INVENTORY PLANNING AND CONTROL: A CASE OF ACCESSORY PARTS OF AN AUTOMAKER

By
CHAD KLYTHOM

A Final Report of the Six-Credit Course
SCM 2202 Graduate Project

Submitted in Partial Fulfillment of the Requirements for the Degree of
MASTER OF SCIENCE IN SUPPLY CHAIN MANAGEMENT

Martin de Tours School of Management and Economics
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Declaration of Authorship Form

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declare that this thesis/project and the work presented in it are my own and has been generated by me as the result of my own original research.

Inventory Planning and Control: A Case of Accessory Parts of an Automaker

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I confirm that this thesis/project has been carried out under my supervision and it represents the original work of the candidate.

Signed ____________________

(Dr. Vatcharapol Sukhotu)

Date c1 Dec 2011

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Chad Klythom
Assumption University
November 2011

ABSTRACT

Inventory is the one important asset that supports the activity of business including internal and external activities. The internal activities can be identified as the production lines, availability of raw materials, usage of office equipment and stationary, etc. Meanwhile, inventory also supports the external activities such as selling, marketing campaign, distribution network, retailing, etc. The most important factor about inventory is it can be the indicator of management ability since management can carry suitable inventory or too much inventory. This indicator also affects the financial situation of the business as well.

This study focuses on the method of applying forecasting method to the demand of accessory parts of an automotive manufacturing company. This study also applies Economic Order Quantity (EOQ) technique and the determination of safety inventory and reorder point as a tools of supply planning and inventory control.

This study attempts to contribute to a better understanding of inventory planning against the uncertain demand in order to have sufficient level of products and not lose the selling opportunity although businesses have to encounter demand fluctuation. The decision making of inventory levels can be obtained according to the current industry situation by comparing and trade off of inventory cost between shortage cost and carrying cost. The business can then identify the importance of supply planning and how much the new system can deliver for the improvement of inventory management.

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and she hereby certifies that the verbiage, spelling and format is commensurate with the quality of internationally acceptable writing standards for a Master Degree in Supply Chain Management.

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CHAPTER I

GENERALITIES OF THE STUDY

The consumers in today's marketplace are empowered by the information technology from the internet and from many other sources. They not only have an opportunity to compare prices and quality but also customized products and services. As the market expands and competition increases, the business must pay more attention beginning at the place where materials come from until the finished products are transported and stored.

Supply Chain Management is considered as playing an important role in today's competition. It helps businesses to design, plan, operate and make a decision relating to the flow of products and information from the source of raw materials to the consumption points. Coyle, Bardi, and Langley (2003) suggest that inventory is one of the four important elements of supply chain driver besides transportation, facilities location and information. Inventory policy is able to indicate the supply chain's efficiency and responsiveness. Water (1992) explains that inventory is the important part in the supply chain which helps the business to provide a buffer between variables and uncertain supply and demand.

1.1 Background of the Company

This is a case study of an automotive manufacturing which hereafter will be called "TM Company". This research focuses on the business unit of accessory parts as aero parts, alloy wheel, car audio, air conditioning, bumpers, spoilers, skirts, side step covers for primer and color types, etc. and service parts as engine oil, air filters, etc. These parts are normally manufactured and delivered from the suppliers in Thailand to the distribution centers and then to the production line of TM Company. The following area is devoted to introducing all members in this loop of supply chain which consists of suppliers, distribution centers, production lines and dealers.

1.1.1 The Suppliers

There are many suppliers who are qualified by TM Company to supply the accessory and service parts to its distribution centers and production lines. All suppliers are located nearby the distribution centers and production lines of the TM Company. The suppliers normally transport the accessories and service parts to the distribution centers and production lines of TM Company directly and separately.

1.1.2 The Distribution Centers

TM Company sets up its distribution centers of accessory parts in 2 locations. There are facilities in Thailand and another one in Singapore. The main role of the distribution centers is to supply and distribute the accessory and service parts to the dealers in Thailand the other 9 countries in the Asia Pacific Region. The mentioned distribution centers include:

DC#1: This distribution center is based in Thailand. They supply the product in 2 categories 1) service parts: oil filters, motor oil, etc and 2) accessory parts: bumpers, spoilers, etc to the dealers in Thailand. These accessory and service parts are installed outside the production line which is called offline installation.

DC#2: This distribution center is located in Singapore. They are assigned to supply and distribute the accessory parts to the dealers of 9 countries in the Asia Pacific region. All parts will be also installed in a car as offline installation.

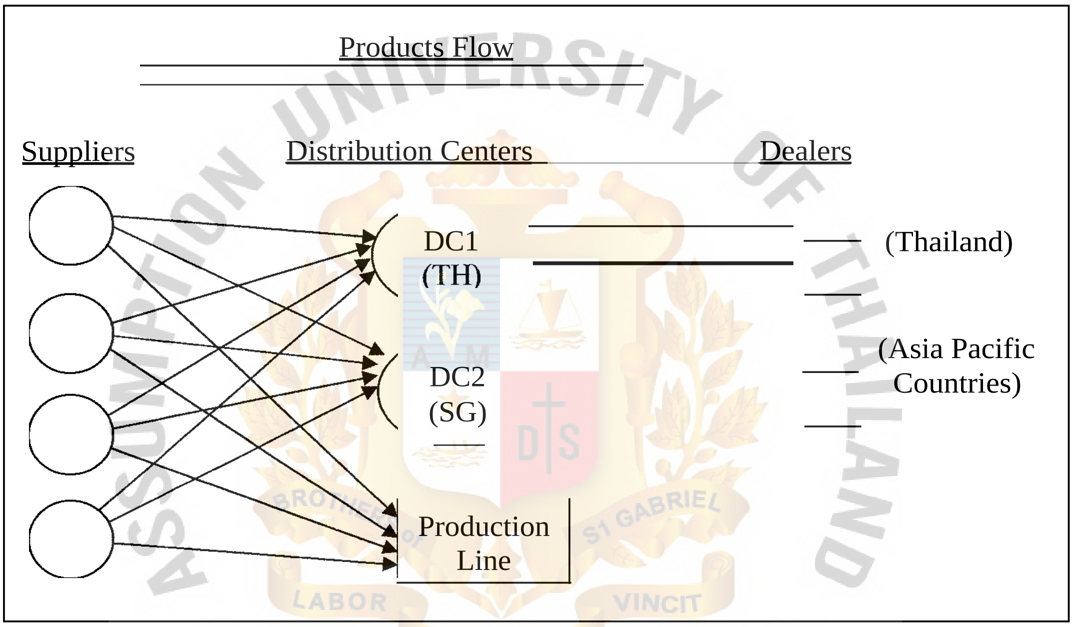
1.1.3 The Production Line

This is the place where a car is assembled and completed. Production of a car normally needs many parts for an assembly process including engine parts, body parts, tires, etc. The accessory parts which are focused on this research are also the one of major products in the production line. The installation of accessory parts in the production line can be called as inline installation. A car is completed here as a standard type and is ready to deliver to the dealers.

1.1.4 The Dealers

The dealers are appointed as retailers of the TM Company. There are many dealers that are authorized by TM Company located in Thailand and countries in Asia Pacific region. Accessory parts are installed at the dealers' shop as offline installation. Figure 1.2 illustrates the flow of material of accessories and service parts of this supply chain.

Figure 1.1: Flow of Accessory and Service Parts



1.2 Statement of the Problem

The current competition in the automotive industry encourages automakers to often apply their marketing strategy by changing major or minor designs for each car model in a specific period. Accessory items are the important parts that are often re-designed to respond with this marketing strategy. The automakers usually apply this marketing strategy to boost the sales volume to compete against the competitors when their product life cycle reaches the decline period.

There are 4 main problems in the supply chain area of accessory parts that the TM Company encounters which are:

1.2.1 Limited Capacity of the Suppliers

Nowadays, the accessory parts business unit of TM Company has been sharply growing with unexpected demand not only from the dealers in Thailand but also from the countries in the Asia Pacific Region. The suppliers are not willing to invest much in production capacity expansion and keeping production stable to avoid their additional investment is difficult.

1.2.2 Inefficient Forecasting Method and Order Planning

Each distribution center and production line has a different order planning for the same suppliers. Their order date, forecasting and ordering system are totally different as illustrated in the Table 1.1 below:

Table 1.1: Ordering System and Forecast of Distribution Centers and Production Line

	Order Date	Forecasting period	Ordering System
DC#1	30th	5 months	TOPAS
DC#2	8th	0-3 months	TOPIXCS
Production Line	22th	Fixed Plan	SCP

Source: Data from the interview

Currently, the business unit of accessory parts of TM Company has not built up a systematic forecasting method. They normally apply qualitative methods whether by data from sales persons or from the dealer's prediction to its forecasting model.

1.2.3 Demand Uncertainty

Each distribution center and production line normally forecast their own demand by using their historical data. Unfortunately, there is often an unexpected additional requirement from the dealers through the production line. This unexpected demand is because of the impact from marketing trends and promotional campaigns.

The demand uncertainty can also occur when new accessory parts are designed and launched for a minor change according to the marketing campaign of TM Company. The existing car users who know this information often need to install those parts as well. The advance of current information technology helps to create this situation. The worldwide communication and social networks through the internet between the car users can be easily found in many websites and web boards.

