	0.81%	
16	6,703,950	0.73%	
17	6,399,200	0.69%	
18	5,100,645	0.55%	
19	4,415,268	0.48%	
20	3,719,940	0.40%	
21	1,925,250	0.21%	
22	3,946,680	0.43%	
23	3,370,305	0.36%	
24	3,119,360	0.34%	
25	3,186,820	0.35%	
26	2,542,430	0.28%	
27	2,267,802	0.25%	
28	2,034,045	0.22%	
29	1,602,630	0.17%	
30	1,559,055	0.17%	3.56%
31	1,264,501	0.14%	
32	1,197,185	0.13%	
33	1,155,367	0.13%	
34	1,064,460	0.12%	
35	975,600	0.11%	
36	939,880	0.10%	
37	757,620	0.08%	

Figure 6.3 Formula for calculate Coefficient Variation (CV) for XYZ classification.

=STDEV.P(F2,H2,J2,L2,N2,P2,R2,T2,V2,X2,Z2)/AVERAGE(F2,H2,J2,L2,N2,P2,R2,T2,V2,X2,Z2)

	AA	AB	AC	AD	AE	AF
1	Total Cost (Baht)	% Total cost	% ABC	ABC Analysis	Coefficient Variation	XYZ Analysis
2	658,025,120	71.24%		A	1.91%	X
3	80,388,060	8.70%		A	21.73%	Y
4	20,541,360	2.22%	85.05%	A	5.33%	X
5	13,401,630	1.45%		A	29.98%	Y
6	13,179,285	1.43%		A	57.13%	Z
7	10,917,180	1.18%		B	13.43%	Y
8	9,452,690	1.02%		B	26.92%	Y
9	8,592,210	0.93%		B	64.33%	Z
10	8,517,960	0.92%		B	53.20%	Z
11	8,849,400	0.96%		B	4.35%	X
12	8,589,250	0.93%		B	20.69%	Y
13	8,223,600	0.89%	11.39%	B	39.28%	Y
14	8,267,220	0.90%		B	34.13%	Y
15	7,468,110	0.81%		B	14.43%	Y
16	6,703,950	0.73%		B	37.90%	Y
17	6,399,200	0.69%		B	17.87%	Y
18	5,100,645	0.55%		B	72.85%	Z
19	4,415,268	0.48%		B	44.93%	Y
20	3,719,940	0.40%		B	57.06%	Z
21	1,925,250	0.21%		C	11.60%	Y
22	3,946,680	0.43%		C	47.76%	Y
23	3,370,305	0.36%		C	66.59%	Z
24	3,119,360	0.34%		C	18.13%	Y
25	3,186,820	0.35%		C	10.42%	Y
26	2,542,430	0.28%		C	6.87%	X
27	2,267,802	0.25%		C	82.83%	Z
28	2,034,045	0.22%		C	73.77%	Z
29	1,602,630	0.17%		C	33.18%	Y
30	1,559,055	0.17%	3.56%	C	74.10%	Z
31	1,264,501	0.14%		C	70.61%	Z
32	1,197,185	0.13%		C	36.86%	Y
33	1,155,367	0.13%		C	66.86%	Z
34	1,064,460	0.12%		C	43.45%	Y
35	975,600	0.11%		C	58.71%	Z
36	939,880	0.10%		C	24.07%	Y
37	757,620	0.08%		C	17.23%	Y

Appendix B

Method and Calculation in Demand Forecasting

Forecasting Process in Glyphosate

	A	B	C	D	E	F	G	H
1			Moving average			Forecast Error (%)		
2	Year	Order per year	3 year each	4 year each	5 year each	3 year each	4 year each	5 year each
3	2552	175931						
4	2553	175651						
5	2554	178172						
6	2555	182088	=AVERAGE(B3:B5)			3.02		
7	2556	171424	178637.00	177960.50		4.21	3.81	
8	2557	176116	177228.00	176833.75	176653.20	0.63	0.41	0.31
9	2558	178940	176542.67	176950.00	176690.20	1.34	1.11	1.26
10	2559	174820	175493.33	177142.00	177348.00	0.39	1.33	1.45
11	2560	175540	176625.33	175325.00	176677.60	0.62	0.12	0.65
12	2561	169036	176433.33	176354.00	175368.00	4.38	4.33	3.75
13	2562	177650	173132.00	174584.00	174890.40	2.54	1.73	1.55
14	2563		174075.33	174261.50	175197.20			
15						2.14	1.83	1.49

In Moving Average method, we are calculated as follow:

$$MA = \frac{(D_1 + D_2 + \cdots + D_n)}{n}$$

Where:

D = data in period n

n = number of time periods

In the cell of C6 in moving average of 3 year each method, the result is computed in the code of =AVERAGE(B3:B5)

In the cell of C7 in moving average of 3 year each method, the result is computed in the code of =AVERAGE(B4:B6)

In the cell of C8 in moving average of 3 year each method, the result is computed in the code of =AVERAGE(B5:B7)

In the cell of C9 in moving average of 3 year each method, the result is computed in the code of =AVERAGE(B6:B8)

In the cell of C10 in moving average of 3 year each method, the result is computed in the code of =AVERAGE(B7:B9)

In the cell of C11 in moving average of 3 year each method, the result is computed in the code of =AVERAGE(B8:B10)

In the cell of C12 in moving average of 3 year each method, the result is computed in the code of =AVERAGE(B9:B11)

In the cell of C13 in moving average of 3 year each method, the result is computed in the code of =AVERAGE(B10:B12)

In the cell of C14 in moving average of 3 year each method, the result is computed in the code of =AVERAGE(B11:B13)

In moving average of 4 year each, the result is computed in the code of =AVERAGE(B3:B6) in cell of D7, and use this format of formula until cell D14 while In moving average of 5 year each, the result is computed in the code of =AVERAGE(B3:B7) in cell of E8, and use this format of formula until cell E14

In moving average method, we are calculated as follow:

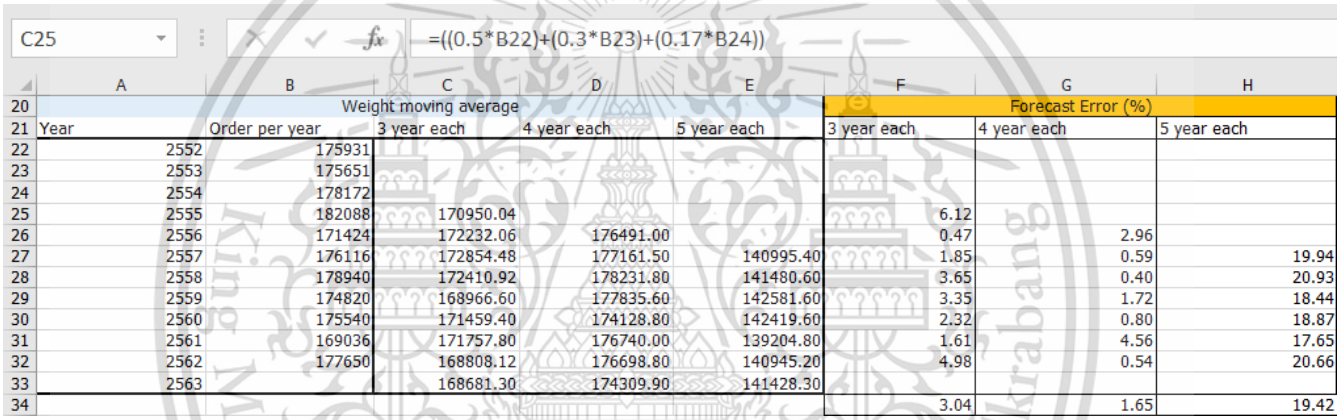
In weight moving average method, we are calculated as follow:

$$WMA = W_1D_1 + W_2D_2 + \cdots + W_nD_n$$

Where:

W = the weight for period n, between 0 and 1.0

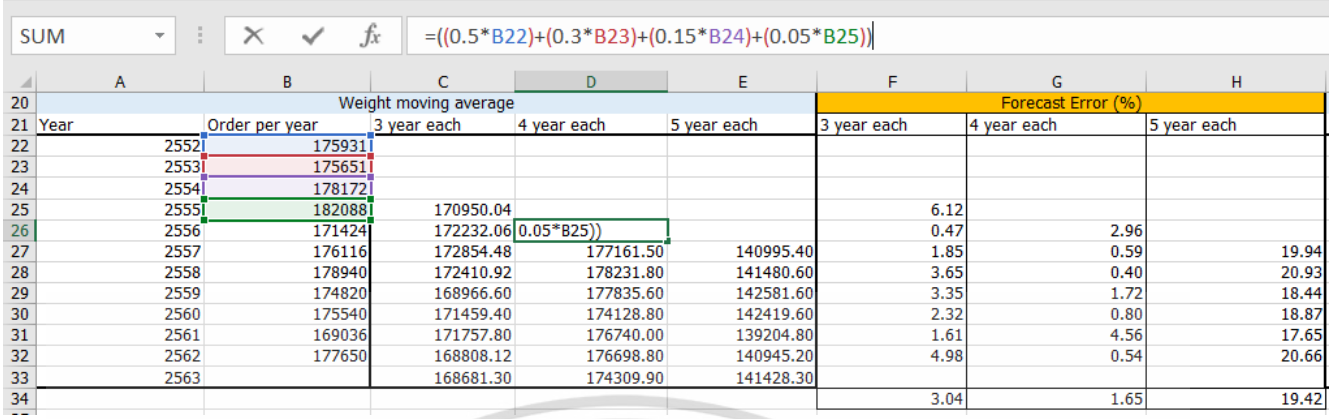
D = data in period n



C25 =((0.5*B22)+(0.3*B23)+(0.17*B24))

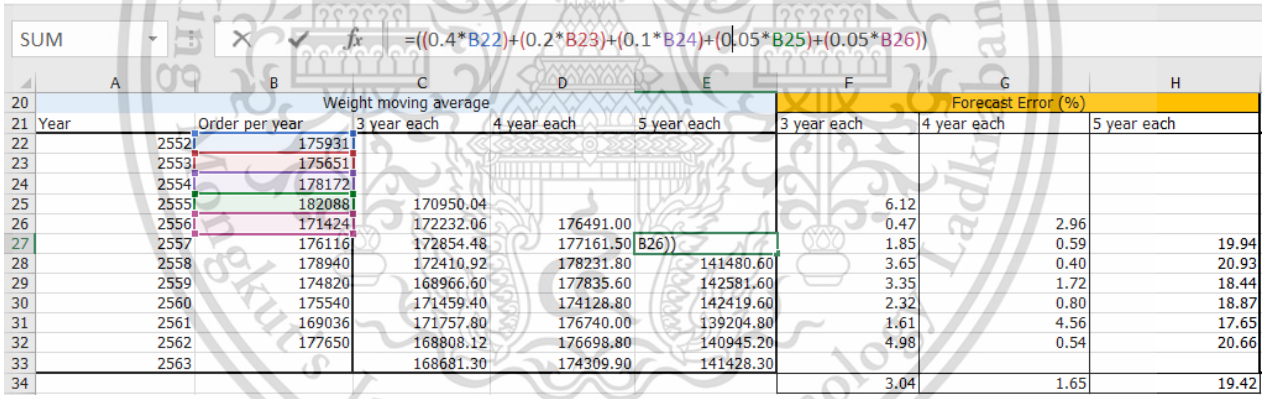
	A	B	C	D	E	F	G	H
20			Weight moving average			Forecast Error (%)		
21	Year	Order per year	3 year each	4 year each	5 year each	3 year each	4 year each	5 year each
22	2552	175931						
23	2553	175651						
24	2554	178172						
25	2555	182088	170950.04			6.12		
26	2556	171424	172232.06	176491.00		0.47	2.96	
27	2557	176116	172854.48	177161.50	140995.40	1.85	0.59	19.94
28	2558	178940	172410.92	178231.80	141480.60	3.65	0.40	20.93
29	2559	174820	168966.60	177835.60	142581.60	3.35	1.72	18.44
30	2560	175540	171459.40	174128.80	142419.60	2.32	0.80	18.87
31	2561	169036	171757.80	176740.00	139204.80	1.61	4.56	17.65
32	2562	177650	168808.12	176698.80	140945.20	4.98	0.54	20.66
33	2563		168681.30	174309.90	141428.30			
34						3.04	1.65	19.42

For 3 year each of weight moving average, C25 is starting cell which is computed in code of = ((0.5*B22)+(0.3*B23)+(0.2*B24)) until C33 with code of =((0.5*B30)+(0.3*B31)+(0.2*B32))



	A	B	C	D	E	F	G	H
20	Weight moving average					Forecast Error (%)		
21	Year	Order per year	3 year each	4 year each	5 year each	3 year each	4 year each	5 year each
22	2552	175931						
23	2553	175651						
24	2554	178172						
25	2555	182088	170950.04			6.12		
26	2556	171424	172232.06	0.05*B25))		0.47	2.96	
27	2557	176116	172854.48	177161.50	140995.40	1.85	0.59	19.94
28	2558	178940	172410.92	178231.80	141480.60	3.65	0.40	20.93
29	2559	174820	168966.60	177835.60	142581.60	3.35	1.72	18.44
30	2560	175540	171459.40	174128.80	142419.60	2.32	0.80	18.87
31	2561	169036	171757.80	176740.00	139204.80	1.61	4.56	17.65
32	2562	177650	168808.12	176698.80	140945.20	4.98	0.54	20.66
33	2563		168681.30	174309.90	141428.30			
34						3.04	1.65	19.42

For 4 year each of weight moving average, D26 is starting cell which is computed in code of =((0.5*B22)+(0.3*B23)+(0.15*B24)+(0.05*B25)) until D33 with code of =((0.5*B29)+(0.3*B30)+(0.15*B31)+(0.05*B32))



	A	B	C	D	E	F	G	H
20	Weight moving average					Forecast Error (%)		
21	Year	Order per year	3 year each	4 year each	5 year each	3 year each	4 year each	5 year each
22	2552	175931						
23	2553	175651						
24	2554	178172						
25	2555	182088	170950.04			6.12		
26	2556	171424	172232.06	176491.00		0.47	2.96	
27	2557	176116	172854.48	177161.50	B26))	1.85	0.59	19.94
28	2558	178940	172410.92	178231.80	141480.60	3.65	0.40	20.93
29	2559	174820	168966.60	177835.60	142581.60	3.35	1.72	18.44
30	2560	175540	171459.40	174128.80	142419.60	2.32	0.80	18.87
31	2561	169036	171757.80	176740.00	139204.80	1.61	4.56	17.65
32	2562	177650	168808.12	176698.80	140945.20	4.98	0.54	20.66
33	2563		168681.30	174309.90	141428.30			
34						3.04	1.65	19.42