1.2.4 Supply Shortage: Back Order and Lost Sales

This is a result of inefficient inventory management. The supply shortage occurs when the TM Company has insufficient levels of products to serve the demand. The impact of supply shortage can be back orders which mean that the customer is able to wait for the availability of the products. However, if the customer is impatient, the company has to encounter the loss of sales. For the production line and dealers, if the company is not able supply the accessory parts for installation on time, their orders of a completed car from the customer might be cancelled. For the TM Company, getting loss of sales for just only one car means they lose a lot of money and margins that should be received.

1.3 Research Questions

The current situation of accessory part business unit the TM Company raises a question for this research which is "How inventory techniques can be applied to improve the availability of accessory parts and maintain the optimal level of inventory for distribution centers and production lines of the TM Company?"

1.4 Research Objectives

This research attempts to accomplish the following objectives:

1.4.1 To understand the nature of demand of the accessory parts market in the automotive industry and identify the problems of the selected case.

1.4.2 To study the forecasting methods and select a suitable model to apply to he TM Company.

1.4.3 To study and apply the techniques of inventory management in order to have available products with an optimal level of inventory for demand uncertainty situation.

1.4.4 To understand the impact when the inventory is set up as a buffer against uncertain demand.

1.5 Scope of the Study

This research will apply tools and methodologies of inventory management to the accessory parts business unit of TM Company. This research will not only analyze the demand type of distribution center and production line but also analyze the fluctuation of the demand in the market of the automotive industry.

The appropriate method of forecasting will be selected from the study. The approach of inventory management as Economic Order Quantity (EOQ) and determination of Reorder Point (ROP) and level of Safety inventory will be considered for this study in order to have sufficient availability of products to serve the demand and accomplish the optimal level of inventory and accepted service levels.

1.6 Significance of the Study

The model that will be studied in this research can be applied the TM Company. The better processing in inventory management is expected to be the outcome from this study. This will benefit the TM Company for its future planning.

1.6 Limitations of the Research

There are many different items of accessory parts that are normally be assembled in a car. The important items which are standard parts and safety parts are selected for this study. These items are encountering critical problems such as long lead time of the suppliers and demand that exceeds the limited capacity of the suppliers. These items are selected to be the representation for all accessory parts. The selected approaches and the outcomes from this study are also expected to be generalized with all SKUs of accessory parts of the TM Company.

1.7 The Definition of Terms

Accessory Parts: The parts that are required to be installed in a car whether as a standard type or special / limited edition. (Author)

Demand Forecasting: The method that helps manager about future decision-making against uncertainty. (Render, B., Stair, R.M. Jr., & Hanna, M.E. (2006))

Economic Order Quantity (EOQ): One of the inventory replenishment models that is used to determine the order quantity in economic lot size. (Tersine (1994))

Holding Cost or Carrying Cost: The associated cost involves the investment in keeping the product in storage. (Wisner, J.D., Tan, K.C., & Leong, G.K. (2009))

Inline Installation: The accessory parts will be installed inside the Production Line before releasing the finished car to the car dealers. (Author)

Inventory Cost: The cost that occurs when the business decides to keep the amount of goods which consists of purchasing cost, holding cost, ordering cost and shortage cost. (Silver, Pyke, & Peterson (1998))

Lead Time: The period of time between when an order was placed and the arrival of the order for replenishment. (Tersine (1994))

Lead Time Demand (LTD): The demand that occurs during the period of time between when an order was placed and the arrival of the order. (Anupindi, Chopra, Deshmukh, Van Mieghem, & Zemel (2006))

Ordering Cost: This expense arises when a business places an order to the suppliers. It also includes the setup cost when there is a modification or changeover of the assembly process in a production line. (Render et al. (2006))

Offline Installation: The accessory parts will be installed outside the Production Line after the finished car is completed and released to the car dealers. (Author)

Reorder Point (ROP): The time that is determined to place an order when the level of inventory meets this point. (Anupindi, et al. (2006))

Safety Stock: The inventory that is kept as a buffer and will be used to protect the company against higher than expected demand levels (Tersine (1994))

Service Level: The order fulfilled rate that is determined as a percentage. (Anupindi, et al. (2006))

Service Parts: The example of service parts which includes engine oil, air filters, etc. These parts are normally required when a car needs to be kept as an inventory for car maintenance. (Author)

Stock Keeping Units (SKUs): A unique identifier for each distinct product that can be ordered from the supplier. (Water (1992))

CHAPTER II

REVIEW OF RELATED LITERATURE AND RESEARCH FRAMEWORKS

This research intends to study the important factors, techniques and approaches to obtain adequate accessory parts for demand uncertainty situation of the TM Company. The main topics that are determined as a framework for this study consists of:

1. Inventory Management Conceptual
2. Nature of Demand and Forecast Models Development
3. Economic Order Quantity (EOQ) and determination of safety stock and reorder point

2.1 Inventory Management

Tersine (1994) mentioned that the objective of inventory management is to provide the availability of products or materials to the place and time where and when required at the appropriate cost. Businesses normally set their own inventory policy in order to affect the efficient usage of its assets in producing goods and services. As Wisner, Tan & Leong (2008) explain that it is a complex subject to develop inventory control systems in an efficient way to reduce waste and avoid stockouts situation whether in manufacturing or service businesses. The businesses are able to have the sufficient amount of inventory to support the process of manufacturing, logistics, and other functions. However, the excessive inventory can indicate to a sign of poor inventory management which is able to create unnecessary waste of scarce resources. Moreover, the excessive inventory is also adversely affects financial performance.

Inventory provides a level of product or service availability which can meet the expectation of the customer for product availability. It helps the company not only maintain sales but also increase them. Moreover, holding inventory is able to encourage production when it exists to act as buffers (Ballou, 2004). In the other hand, if the businesses do not have enough raw materials or finished goods to respond to the requirements of the customers, a stockout situation occurs.

Coyle et al. (2003) explains that inventory levels have to be sufficient to provide the accepted service levels to the customer but must not have too much waste and increase the supply chain costs. The ideal approach to balance supply and demand for appropriate inventory level is to have integration between the members in the supply chain. Therefore, the fundamental issue for inventory management is to have the optimal level of inventory to serve the requirement of the customers. Meanwhile, inventory should not be excess to be wastes for the businesses.

2.1.1 Types of Inventory

Wisner et al. (2008) suggest that inventory not only consists of all raw materials and finished products that are procured but also of partially completed materials and component parts.

Generally, inventory can be categorized into 4 types as follows:

1. Raw Materials: This type of inventory is unprocessed materials that are provided to produce the finished goods.
2. Work-in-process (WIP): Inventory in this type is materials that are partially processed in the manufacturing but not ready for sales.
3. Finished Goods: It is the finished products that are ready for shipment and for sales. The other purpose of finished products is storage as a buffer against demand uncertainty.
4. Maintenance, Repair, and Operating (MRO): This type of inventory normally is stored to benefit purchase economies and to avoid material shortages that may impact the production shut down.

2.1.2 Inventory Associated Costs

Tersine (1994) explain that inventory costs are involved with the inventory operation systems and the results can be transformed to be practical at a managerial level. Coyle et al. (2003) suggest that the important of inventory costs can be clarified into 3 major topics. First, inventory costs are indicated as the important component of total logistics costs. Second, the inventory level that a business is carrying in its logistics system is an indicator of the level of service that the businesses are able to provide to their customers. And the last reason is about decision making of cost trade-off in inventory level which depends on and impact carrying cost. The associated cost for operating inventory consists of four components which are as follows:

1. Purchase Cost: This cost includes unit price that businesses purchase from an external source including transportation cost. The purchase cost is altered for different quantity levels when there is a quantity discount offered by suppliers.

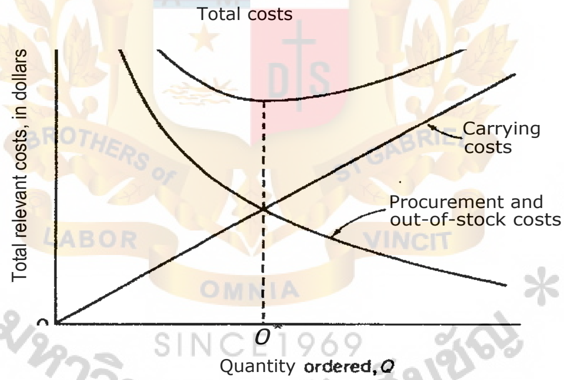
2. Order / Setup Cost: Ordering Cost occurs when the order of additional inventory is placed. It does not include the expense of the product itself. Setup cost is usually concerned with the production line that is related to the expense of changing or modifying a production or assembly process in order to facilitate product line changeovers.

3. Holding Cost: It is also called Carrying Cost. There are four components of inventory holding cost which are as follows:
   a) Capital Cost: This cost can be called the interest or opportunity cost. Capital cost indicates lost gaining power or opportunity cost. If the capital was invested elsewhere, a return on the investment would be expected. Capital Cost is a charge relevant to the business when there is unreceived return.
   b) Storage Space Cost: This cost includes handling costs that is associated with flowing of products whether inbound and outbound. This cost also refers to storage costs such as rent and lighting.
   c) Inventory Service Cost: This component of holding cost includes insurance and taxes. High level of inventory results in high tax costs. It is a significant factor for businesses to determine the location where products are stored.

d) Inventory Risk Cost: The situation that occurs with the products, like obsolescence, damage pilferage, theft, etc. can be calculated as inventory risk costs.