For 5 year each of weight moving average, E27 is starting cell which is computed in code of =((0.6*B22)+(0.2*B23)+(0.1*B24)+(0.05*B25)+(0.05*B26)))) until E33 with code of =((0.6*B28)+(0.2*B29)+(0.1*B30)+(0.05*B31)+(0.05*B32))

In Exponential Smoothing method, we are calculated as follow:

$$F_{t+1} = \alpha \times D_t(1-\alpha)F_t$$

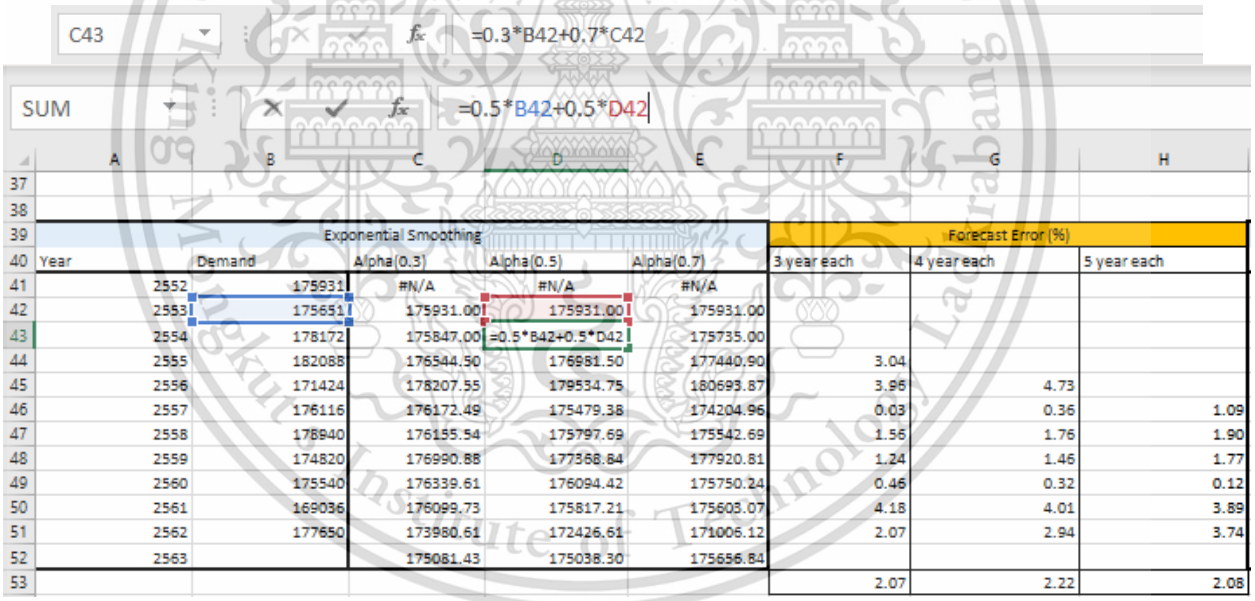
Where:

F_{t+1} =The forecast for the next period

D_t = Actual demand in the present period

F_t = The previously determined forecast for the present period

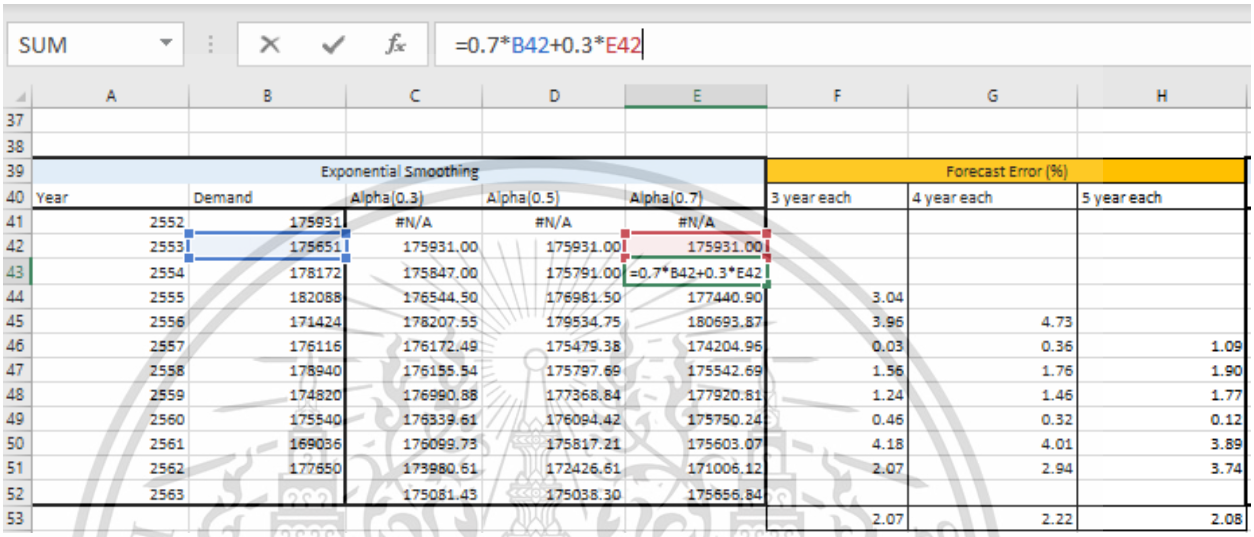
α = A weighting factor referred to as the smoothing constant



	A	B	C	D	E	F	G	H
37								
38								
39			Exponential Smoothing			Forecast Error (%)		
40	Year	Demand	Alpha(0.3)	Alpha(0.5)	Alpha(0.7)	3 year each	4 year each	5 year each
41	2552	175931	#N/A	#N/A	#N/A			
42	2553	175651	175931.00	175931.00	175931.00			
43	2554	178172	175847.00	=0.5*B42+0.5*D42	175735.00			
44	2555	182088	176544.50	176981.50	177440.90	3.04		
45	2556	171424	178207.55	179534.75	180693.87	3.96	4.73	
46	2557	176116	176172.49	175479.38	174204.96	0.03	0.36	1.09
47	2558	178940	176155.54	175797.69	175542.69	1.56	1.76	1.90
48	2559	174820	176990.88	177368.84	177920.81	1.24	1.46	1.77
49	2560	175540	176339.61	176094.42	175750.24	0.46	0.32	0.12
50	2561	169036	176099.73	175817.21	175603.07	4.18	4.01	3.89
51	2562	177650	173980.61	172426.61	171006.12	2.07	2.94	3.74
52	2563		175081.43	175038.30	175656.84			
53						2.07	2.22	2.08

For 0.3 alpha of exponential smoothing, C41 is starting point of this forecasting, but the computation of this method starts at C43 in the code of = (0.3*B42)+(0.7*C42) until C52 with code of = (0.3*B51)+(0.7*C51)