4. Stockout Cost: This is the cost when the businesses cannot provide an item available for sale. For a manufacturer that deals with raw materials or suppliers for a production line, a stock out is able to impact wholly or partially shutting down operations. A manufacturer should decide the level of safety inventory to carry and thoroughly understand the cost consequences of shutting down the operation if the required parts or materials are unavailable. Moreover, the hourly or daily production rates multiply by the profit loss and the number of units not produced should be determined as well.

Figure 2.1 Inventory Costs



2.2 Nature of Demand and Forecasting Approaches

2.2.1 Demand Pattern

Dependent and Independent

1. Dependent Demand: this type of demand can be referred to as internal demand in the production line which requires raw materials or component parts. Demand often depends on the finished products which consist of those parts.
2. Independent Demand: this is the demand of finished products and demand pattern depended on trends and seasonal and general market conditions.

Deterministic and Probabilistic

1. Deterministic Demand: this type of demand maintains the condition that all variables must take values which are known exactly.
2. Probabilistic Demand: this type of demand removes the condition of certainty and allows probabilities to be assigned to variables.

2.2.2 A Viewpoint of Forecasting for Inventory Management

Coyle et al. (2003) mention that all businesses are usually encountered with demand uncertainty which can occur from the customer side. The demand uncertainty usually involves the volume of products that customers will buy and when. The approach to resolve uncertainty is forecasting demand. However, the limitation of forecasting demand is it is never completely accurate. Waters (1992) explains that demand in the future of an item is generally the most important input to an inventory control model. It is the factor which has the most impact on the level of inventory. Silver, Pyke and Peterson (1998) suggest that forecasting in the function of inventory management is required for these purposes:

1. To have standards of customer service performance
2. To allocate and plan the investment of inventory
3. To have the appropriate number of replenishment orders
4. To realize needs of additional production capacity
5. To have an alternative selection of operating strategies.

However, a business should determine the characteristics of forecasting and the constraints of using forecasting which can be as follows:

1. Forecasts are always wrong so the forecast error should be measured.
2. Forecasts in long term are usually less accurate than forecasts in short term.
3. Aggregation in forecasts is usually more reliable than disaggregation of forecasts.

2.2.3 Forecasting Models

Forecasting models are identified as four types which are as follows:

1. Qualitative Method: The judgment and opinion of a person must be relied upon to make this type of forecast. This method is often applied when the historical data is not available or there are experts who have a plenty of experience in that market. The approach on the qualitative method can be identified as below:

Delphi methods: The experiences from the experts in different functions are united to make forecasts.

Jury of executive opinion: The high level managers will share their opinions and combine with statistical data.

Sales force composite: Salespersons will estimate the future sales that should occur in the region.

Consumer market survey: This method applies the information from customers or potential customers about their future purchasing plans. Business is able to prepare a forecast and improve its product design and plan for new products.

2. Time Series Method: The historical data of demand is applied to obtain a forecast on this approach. The historical data are assumes that past demand can be used to be an indicator for future demand. These methods will be useful when the market situation and patterns of demand are stable and do not vary significantly.

Moving Averages: This method is useful if market demands are stable over time. The period of moving average forecast serves as an estimate of the next period's demand. It is expressed as follows:

$$\text{Moving average forecast} = \frac{\text{Sum of demands in previous n periods}}{n}$$

Mathematically, this is written as

$$F_{t+1} - \frac{\quad + Y_{t-1} + \quad + Y_{t-n+1}}{}$$

where

F_{t+1} = forecast of period t+1

Yr = actual number in period t

n = number of periods to average

In case there is a trend included, businesses can apply weights to emphasize on recent data. The addition of weight makes the approach more responsive to the situation because the recent value is weighted more heavily. However, there is no fixed formula to determine the appropriate weights. The experience of the forecasting maker is required.

A weighted moving average can be expressed as:

$$F_{t+1} = \frac{E\ (\text{weight in period i})(\text{ Actual value in period})}{E\ (\text{Weights})}$$

Mathematically this is

$$F_{t+1} = \frac{W\ Yr + W_2 Y_{t-} + \ldots + W_n Y_{t-n+1}}{w1 + w2\ '\ldots W_n}$$

where

W_1 = weight for nth

Exponential Smoothing: This forecasting method can be simply applied; much software can handle this method efficiently. This method is a type of moving average approach which concerns not much of past data recording. The exponential smoothing formula can be written mathematically as follows:

$$F_{t+1} = F_t + a (Y_t - F_t)$$

where

F_{t+1} = new forecast

F_t = previous forecast

a = smoothing constant ($0 < a < 1$)

Y_t = previous period's actual demand

Trend Projections: This approach involves a trend line of historical data and applies line into the future forecast. A trend line is a type of linear regression equation which is as follows:

$$b_0 + b_1 X$$

where

= predicted value

b_0 = intercept

b_1 = slope of the line

X = time period (i.e. X = 1, 2, 3, 4,... n)

Decomposition: This is the process of identifying linear trends and seasonal factors to develop the forecast for more accuracy. Hanke, Wichern & Reitsch., (2001) explain that there are components in time series data analysis which can be identified as following.

- Level: The level component is present in all data and represents the central tendency of a time series at any given time.
- Trend: The trend is the component that represents the growth or decline in a time series. The trend may arise from inflation, population change, productivity increases and technological changes.

Cyclical: This component can be expressed as wavelike fluctuations of more than a year's period. Changing economic conditions generally produce a cycle. *C* denotes the cyclical component.

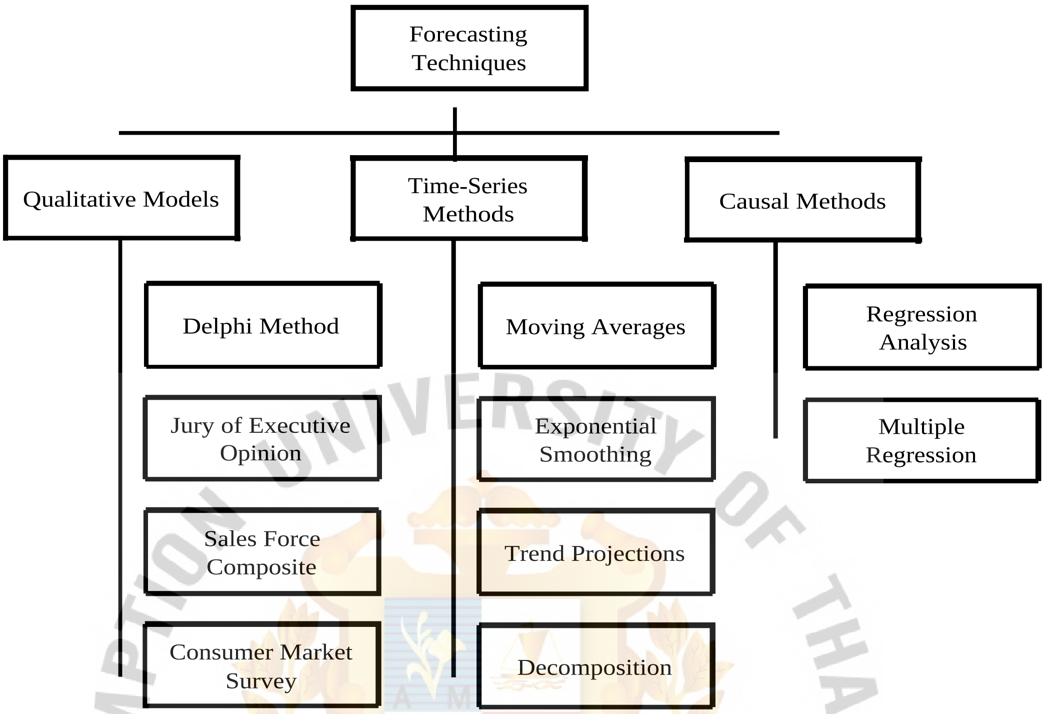
- Seasonal: This type of fluctuation can be found in quarterly, monthly, or weekly data. Seasonal variations refer to a more or less stable demand pattern that appears annually and repeats itself year after year.
- Irregular: This component consists of random or unpredictable fluctuations. This kind of fluctuation is the result of many events that may not be important individually but the effect could be large when combined.

3. Causal Method: This method assumes that forecasting involves the environment factors which will be the component for making a forecast future demand. The causal method can be classified into:

Regression Analysis: Tersine (1994) explains that regression analysis establishes a variable relationship for the forecast. The predicted variable (demand) is referred to the dependent variable. Meanwhile, the variable used in predicting (time) is called as the independent variable.

Multiple Regression Analysis: This model will be used when there are several independent variables to predict the forecast. It involves determining the complex parameters of the multiple regression equation and requires numerous data compared to other techniques.

Figure 2.2: Forecasting Models



Source: Render, Stair & Hanna. (2006).

In the ideal practice, the member in supply chain whether the producers or the buyers should share the information to establish a single consensus forecast. Then the result of corrected decisions whether on supply or demand can be made. The better forecasting can result in reduced stock outs, lower inventory, reduced cost, production plans smoothing and development of customer service.

2.3 Inventory Control System

The two fundamental questions posed to any inventory system are when and how many to order. The answers depend on the nature of inventory demands and the parameters used to define the system (Tersine, 1994).

Inventory control not only supports important functions but also increases flexibility of operations of the business. Render et al. (2006) explains that the function of using inventory can be:

- The decoupling function: This is the important function of inventory for the manufacturing process. The delays and inefficiencies may occur if there is no inventory stored to serve the process.
- Storing resources: The kind of seasonal products such as agricultural and seafood often be stored in inventory to meet the constant demand of the customers during the year.

  Irregular supply and demand: When the business faces uncertainty supply or demand, storing certain amount can be important.
- Quantity discounts: This is a benefit for the businesses when they place an order of large quantities. Many suppliers often offer quantity discount to the businesses.
- Avoiding stockout and shortages: If the business cannot replenish the requirement of the customer because the products are unavailable, the customers may go elsewhere to satisfy their needs.

2.3.1 Replenishment Policies

The inventory replenishment consists of decisions concerning when to reorder and how much to reorder. There are mainly two approaches to control the replenishment of inventory:

a) Fixed Order Quantity Approach (Continuous Inventory System)

This model involves reordering a fixed quantity of products that will be placed in each time. The actual amount of products will be ordered depending on the cost of product, demand characteristics and upon relevant inventory carrying and reordering costs.

The order size that minimizes the total inventory cost has been introduced as Economic Order Quantity (EOQ). However, in order to apply this approach, the businesses have to be aware of the assumptions of EOQ model which are as follows:

1. The demand rate is known, constant, and continuous
2. The lead time is known and constant
3. The entire lot size is added to inventory at the same time
4. No stockouts are permitted; since demand and lead time are known, stockouts can be avoid
5. The cost structure is fixed; order / setup cost are the same regardless of lot size, holding cost is a linear function based on average inventory, and unit purchase cost is constant (no quantity discount)
6. There is sufficient space, capacity, and capital to procure the desired quantity.
7. The item is a single product; it does not interfere with any other inventory items

Ballou (2004) suggests that the determination of Reorder Point (ROP) is a part of basic inventory control and is the quantity to which inventory is allowed to drop before a replacement order is placed.

b) Fixed order Interval Approach (Periodic Inventory system)

This technique involves ordering inventory at fixed or regular intervals or time-based inventory system. The amount is ordered depends on how much inventory is in the inventory and available at the time of review. Inventory replenishment is useful for the businesses like retailing and wholesaling that have to manage with many SKUs in the inventory. A supplier provides numerous items and it is more economical to place joint orders. The basic problem in this situation is the determination of the time interval which will minimize inventory costs for the group as a whole (Tersine, 1994). Waters (1992) suggest the example of Periodic Inventory System as in the supermarket shelves in which the inventory may be refilled every evening to replace the items that were sold during the day.

In a firm knowing demand and lead time length with certainty, either the basic EOQ or the fixed order interval approach will be the best choice. If either demand or lead time varies, however, approach selection must consider the potential consequences of a stockout (Coyle et al., 2003)

2.3.2 Safety Inventory

Silver et al. (1998) explain that when the products as the customer's orders are temporary out of stock, there are two extreme cases occurring 1) complete backordering and 2) complete lost sales. Businesses often find that it wise to keep extra inventory just in case actual demand exceeds the forecast to provide a better level of customer service and avoid stockouts situation (Anupindi, Chopra, Deshmukh, Van Mieghem & Zemel, 2006). Inventory that was excess of the forecast demand is called safety inventory or safety stock.

Tersine (1994) suggests that the volume of safety inventory will be large when the following factors occur:

- Higher stockouts cost or service levels
- Lower holding costs
- Larger variations in demand

  Larger variation in lead time

Render et al. (2006) mentioned that the way to set up a safety stock policy is to adjust the Reorder Point (ROP). Safety stock units can be added as a buffer to the ROP to complete this approach. The ROP calculation when there is stable demand and lead time is ROP = d x L (demand multiplied by lead time). However, when there is demand uncertainty during the lead time then safety stock is considered and the reorder point becomes ROP = d x L + SS.

Safety Stock with known Stockout Cost

The objective is to find the quantity of safety stock that will minimize the total of the expected stockout cost plus the expected holding cost. To compute these costs, it is necessary to know the stockout cost per unit as well as the probability distribution describing the demand during the lead time. The stockout cost should normally include the lost sales resulting from customers being unable to purchase the item due to the current stockout.

Stockout Cost = Number of units short x Stockout cost per unit x Number of orders per year (when the ROP is less than demand over lead time)

Safety Stock with unknown Stockout Cost

In some cases, it is difficult to know the stockout cost such as when the customer comes in for warranty claim of spare parts but the company does not have that spare part available in its inventory. Render et al. (2006) suggest that an alternative approach to determining safety stock levels is to use a service level. To determine the safety stock level, it is necessary to know the probability of demand during the lead time and the desired service level. Tersine (1994) explain that under the condition that the business does not know its stockout cost, it is customary for management to set service levels for which reorder point can be ascertained.

2.3.3 Service Level Measurement

A policy of never having a stockout is generally not economic. The principle of diminishing returns is applied. As the service level approaches 100%, the investment in safety stock often increase drastically. Thus, most organizations consider a "reasonable" number of stockout acceptable because of the high cost of trying to eliminate them altogether. No one service level measure is usually appropriate for all the items in inventory. Different levels of control may be desirable for different classes of inventory items (Tersine, 1994).

The service level takes on different meanings, depending upon how it is stated as a decision criterion. Two commonly used service levels are:

Service per order cycle: this approach is not concerned with how large the shortage is, but with how often it can occur.

Service per units demanded: indicate the percentage of demand that will be satisfied and allows for uniform treatment of difference products.

The service level per cycle indicates the probability of no stockout during the lead time. It is the proportion of cycles without a stockout. It is appropriate when the shortage occurrence has the same consequence independent of its time or amount. The service level per units demanded, also known as the fill rate, measures the proportion of demands that are met from stock. It is generally a more meaningful measure for managers, since it is consistent among different products

To determine the optimal level of safety inventory, the businesses should consider economic trade-off between the cost of stockout and the cost of carrying excess inventory (Anupindi et al., 2006)

2.4 Summary

The one solution to handle the uncertain demand in the supply planning function is to have an efficient forecasting method and inventory control system. However, if the businesses decide to hold the inventory to serve the demand from the customer, they should consider the trade-off between keeping more inventory, gaining more service levels and reducing lost sales, to allow the shortage of cost to occur.

CHAPTER III

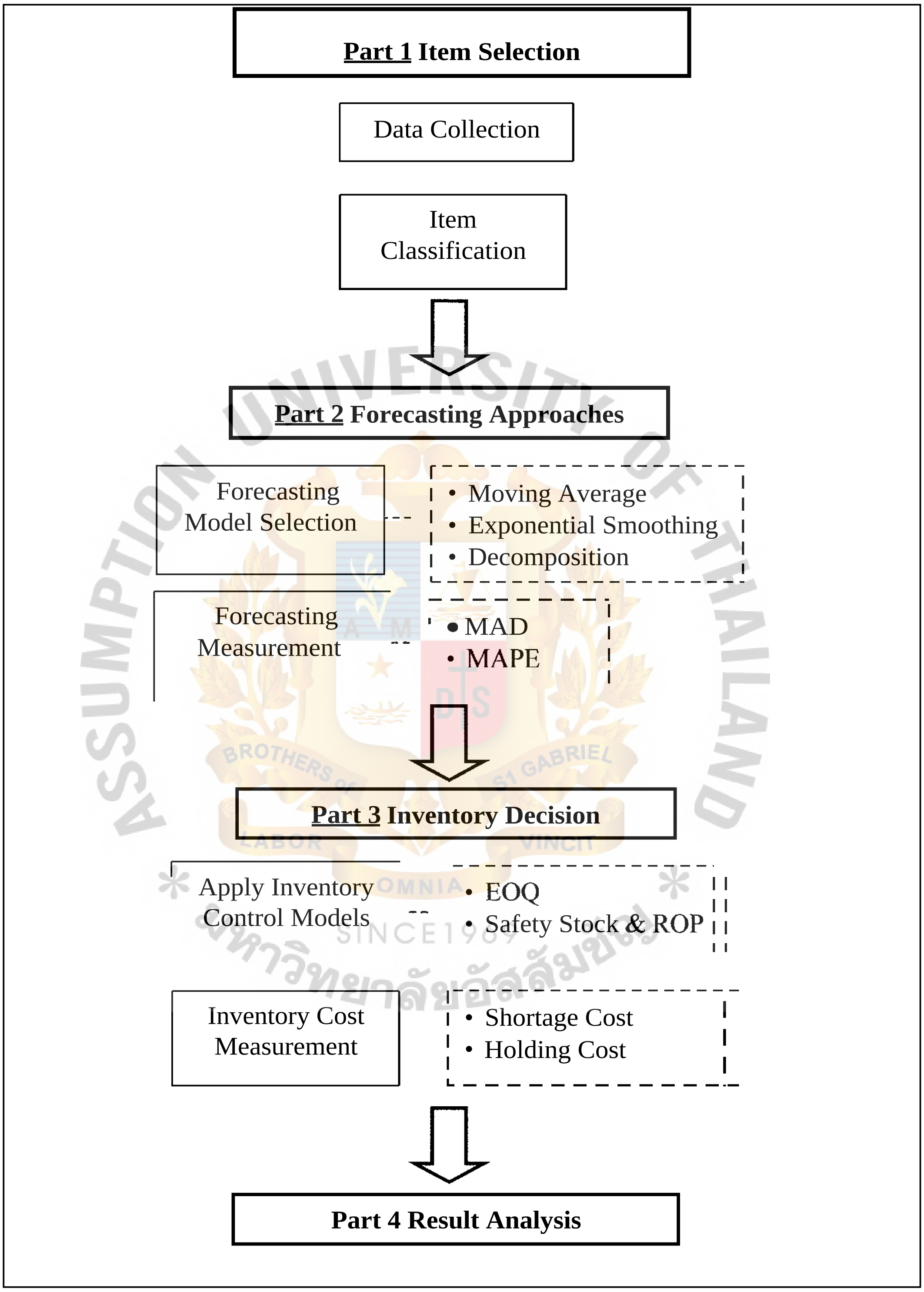
RESEARCH METHODOLOGY

The literature review in chapter II indicated that there were techniques to improve the inventory issues of the company. Those techniques will be applied and utilized as a guideline with the expectation of improvement for the company