For 0.5 alpha of exponential smoothing, D41 is starting point of this forecasting, but the computation of this method starts at D43 in the code of = (0.5*B42)+(0.5*D42) until D52 with code of = (0.5*B51)+(0.5*D51)



	A	B	C	D	E	F	G	H
37								
38								
39	Exponential Smoothing					Forecast Error (%)		
40	Year	Demand	Alpha(0.3)	Alpha(0.5)	Alpha(0.7)	3 year each	4 year each	5 year each
41	2552	175931	#N/A	#N/A	#N/A			
42	2553	175651	175931.00	175931.00	175931.00			
43	2554	178172	175847.00	175791.00	=0.7*B42+0.3*E42			
44	2555	182088	176544.50	176981.50	177440.90	3.04		
45	2556	171424	178207.55	179534.75	180693.87	3.96	4.73	
46	2557	176116	176172.49	175479.38	174204.96	0.03	0.36	1.09
47	2558	178940	176155.54	175797.69	175542.69	1.56	1.76	1.90
48	2559	174820	176990.88	177368.84	177920.81	1.24	1.46	1.77
49	2560	175540	176339.61	176094.42	175750.24	0.46	0.32	0.12
50	2561	169036	176099.73	175817.21	175603.07	4.18	4.01	3.89
51	2562	177650	173980.61	172426.61	171006.12	2.07	2.94	3.74
52	2563		175081.43	175038.30	175856.84			
53						2.07	2.22	2.08

For 0.7 alpha of exponential smoothing, E41 is starting point of this forecasting, but the computation of this method starts at E43 in the code of =0.7*B42+0.3*E42until D52 with code of =0.7*B51+0.3*E51

In Adjust Exponential Smoothing method, we are calculated as follow:

$$AF_{t+1} = F_{t+1} + T_{t+1}$$

Where:

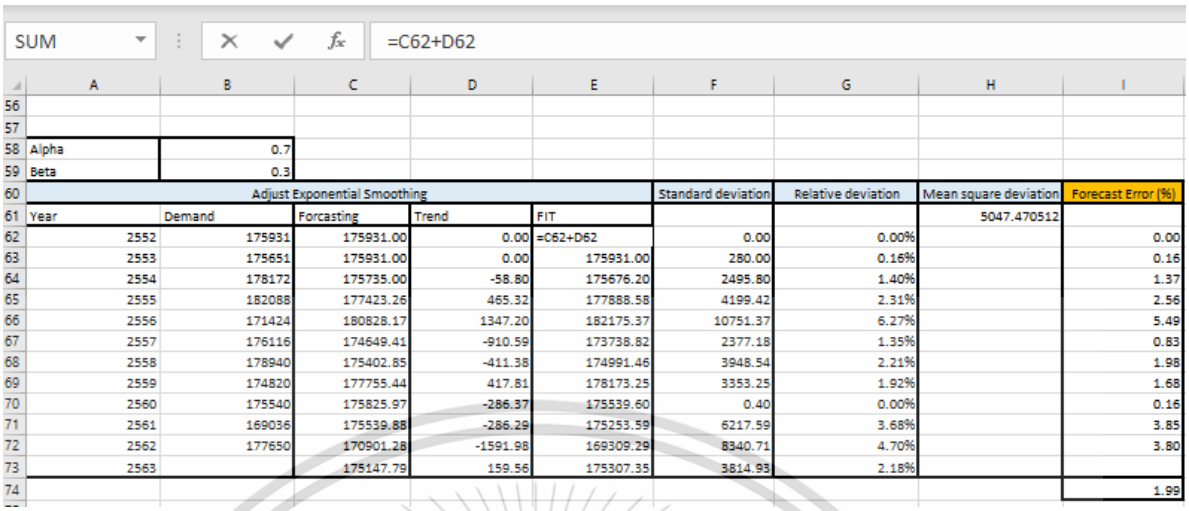
T = An exponentially smoothed trend factor

And $T_{t+1} = \beta(F_{t+1} - F_t) + (1 - \beta)T_t$

Where:

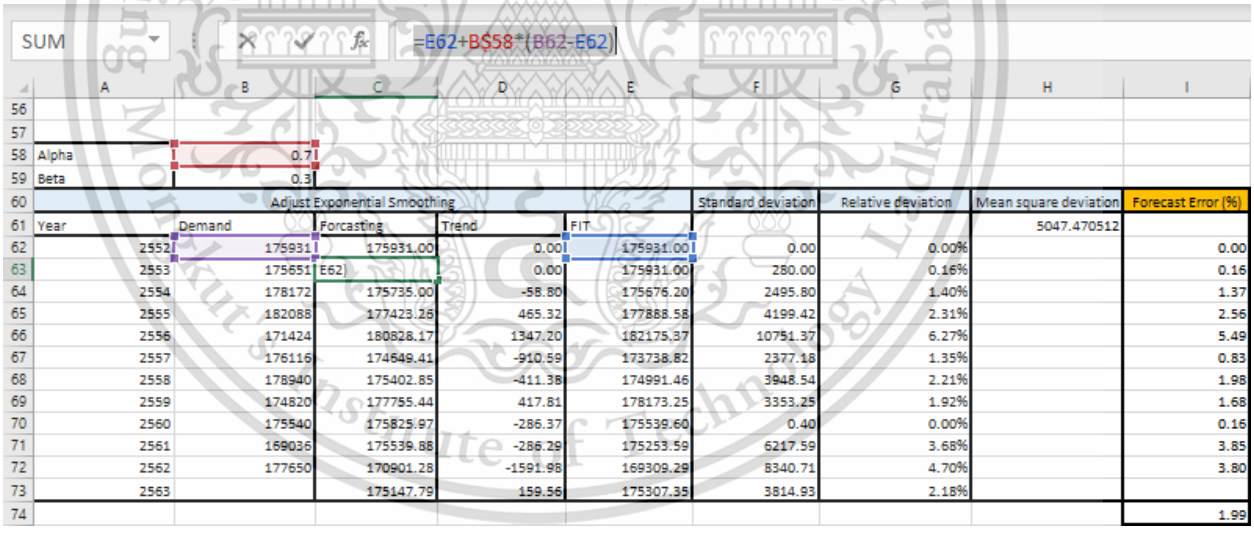
T_t = The last period trend factor

β = A smoothing constant for trend



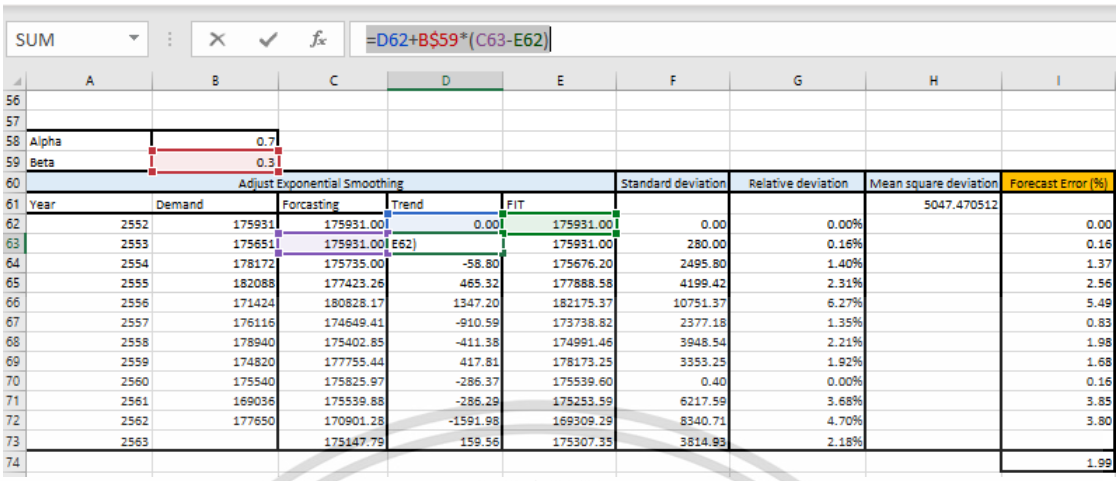
	A	B	C	D	E	F	G	H	I
56									
57									
58	Alpha	0.7							
59	Beta	0.3							
60	Adjust Exponential Smoothing					Standard deviation	Relative deviation	Mean square deviation	Forecast Error (%)
61	Year	Demand	Forcasting	Trend	FIT			5047.470512	
62	2552	175931	175931.00	0.00	=C62+D62	0.00	0.00%		0.00
63	2553	175651	175931.00	0.00	175931.00	280.00	0.16%		0.16
64	2554	178172	175735.00	-58.80	175676.20	2495.80	1.40%		1.37
65	2555	182088	177423.26	465.32	177888.58	4199.42	2.31%		2.56
66	2556	171424	180828.17	1347.20	182175.37	10751.37	6.27%		5.49
67	2557	176116	174649.41	-910.59	173738.82	2377.18	1.35%		0.83
68	2558	178940	175402.85	-411.38	174991.46	3948.54	2.21%		1.98
69	2559	174820	177755.44	417.81	178173.25	3353.25	1.92%		1.68
70	2560	175540	175825.97	-286.37	175539.60	0.40	0.00%		0.16
71	2561	169036	175539.88	-286.29	175253.59	6217.59	3.68%		3.85
72	2562	177650	170901.28	-1591.98	169309.29	8340.71	4.70%		3.80
73	2563		175147.79	159.56	175307.35	3814.93	2.18%		
74									1.99

At the first period in adjust exponential smoothing, adjust exponential smoothing forecasting starts at E62 with code of =C62+D62. After that, forecasting value of next period in C63 is 175,931 with code of =E62+B$58*(B62-E62)



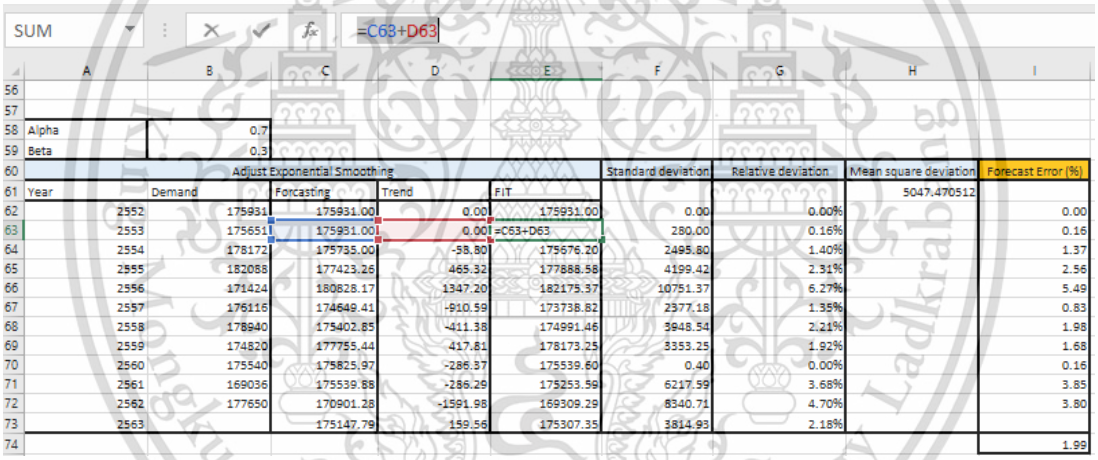
	A	B	C	D	E	F	G	H	I
56									
57									
58	Alpha	0.7							
59	Beta	0.3							
60	Adjust Exponential Smoothing					Standard deviation	Relative deviation	Mean square deviation	Forecast Error (%)
61	Year	Demand	Forcasting	Trend	FIT			5047.470512	
62	2552	175931	175931.00	0.00	175931.00	0.00	0.00%		0.00
63	2553	175651	E62)	0.00	175931.00	280.00	0.16%		0.16
64	2554	178172	175735.00	-58.80	175676.20	2495.80	1.40%		1.37
65	2555	182088	177423.26	465.32	177888.58	4199.42	2.31%		2.56
66	2556	171424	180828.17	1347.20	182175.37	10751.37	6.27%		5.49
67	2557	176116	174649.41	-910.59	173738.82	2377.18	1.35%		0.83
68	2558	178940	175402.85	-411.38	174991.46	3948.54	2.21%		1.98
69	2559	174820	177755.44	417.81	178173.25	3353.25	1.92%		1.68
70	2560	175540	175825.97	-286.37	175539.60	0.40	0.00%		0.16
71	2561	169036	175539.88	-286.29	175253.59	6217.59	3.68%		3.85
72	2562	177650	170901.28	-1591.98	169309.29	8340.71	4.70%		3.80
73	2563		175147.79	159.56	175307.35	3814.93	2.18%		
74									1.99

Then, Trend in this period is 0 with code of =D62+B$59*(C63-E62)



	A	B	C	D	E	F	G	H	I
56									
57									
58	Alpha	0.7							
59	Beta	0.3							
60	Adjust Exponential Smoothing					Standard deviation	Relative deviation	Mean square deviation	Forecast Error (%)
61	Year	Demand	Forcasting	Trend	FIT			5047.470512	
62	2552	175931	175931.00	0.00	175931.00	0.00	0.00%		0.00
63	2553	175651	175931.00	E62)	175931.00	280.00	0.16%		0.16
64	2554	178172	175735.00	-58.80	175676.20	2495.80	1.40%		1.37
65	2555	182088	177423.26	465.32	177888.58	4199.42	2.31%		2.56
66	2556	171424	180828.17	1347.20	182175.37	10751.37	6.27%		5.49
67	2557	176116	174649.41	-910.59	173738.82	2377.18	1.35%		0.83
68	2558	178940	175402.85	-411.38	174991.46	3948.54	2.21%		1.98
69	2559	174820	177755.44	417.81	178173.25	3353.25	1.92%		1.68
70	2560	175540	175825.97	-286.37	175539.60	0.40	0.00%		0.16
71	2561	169036	175539.88	-286.29	175253.59	6217.59	3.68%		3.85
72	2562	177650	170901.28	-1591.98	169309.29	8340.71	4.70%		3.80
73	2563		175147.79	159.56	175307.35	3814.93	2.18%		
74									1.99

Finally, adjust exponential smoothing forecasting value in this period is computed with the same pattern of first period which is =C63+D63 and do the same pattern until E73