The methodology of this research is separated into 3 main parts. The first part expresses the process of item selection from more than two thousand accessory part items. The selected item that be a representation of the total parts. The second part is to apply the forecast method to the selected items and find out the suitable model for each selected item by measuring the forecasting error. Finally, the third part involves the inventory decision by applying technique as Economic Order Quantity (EOQ), safety inventory and reorder point to the historical demand and comparing the traditional method of TM Company to the present method. The inventory cost is the measurement of decision making concerned with the suitable inventory level.

The methodology can be indicated as figure 3.1 to clarify the research framework of this study.

Figure 3.1 Research Methodology Flowchart



A business unit of accessory parts of the TM Company is focused in this study. The methodology of this research is determined according to the above flowchart. Details of each step are going to be described in a practical way and are as follows:

3.1 Data Collection

This research is going to find out the best method in the areas of inventory management to solve the problem of inefficiency of forecasting and insufficient inventory levels to supply to the Production Line and Dealers. The required data in this study is concerned with the historical data of product demand which is collected for 36 months from April 2008 to March 2011. Data from the experience of the participants such as nature of demand, trends in the market, promotional activities, campaigns of the company, etc. will be also be collected and considered as the important elements for inventory decision in this study.

3.2 Item Classification and Selection

The process of item selection can be classified as follows:

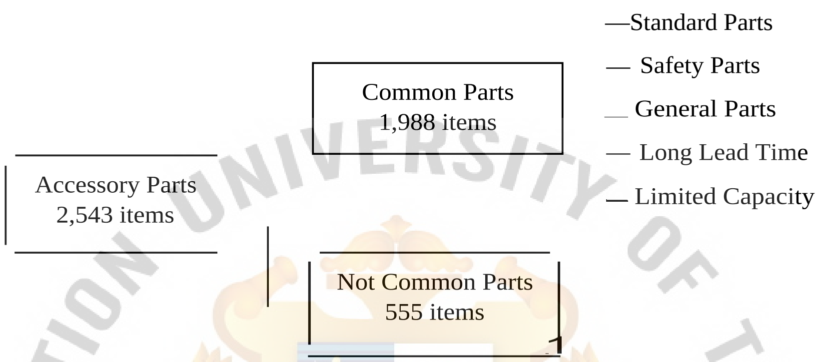
1. Select common parts that are normally required for DC#1, DC#2 and production lines. A total of 1,998 are deducted from 2,543 items of accessory parts.
2. The remaining items are identified into 4 categories based on different situations below:

- Standard parts that must be installed in a car before release to the market.
- The longest delivery lead time from suppliers at 3 months which make the TM Company control and monitor the inventory level closely: air conditions, car audios, etc. are the sample of items in this category.
- Safety parts which have to be guaranteed for quality from the TM Company. If these parts are not available when the consumers need then they might purchase the counterfeit parts which have a lower quality and this impacts the reputation of the TM Company. When there is an accident because of the problem with these parts, a

reporter will present only the name of the TM Company not post that the reasons for using of the counterfeit parts.

- Demand is going to exceed the capacity of suppliers due to the trends in the market, etc. Fog lamps, muffler cutters, etc. are the items on this category.
- General accessory parts such as bed liners, floor mats, emblems, etc.

Figure 3.2 Identification of Accessory Parts



3. The top 2 items are based on total usage of each category and is representative of the category for this study.

Table 3.1 Selected Items for the Study

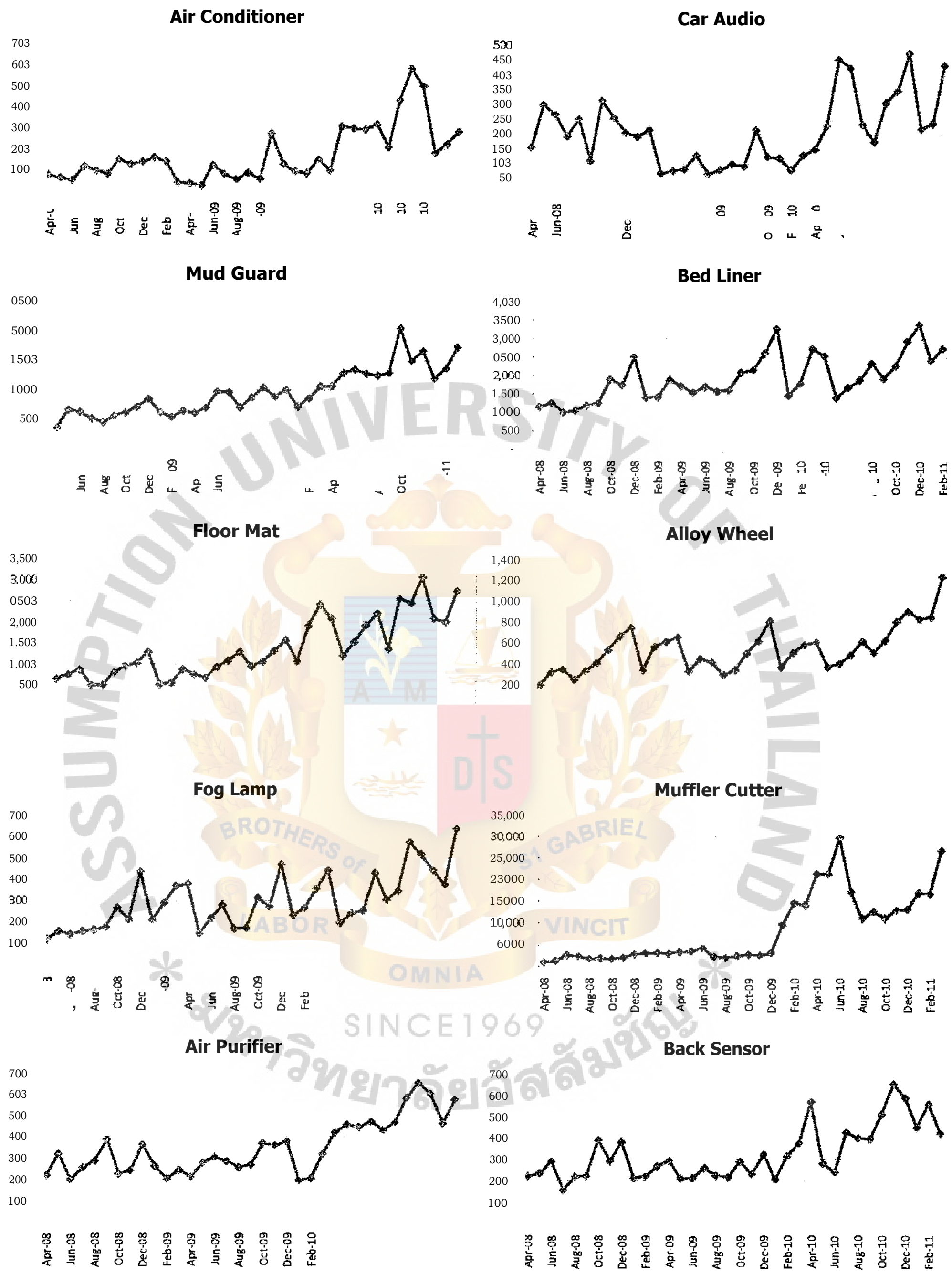
Part Name	Quantity	Unit Cost (baht)	Total Usage (baht)
Standard Parts			
Air Purifier	12,869	3,269	42,068,761
Mud Guard	34,372	694	23,854,168
Long Lead Time			
Car Audio	7,505	13,200	99,066,000
Air Conditioner	6,199	13,472	83,512,928
Safety Parts			
Alloy Wheel	19,589	3,771	73,870,119
Back Sensor	11,735	2,749	32,259,515
Demand exceed capacity of the suppliers			
Muffler Cutter	295,371	194	57,301,974
Fog Lamp	10,713	3,257	34,892,241
General accessory parts			
Bed Liner	71,292	3,770	268,770,840
Floor Mat	49,397	3,304	163,207,688

3.3 Forecasting Models

3.3.1 As-Is Situation of Demand Pattern and Forecasting Method

Each distribution center and production line has applied their own forecast number to the suppliers. Thus, the suppliers normally receive 3 forecasts which have a different number of requirements. Currently, distribution centers of the TM Company do not have an efficient forecasting method. They normally do a demand forecast based on qualitative approach, moreover, this is a less systematic method which causes forecast errors of 50-100%. The current situation of marketing growth in accessory parts business also drives the forecasting far beyond the actual demand. Figure 3.3 illustrates the demand patterns of the selected items between April 2008 – March 2011.

Figure 3.3 Demand Pattern of Selected Item during the Period of Study



The raw data that was collected for this study is historical data. Therefore, time series model is considered as a forecasting model applied show in this study. To be ensured that the selected forecasting approach is suitable, all the outcome of selected forecasting models will be measured to find the lowest error number.

All historical data are put in the forecasting module of the software called "QM for Window version 3.1". The forecasting models such as Moving Averages, Simple Exponential Smoothing, Exponential with Trends and Multiplicative Decomposition (Seasonal) are selected for this study. These forecasting models measure the error by MAD (Mean Absolute Deviation) and MAPE (Mean Absolute Percentage Error). The model that gives the least errors in terms of numbers will be selected to apply for the business.

The formula to calculate the error measurement is as follow:

$$MAD = \frac{\Sigma |\text{Forecast Error}|}{n}$$

$$MAPE = \frac{\Sigma |\text{Error / Actual}| \times 100}{n}$$

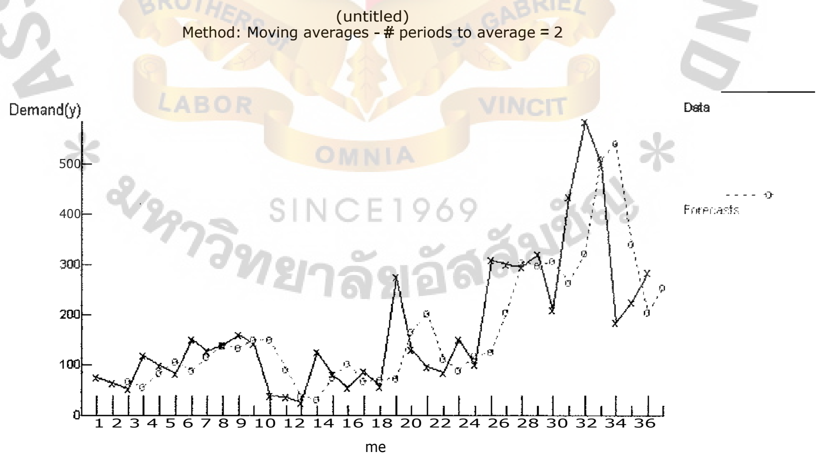
3.3.2 Moving Averages Method

The approach of this method is to find the mean value of the previous data in the desired period to forecast the next period in the future. The sample data of Air conditions are put in the software QM for Windows. The forecast using the Moving Average model is illustrated in Table 3.2.

Table 3.2 Forecast of Air Condition by Moving Averages at Period of Average =2

Period	Demand	Forecast	Error	Absolute	Squared	|% Error|
Apr-08	75					
May-08	63					
Jun-08	52	69.00	(17.00)	17.00	289.00	0.33
Jul-08	118	57.50	60.50	60.50	3,660.25	0.51
Aug-08	98	85.00	13.00	13.00	169.00	0.13
Sep-08	82	108.00	(26.00)	26.00	676.00	0.32
	-			-		
		-			-	
-	-		-	-	-	
Oct-10	435	265.00	170.00	170.00	28,900.00	0.39
Nov-10	585	322.50	262.50	262.50	68,906.25	0.45
Dec-10	500	510.00	(10.00)	10.00	100.00	0.02
Jan-11	185	542.50	(357.50)	357.50	127,806.25	1.93
Feb-11	225	342.50	(117.50)	117.50	13,806.25	0.52
Mar-11	285	205.00	80.00	80.00	6,400.00	0.28
		Total	297.00	2,439.00	394,221.00	17.03
		Average	8.74	71.74	11,594.74	0.50
			Bias	MAD	MSE	MAPE

Figure 3.4 Moving Averages of Air condition at Period of Average =2



The results provide the forecast number according to Moving Averages method for a 2 months period. There is a measurement of forecast error at 50% based on Mean Absolute Percentage Error (MAPE) which indicates that this method is quite acceptable when compared to the As-is situation of the TM company in which the error is about 50-100%. However, this method will be applied at different periods of averages to achieve the lowest error number.

3.3.3 Simple Exponential Smoothing

Simple exponential smoothing is often referred to as first order smoothing. When the trend is adjusted for smoothing, it is called second-order, double smoothing, or Holt's method. The sample data are calculated in the formula at the difference smoothing constant or a (alpha) between 0.2 to 0.9. The formula of Simple Exponential Smoothing can be written as:

$$F_{t+1} = F_t + a\,(Y_t - F_t)$$

where

F_{t+1} = new forecast (for time period $t + 1$)

F_t = previous forecast (for time period t)

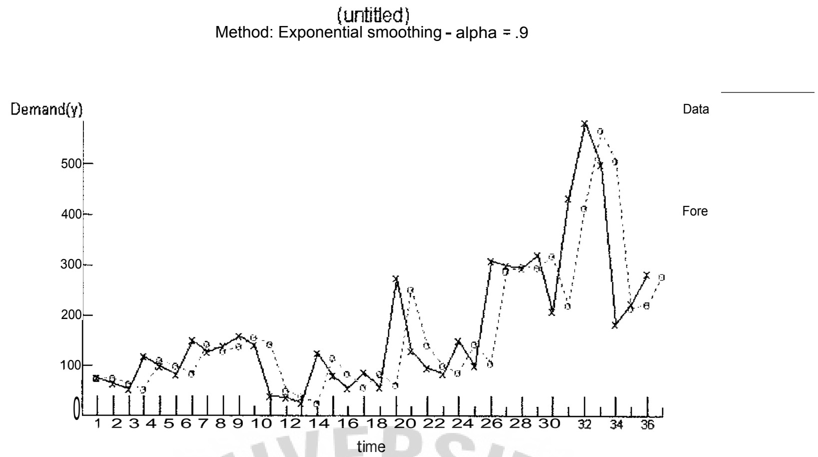
a = smoothing constant ($0 < a < 1$)

Y_t = previous period's actual demand

Table 3.3 Forecast of Air Condition by Exponential Smoothing at a =0.9

Period	Demand	Forecast	Error	Absolute	Squared	|% Erroll
Apr-08	75	75				
May-08	63	75	-12.0	12.0	144.0	0.2
Jun-08	52	64	-12.2	12.2	148.8	0.2
Jul-08	118	53	64.8	64.8	4196.4	0.5
Aug-08	98	112	-13.5	13.5	182.8	0.1
Sep-08	82	99	-17.4	17.4	301.1	0.2
				-	-	
	-			-		
			-		-	
Oct-10	435	221	214.2	214.2	45901.4	0.5
Nov-10	585	414	171.4	171.4	29386.4	0.3
Dec-10	500	568	-67.9	67.9	4604.6	0.1
Jan-11	185	507	-321.8	321.8	103546.1	1.7
Feb-11	225	217	7.8	7.8	61.2	0.0
Mar-11	285	224	60.8	60.8	3694.5	0.2
		Total	226.6	2300.0	346228.0	15.7
		Average	6.5	65.7	9892.2	0.4
			Bias	MAD	MSE	MAPE

Figure 3.5 Simple Exponential Smoothing of Air Condition at a = 0.9



The smoothing constant (a alpha) between 0.1 to 0.9 is the variation factor of simple exponential smoothing method. The more alpha value means that the forecast weights, the more important to the latest demand is compared to the previous demand. This research will apply the value of alpha between 0.1 to 0.9 and consider the range of alpha that provides the lowest error number.

3.3.4 Exponential Smoothing with Trend

According to the demand patterns of each item during the period of study, trend of demand can be notified obviously. Therefore, the exponential smoothing method should consider this component in forecast. The formula to calculate the exponential smoothing with trend adjustment can be written as:

$$T1+1 = (1-\beta)\, T1 + _{R} (F_{t+1}\ Ft)$$

where

T_{t+1} = smoothed trend for period $t + 1$

T_1 = smoothed trend for preceding period

β = trend smooth constant that we select

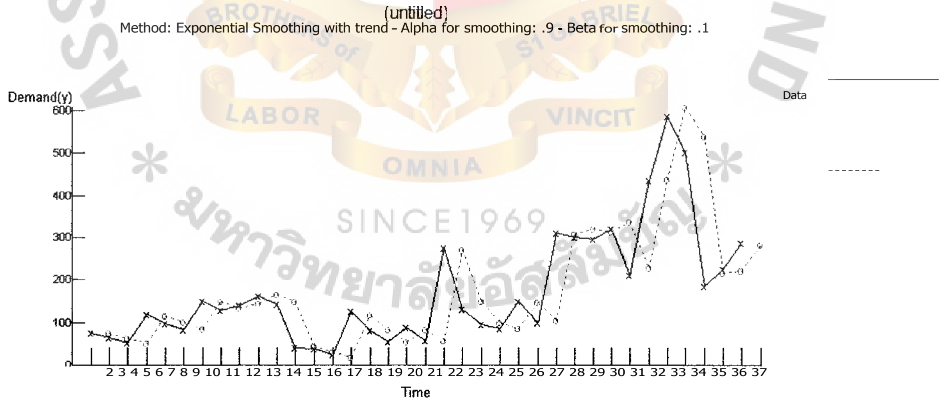
F_{t+1} = simple exponential smoothed forecast for period $t + 1$