	A	B	C	D	E	F	G	H	I
56									
57									
58	Alpha	0.7							
59	Beta	0.3							
60	Adjust Exponential Smoothing					Standard deviation	Relative deviation	Mean square deviation	Forecast Error (%)
61	Year	Demand	Forcasting	Trend	FIT			5047.470512	
62	2552	175931	175931.00	0.00	175931.00	0.00	0.00%		0.00
63	2553	175651	175931.00	0.00	=C63+D63	280.00	0.16%		0.16
64	2554	178172	175735.00	-58.80	175676.20	2495.80	1.40%		1.37
65	2555	182088	177423.26	465.32	177888.58	4199.42	2.31%		2.56
66	2556	171424	180828.17	1347.20	182175.37	10751.37	6.27%		5.49
67	2557	176116	174649.41	-910.59	173738.82	2377.18	1.35%		0.83
68	2558	178940	175402.85	-411.38	174991.46	3948.54	2.21%		1.98
69	2559	174820	177755.44	417.81	178173.25	3353.25	1.92%		1.68
70	2560	175540	175825.97	-286.37	175539.60	0.40	0.00%		0.16
71	2561	169036	175539.88	-286.29	175253.59	6217.59	3.68%		3.85
72	2562	177650	170901.28	-1591.98	169309.29	8340.71	4.70%		3.80
73	2563		175147.79	159.56	175307.35	3814.93	2.18%		
74									1.99

In linear trend line method, we are calculated as follow:

Linear trend line is computed as follow:

$y = a + bx$

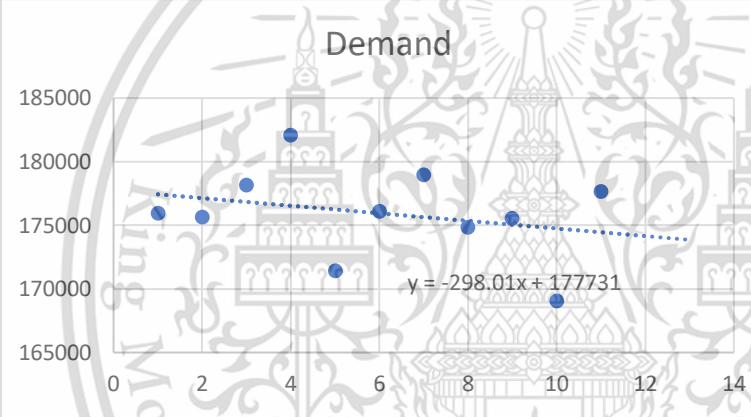
Where:

a = Intercept (at period 0) x = Time period

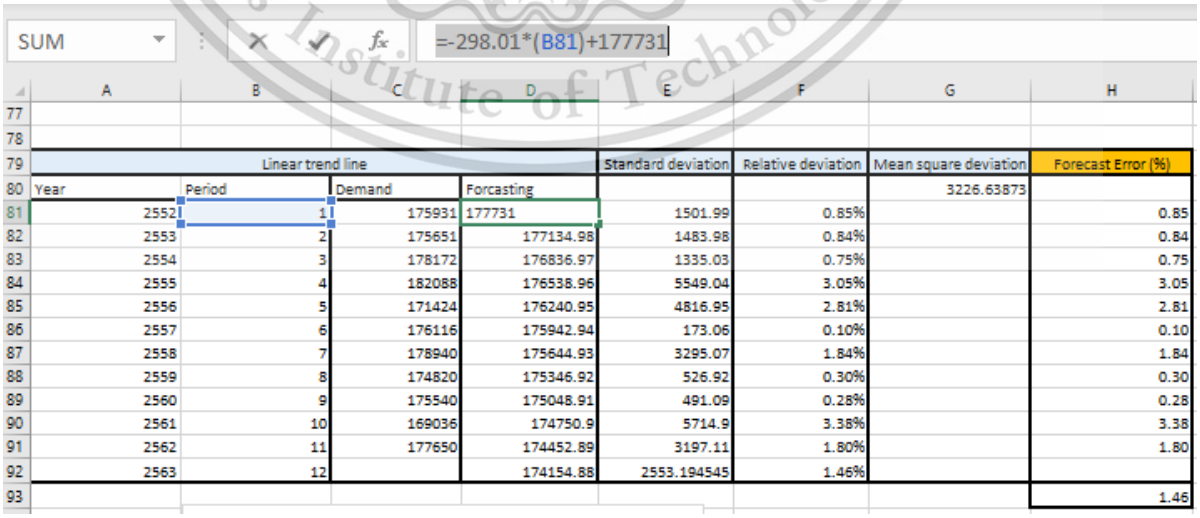
b = Slope of the line y = Forecast for demand for period x

	A	B	C	D	E	F	G	H
77								
78								
79	Linear trend line				Standard deviation	Relative deviation	Mean square deviation	Forecast Error (%)
80	Year	Period	Demand	Forcasting			3226.63873	
81	2552	1	175931	177432.99	1501.99	0.85%		0.85
82	2553	2	175651	177134.98	1483.98	0.84%		0.84
83	2554	3	178172	176836.97	1335.03	0.75%		0.75
84	2555	4	182088	176538.96	5549.04	3.05%		3.05
85	2556	5	171424	176240.95	4816.95	2.81%		2.81
86	2557	6	176116	175942.94	173.06	0.10%		0.10
87	2558	7	178940	175644.93	3295.07	1.84%		1.84
88	2559	8	174820	175346.92	526.92	0.30%		0.30
89	2560	9	175540	175048.91	491.09	0.28%		0.28
90	2561	10	169036	174750.9	5714.9	3.38%		3.38
91	2562	11	177650	174452.89	3197.11	1.80%		1.80
92	2563	12		174154.88	2553.194545	1.46%		
93								1.46

This raw data can generate the formula of y = -298.01x + 177731 in linear trend line



Then, forecasting value can be computed with the formula of this method. For example, D81 is forecasting value in the first period with code of = -298.01*(B81)+177731