F_t = forecast for previous period

Table 3.4 Forecast of Air Condition by Exponential Smoothing with Trend Adjustment at a 0.9 and β 0.1

Period	Demand	Forecast	Error	Absolute	Squared	|% Error|
Apr-08	75					
May-08	63	75	-12	12	144	0.19
Jun-08	52	63.12	-11.12	11.12	123.65	0.21
Jul-08	118	51.03	66.97	66.97	4484.82	0.57
Aug-08	98	115.25	-17.25	17.25	297.55	0.18
Sep-08	82	102.12	-20.12	20.12	404.77	0.25
-					-	
-	-			-	-	
	-		-			
Oct-10	435	227.41	207.59	207.59	43094.83	0.48
Nov-10	585	437.79	147.21	147.21	21671.56	0.25
Dec-10	500	607.07	-107.07	107.07	11464.97	0.21
Jan-11	185	537.87	-352.87	352.87	124514.8	1.91
Feb-11	225	215.69	9.31	9.31	86.72	0.04
Mar-11	285	220.31	64.69	64.69	4185.06	0.23
		Total	22.91	2407.67	378029.9	16.16
		Average	0.65	68.79	10800.85	0.46
			Bias	MAD	MSE	MAPE

Figure 3.6 Exponential Smoothing with Trend of Air condition at a 0.9 and β 0.1



This method considers trend ((3 beta) as the additional factor from the simple exponential method in order to have more accuracy of forecast. Render et al. (2006) suggest that a low f3 value gives less weight to the most recent trends to smooth out the trend present. Value of β can be found by the trial and error approach. In this research, the best result of selected a (alpha) will be referred in order to calculate and select the suitable $_{R}$ (beta) respectively.

3.3.5 Multiplicative Decomposition (Seasonal)

This method considers the process of isolating linear trend and seasonal factors to develop more accurate forecasting. The form of trend line is:

$$\hat{Y} = b_0 + b_1X$$

where

= predicted value

b_0 = intercept

b_1 = slope of the line

X = time period (i.e. X = 1, 2, 3, 4,... n)

Meanwhile, seasonal factors will be calculated as seasonal ratio and seasonal index.

$$\text{Seasonal Ratio} = \frac{\text{Demand in } n \text{ period}}{\text{Center Moving Average}}$$

$$\text{Seasonal Index} = \frac{\text{Average } n \text{ year demand}}{\text{Average monthly demand}}$$

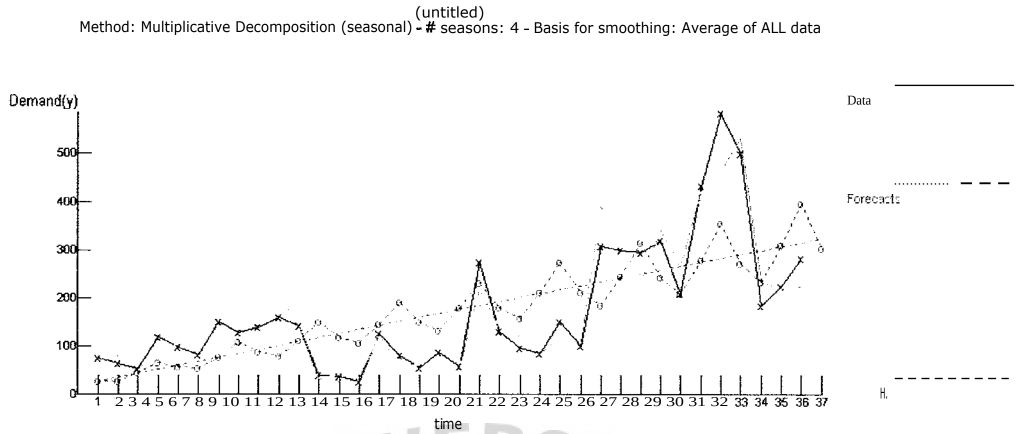
Table 3.5 Forecast of Air condition by Multiplicative Decomposition (seasonal)

Period	Demand	Ratio	Seasonal	Smoothed	Unadjusted	Adjusted	Error	|Error|	Error^2	|% Error|
Apr-08	75	0.44	0.94	79.94	28.20	26.46	48.54	48.54	2356.25	0.65
May-08	63	0.37	0.79	80.23	36.43	28.61	34.39	34.39	1182.84	0.55
Jun-08	52	0.30	1.01	51.26	44.66	45.30	6.70	6.70	44.91	0.13
Jul-08	118	0.69	1.26	93.49	52.89	66.75	51.25	51.25	2626.65	0.43
Aug-08	98	0.57	0.94	104.45	61.11	57.34	40.66	40.66	1653.39	0.41
Sep-08	82	0.48	0.79	104.42	69.34	54.45	27.55	27.55	758.81	034
-			-		-		-			
	-	-		-				-		
Oct-10	435	2.53	1.01	428.84	275.05	279.00	156.00	156.00	24337.35	0.36
Nov-10	585	3.40	1.26	463.50	283.27	357.53	227.47	227.47	51741.50	0.39
Dec-10	500	2.90	0.94	532.93	291.50	273.49	226.51	226.51	51305.47	0.45
Jan-11	185	1.07	0.79	235.58	299.73	235.38	-50.38	50.38	2537.68	0.27
Feb-11	225	1.31	1.01	221.82	307.96	312.38	-87.38	87.38	7635.43	0.39
Mar-11	285	1.66	1.26	225.81	316.19	399.07	-114.07	114.07	13012.62	0.40
						Total	-44.46	2786.79	316158.94	26.12
		Average	172.19	Intercept	19.97297632		-1.24	77.41	8782.19	0.73
				Slope	8.228187466		Bias	MAD	MSE	MAPE

Table 3.6 Calculation of Seasonal Ratios for Air Condition at 4 Seasons

Ratios				
	Season 1	Season 2	Season 3	Season 4
	0.43555412	0.365865	0.301984	0.685272
	0.56912405	0.476206	0.871108	0.743346
	0.80722697	0.929182	0.824649	0.232296
	0.21487337	0.145185	0.725924	0.464591
	0.31940636	0.505243	0.336829	1.597032
	0.75496048	0.551702	0.493628	0.871108
	0.58073883	1.80029	1.742216	1.71318
	1.85836425	1.219552	2.526214	3.397322
	2.90369414	1.074367	1.306662	1.655106
Average	0.93821584	0.785288	1.014357	1.262139

Figure 3.7 Multiplicative Decomposition of Air Condition at 4 seasons



The "Unadjusted" column in Table 3.5 has been developed from the form of the trend line which is $\hat{Y} = b_0 + b_1X$. This method tries to adjust the trend line with seasonal ratio for more accuracy. Thus, the forecast number can be found at the column "Adjusted" which is:

(average season ratio) x (trend line)

The demand for air conditions will be applied to this method at the different seasonal numbers to find the lowest forecast error.

3.4 Forecasting Error Measurement

It is important to measure the forecast error in order to determine which forecasting model is the most suitable for each item. Currently, TM Company has not established the efficient forecasting model. Therefore, the current error of forecasting can be measured at a percentage of 50-100%. Table 3.7 indicate the error measurement for each forecasting model.

Table 3.7 Forecasting Error Measurement of Moving Average by MAD and MAPE

MOVING AVERAGE				MOVING AVERAGE			
Item	**Period**	**MAD**	**MAPE**	**Item**	**Period**	**MAD**	**MAPE**
Air Condition	2 months	71.74	50.08%	Alloy Wheel	2 months	140.25	27.97%
	3 months	76.39	54.68%		3 months	141.28	26.68%
	4 months	79.78	56.89%		4 months	141.88	25.77%
	5 months	81.33	57.86%		5 months	152.13	27.16%
Car Audio	4 months	76.42	42.30%	Fog Lamp	2 months	95.31	32.21%
	5 months	71.19	41.85%		3 months	89.01	29.47%
	6 months	71.69	41.57%		4 months	83.63	27.39%
	7 months	75.89	44.69%		5 months	89.55	29.43%
Mud Guard	3 months	156.86	15.85%	Muffler Cutter	2 months	2557.82	26.87%
	4 months	165.44	16.00%		3 months	3138.55	30.45%
	5 months	164.42	15.27%		4 months	3514.43	31.79%
	6 months	170.52	15.31%		5 months	3913.18	34.24%
Bed Liner	2 months	486.38	24.29%	Air Purifier	4 months	70.94	20.73%
	3 months	461.20	22.34%		5 months	71.23	20.29%
	4 months	445.35	21.10%		6 months	72.56	20.28%
	5 months	464.96	21.53%		7 months	76.57	20.79%
Floor Mat	3 months	387.05	29.52%	Back Sensor	2 months	81.32	25.69%
	4 months	353.23	25.60%		3 months	77.71	23.66%
	5 months	361.03	25.35%		4 months	74.20	21.11%
	6 months	385.22	25.87%		5 months	77.08	21.38%

From above error measurement of Moving Average by MAD and MAPE, each item has a different period for the lowest percentage of error. For example, the lowest percentage error of air conditions is presented between 2 months and 5 months and the lowest error number is 54.68% at period of 3 month. At this step, the researcher selects the lowest error number of each item for selection of the suitable forecast model.