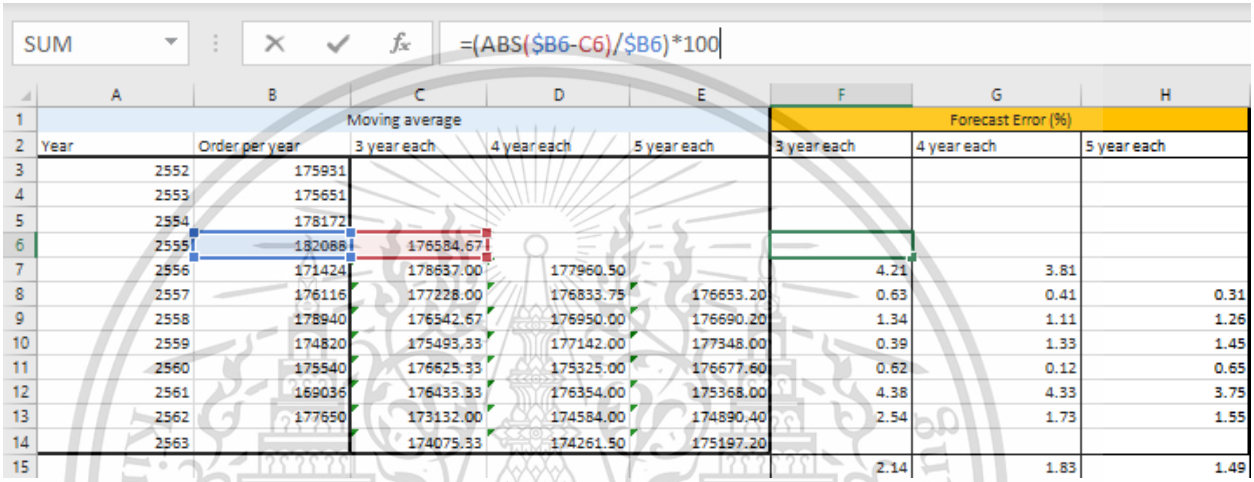


	A	B	C	D	E	F	G	H
77								
78								
79	Linear trend line				Standard deviation	Relative deviation	Mean square deviation	Forecast Error (%)
80	Year	Period	Demand	Forcasting			3226.63873	
81	2552	1	175931	177731	1501.99	0.85%		0.85
82	2553	2	175651	177134.98	1483.98	0.84%		0.84
83	2554	3	178172	176836.97	1335.03	0.75%		0.75
84	2555	4	182088	176538.96	5549.04	3.05%		3.05
85	2556	5	171424	176240.95	4816.95	2.81%		2.81
86	2557	6	176116	175942.94	173.06	0.10%		0.10
87	2558	7	178940	175644.93	3295.07	1.84%		1.84
88	2559	8	174820	175346.92	526.92	0.30%		0.30
89	2560	9	175540	175048.91	491.09	0.28%		0.28
90	2561	10	169036	174750.9	5714.9	3.38%		3.38
91	2562	11	177650	174452.89	3197.11	1.80%		1.80
92	2563	12		174154.88	2553.194545	1.46%		
93								1.46

Forecasting Accuracy

In term of forecasting error, we computed as follow:

$$\left(\frac{|Actual\ Value - Forecast\ Value|}{Actual\ Value}\right) \times 100\%$$



	A	B	C	D	E	F	G	H
1			Moving average			Forecast Error (%)		
2	Year	Order per year	3 year each	4 year each	5 year each	3 year each	4 year each	5 year each
3	2552	175931						
4	2553	175651						
5	2554	178172						
6	2555	182088	176584.67					
7	2556	171424	178637.00	177960.50		4.21	3.81	
8	2557	176116	177228.00	176833.75	176653.20	0.63	0.41	0.31
9	2558	178940	176542.67	176950.00	176690.20	1.34	1.11	1.26
10	2559	174820	175493.33	177142.00	177348.00	0.39	1.33	1.45
11	2560	175540	176625.33	175325.00	176677.60	0.62	0.12	0.65
12	2561	169036	176433.33	176354.00	175368.00	4.38	4.33	3.75
13	2562	177650	173132.00	174584.00	174890.40	2.54	1.73	1.55
14	2563		174075.33	174261.50	175197.20			
15						2.14	1.83	1.49

Cell of F6 is forecasting error of 3 year each and is computed in code of =ABS($B6-C6)/$B6)*100 util F13 with the code of =(ABS($B13-C13)/$B13)*100, so it means code change order of number follow the cell which we want to compute while forecasting error of 4 year each start with cell of G7 in code of =(ABS($B7-D7)/$B7)*100 until cell of G13, and forecasting error of 5 year each start with cell of H8 in code of =(ABS($B8-E8)/$B8)*100 until cell of H13.

The last row of each forecast error is average error value which is computed as =AVERAGE(F6:F13), =AVERAGE(G7:G13) and =AVERAGE(H8:H13) in 3, 4, and 5 year each respectively.

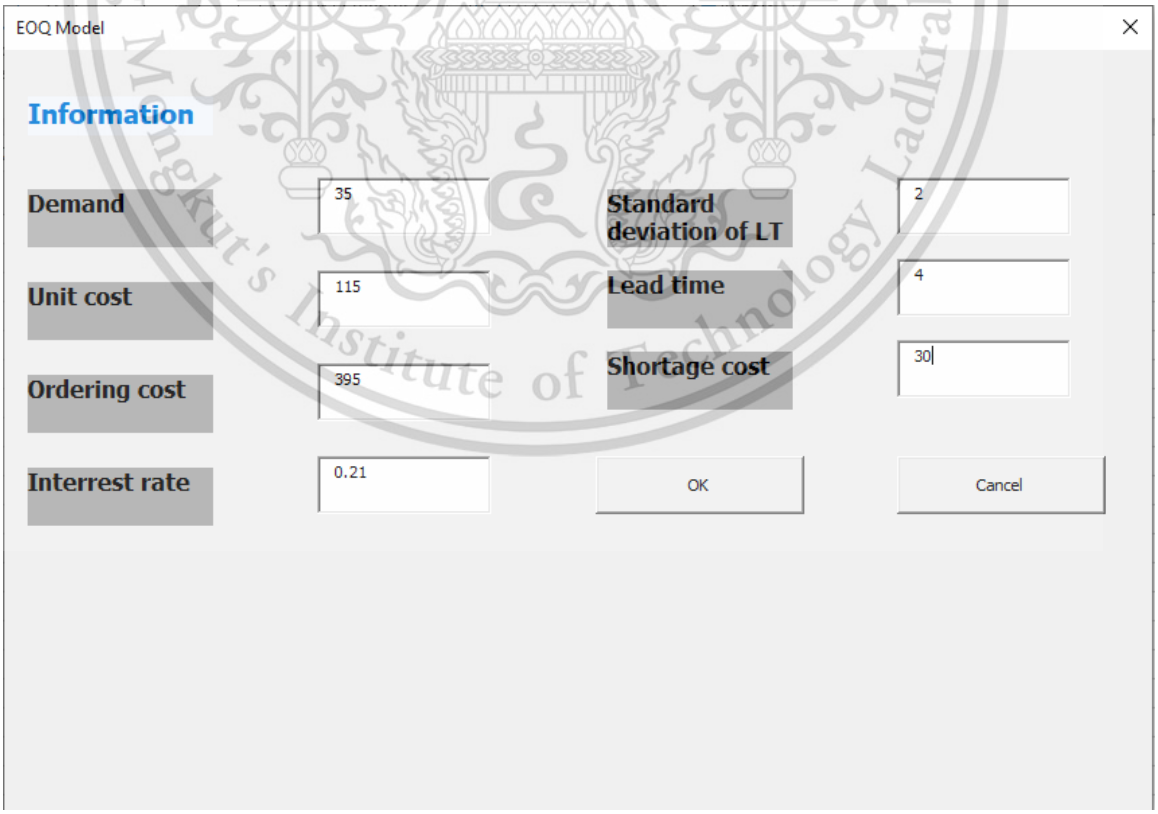
Average forecasting value of all method in 5 production

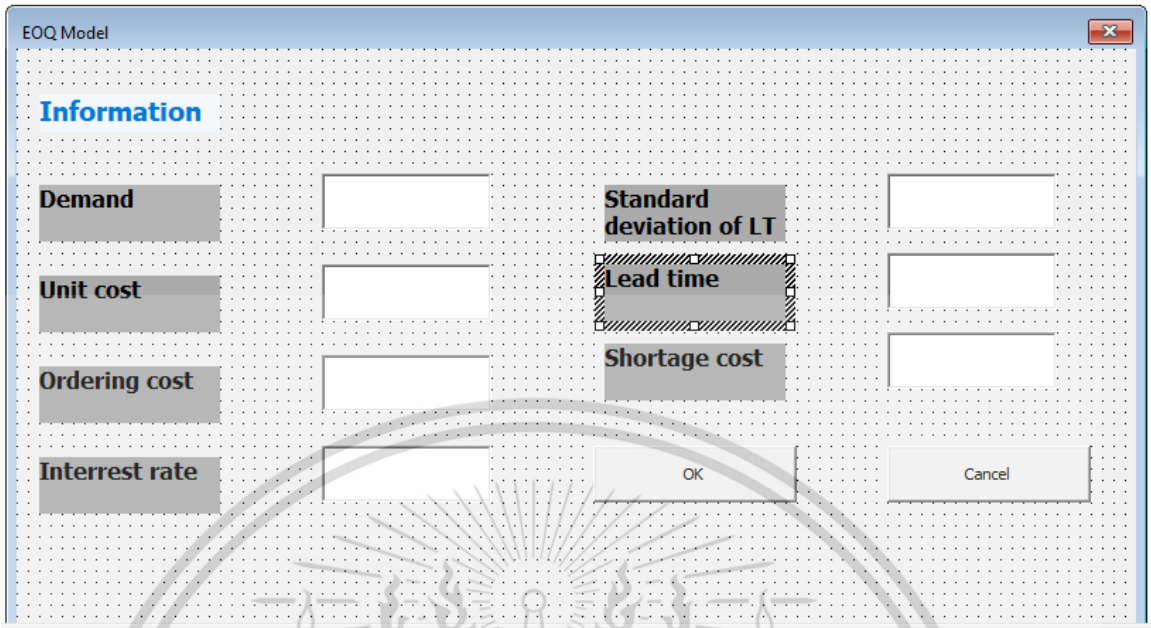
Method	Average forecating error
Moving average	14.286
Weight moving average	18.868
Exponential Smoothing	21.44
Adjust exponential Smoothing	16.76
Linear trend line	14.208

In average of forecasting error, we focus on 3 year each for moving average, weight moving average and exponential smoothing, so linear trend line method has the lowest average forecasting error with 14.208 of all method in 5 production.

EOQ Model with Excel VBA

User forms in Excel VBA





Excel VBA Code for EOQ Model

This is all code in user form for using in EOQ process

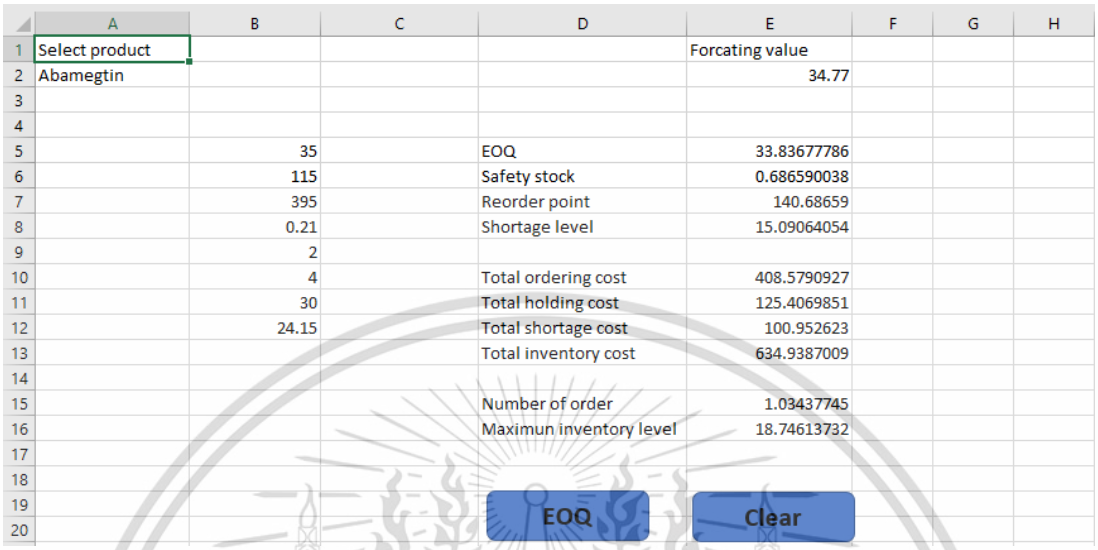
```
Private Sub CommandButton1_Click()

Cells(5, 2).Value = TextBox1.Value

Cells(6, 2).Value = TextBox2.Value

Cells(7, 2).Value = TextBox3.Value

Cells(8, 2).Value = TextBox4.Value

Cells(9, 2).Value = TextBox5.Value

Cells(10, 2).Value = TextBox6.Value

Cells(11, 2).Value = TextBox7.Value

End Sub
```

```
Private Sub CommandButton2_Click()

Unload Me

End

End Sub


Private Sub Label5_Click()

End Sub

Private Sub Label8_Click()

End Sub


Private Sub TextBox1_Change()

If Not IsNumeric(TextBox1.Value) Then

        MsgBox "Only numbers allowed"

      End If

End Sub
```

```
Private Sub TextBox2_Change()
If Not IsNumeric(TextBox2.Value) Then
            MsgBox "Only numbers allowed"
          End If
End Sub

Private Sub TextBox3_Change()
If Not IsNumeric(TextBox3.Value) Then
            MsgBox "Only numbers allowed"
          End If
End Sub

Private Sub TextBox4_Change()
If Not IsNumeric(TextBox4.Value) Then
            MsgBox "Only numbers allowed"
          End If
End Sub
```

```
Private Sub TextBox5_Change()
If Not IsNumeric(TextBox5.Value) Then
            MsgBox "Only numbers allowed"
          End If
End Sub

Private Sub TextBox6_Change()
If Not IsNumeric(TextBox6.Value) Then
            MsgBox "Only numbers allowed"
          End If
End Sub

Private Sub TextBox7_Change()
If Not IsNumeric(TextBox7.Value) Then
            MsgBox "Only numbers allowed"
          End If
End Sub
```

Compute EOQ Process



In A2 cell, we can select product and forecasting value will be in E2 cell with code of =SORT(FILTER(A2:A37,ISNUMBER(SEARCH(EOQ!A2,A2:A37)),"not found")) from raw data sheet

Cell	Formula	Equation
B5	From user form	Demand value
B6	From user form	Unit cost
B7	From user form	Ordering cost
B8	From user form	Interest rate
B9	From user form	SD of LT
B10	From user form	LT
B11	From user form	Shortage cost
B12	=B6*B8	Holding cost
E5	=SQRT((2*B7*B5)/B12)	EOQ
E6	=B37*(B9*SQRT(B10))*(B5/261)	Safety stock
E7	=(B5*B10) +E6	Reorder point
E8	=E5*(B12/(B12+B11))	Shortage level
E10	=B7*B5/E5	Total ordering cost
E11	=B12*((E5-E8)^2)/(2*E5)	Total holding cost
E12	=B11*(E8^2)/(2*E5)	Total shortage cost
E13	=E10+E11+E12	Total inventory cost
E15	=B5/E5	Number of orders
E16	=E5-E8	Maximum inventory level