Table 3.8 Forecasting Measurement of Exponential Smoothing by MAD and MAPE

SIMPLE EXPONENTIAL SMOOTHING				EXPONENTIAL SMOOTHING WITH TREND			
Item	**Alpha**	**MAD**	**MAPE**	**Alpha**	**Beta**	**MAD**	**MAPE**
Air Condition	0.6	64.86	46.68%	0.9	**0.1**	68.79	**46.00%**
	0.7	64.88	45.80%		0.2	73.16	48.00%
	0.8	65.15	45.21%		0.3	78.66	52.00%
	ก	65.71	44.83%		0.4	83.82	56.00%
Car Audio	0.6	77.17	41.05%	0.7	**0,1**	79.83	**43.00%**
	0.7	77.11	40.80%		0.2	83.23	45.00%
	0.8	77.02	40.86%		0.3	87.41	47.00%
	0.9	77.45	41.18%		0.4	91.88	48.00%
Mud Guard	0.3	163.65	16.37%	0.4	**0.1**	153.00	**16.00%**
	0.4	158.08	**16.13%**		0.2	160.70	17.00%
	0.5	157.79	16.35%		0.3	168.21	18.00%
	0.6	158.72	16.60%		0.4	175.19	19.00%
Bed Liner	0.1	462.93	19.97%	0.2	**0.1**	417.55	**20.00%**
	0.2	425.03	**19.45%**		0.2	436.38	22.00%
	0.3	421.82	20.00%		0.3	451.70	23.00%
	0.4	419.26	20.32%		0.4	465.21	23.00%
Floor Mat	0.1	420.80	27.37%	0.2	**0.1**	330.73	25.00%
	0.2	353.64	**25.13%**		0.2	324.21	26.00%
	0.3	349.75	25.96%		0.3	327.85	26.00%
	0.4	349.56	26.62%		0.4	334.64	27.00%
Alloy Wheel	0.5	132.80	26.19%	0.6	**0.1**	126.05	**26.00%**
	0.6	129.41	**25.86%**		0.2	126.71	27.00%
	0.7	129.41	26.42%		0.3	128.95	27.00%
	0.8	130.72	27.03%		0.4	132.18	28.00%
Fog Lamp	0.1	93.42	27.95%	0.2	**0.1**	83.43	29.00%
	0.2	85.07	**27.39%**		0.2	83.98	30.00%
	0.3	83.03	27.63%		0.3	84.15	30.00%
	0.4	82.79	27.88%		0.4	85.21	31.00%
Muffler Cutter	0.6	2522.76	25.68%	0.9	0.1	2169.40	**24.00%**
	0.7	2367.38	24.49%		0.2	2267.74	25.00%
	0.8	2221.38	23.20%		0.3	2347.98	26.00%
	0.9	2146.62	22.73%		0.4	2421.63	26.00%
Air Purifier	0.5	65.98	19.95%	0.6	**0.1**	64.06	20.00%
	0.6	64.92	**19.91%**		0.2	65.61	21.00%
	0.7	65.16	20.12%		0.3	68.80	22.00%
	0.8	65.07	20.20%		0.4	72.27	23.00%
Back Sensor	0.1	79.76	21.20%	0.2	0.1	72.11	21[illegible]%
	0.2	73.98	**21.02%**		0.2	71.77	22.00%
	0.3	73.43	21.65%		0.3	72.73	22.00%
	0.4	73.66	22.29%		0.4	74.21	23.00%

This research has selected the alpha value for each item which results in the lowest number of errors and then refers that alpha value to find the best beta value respectively.

Table 3.9 Forecasting Measurements of Multiplicative Decomposition (Seasonal) by MAD and MAPE

MULTIPLICATIVE DECOMPOSITION (SEASONAL)				MULTIPLICATIVE DECOMPOSITION (SEASONAL)			
Item	**Season**	**MAD**	**MAPE**	**Item**	**Season**	**MAD**	**MAPE**
Air Condition	2	81.63	76.93%	Alloy Wheel	2	136.98	27.21%
	3	78.05	74.64%		3	131.58	26.22%
	4	77.41	72.55%		4	124.28	25.35%
	5	78.28	72.84%		5	135.37	27.08%
Car Audio	2	91.10	61.13%	Fog Lamp	2	74.74	26.35%
	3	91.09	61.38%		3	73.44	26.22%
	4	84.70	59.03%		4	61.88	[redacted]
	5	86.39	61.58%		5	72.96	25.97%
Mud Guard	2	136.31	15.09%	Muffler Cutter	2	3640.30	86.33%
	3	129.19	14.22%		3	3558.56	84.90%
	4	123.68	13.48%		4	3702.13	85.22%
	5	131.83	15.15%		5	3719.95	87.27%
Bed Liner	2	381.52	19.20%	Air Purifier	3	63.64	20.53%
	3	343.73	18.19%		4	64.02	20.42%
	4	312.61	16.68%		5	63.49	19.70%
	5	389.73	19.80%		6	62.53	19.91%
Floor Mat	2	300.26	26.07%	Back Sensor	2	69.38	22.86%
	3	307.79	26.50%		3	70.51	23.15%
	4	258.06	23.24%		4	68.37	22.26%
	5	293.88	25.50%		5	69.03	22.69%

From above error measurement of Multiplicative Decomposition by MAD and MAPE, each item has a different period of seasonal of the lowest percentage of error. For example, the lowest percentage error of air conditions is presented between 2 seasons and 5 seasons and the lowest error number is 72.55% at the period 4 seasons. At this step, the researcher will select the lowest error number of each item for selection of the suitable forecast model.

The different forecast model that obtains the least error value for each item will be selected and applied in the business. Table 3.10 illustrates the result of selection model and the results of forecasting.

Table 3.10 Selected Forecasting Models

Item	Method	MAPE
Air Condition	Simple Exponential Smoothing a 0.9	44.83%
Car Audio	Simple Exponential Smoothing a 0.7	40.80%
Mud Guard	Multiplicative Decomposition at 4 seasons	13.48%
Bed Liner	Multiplicative Decomposition at 4 seasons	16.68%
Floor Mat	Multiplicative Decomposition at 4 seasons	23.24%
Alloy Wheel	Multiplicative Decomposition at 4 seasons	25.35%
Fog Lamp	Multiplicative Decomposition at 4 seasons	23.42%
Muffler Cutter	Simple Exponential Smoothing a 0.9	22.73%
Air Purifier	Multiplicative Decomposition at 5 seasons	19.70%
Back Sensor	Exponential Smoothing with trend (a 0.2, f3 0.1)	21.00%

The selected sample items for this study have their own demand pattern. Thus, it is important to select the suitable forecast model for each item separately. The results of the forecasting model for each item indicates that 60% of samples items are suitable with Multiplicative Decomposition and the remaining items should be applied with the Exponential Smoothing model. The result of forecast error can be a significant improvement for this study. The selected forecast model can reduce the forecast error of the TM Company from 50-100% to 17-45%. Table 3.11 demonstrates the results of forecast models that were applied to the sample items.

Table 3.11 Forecasting Results

	Air Condition	Car Audio	Mud Guard	Bed Liner	Floor Mat	Alloy Wheel	Fog Lamp	Muffler Cutter	Air Purifier	Back Sensor
Apr-08	75	155	360	1,300	456	362	190	807	205	219
May-08	75	155	388	1,009	356	259	122	807	180	219
Jun-08	64	255	497	1,183	518	344	162	1,193	180	222
Jul-08	53	263	524	1,492	608	377	189	2,390	221	237
Aug-08	112	213	479	1,503	708	422	231	2,251	240	221
Sep-08	99	239	506	1,161	529	300	147	1,740	259	220
Oct-08	84	148	637	1,355	742	396	193	1,783	225	221
Nov-08	143	263	662	1,701	846	432	224	1,677	223	258
Dec-08	130	257	597	1,706	960	482	272	1,904	271	268
Jan-09	138	220	624	1,313	702	342	172	2,631	292	296
Feb-09	158	199	778	1,527	966	449	225	2,948	314	284
Mar-09	144	210	800	1,910	1,083	488	259	3,015	270	274
Apr-09	50	110	716	1,910	1,212	542	313	2,921	265	276
May-09	38	86	742	1,464	875	383	197	3,270	321	282
Jun-09	26	83	918	1,698	1,190	501	256	3,426	344	270
Jul-09	115	115	938	2,119	1,321	544	294	4,079	368	259
Aug-09	84	81	834	2,113	1,464	602	354	2,385	315	260
Sep-09	58	80	860	1,616	1,048	424	222	1,993	308	253
Oct-09	84	93	1,059	1,870	1,414	554	287	2,342	371	245
Nov-09	61	92	1,077	2,327	1,558	599	328	2,660	397	254
Dec-09	254	178	953	2,316	1,715	662	395	2,553	422	249
Jan-10	142	141	978	1,768	1,221	465	247	3,048	360	265
Feb-10	100	126	1,199	2,041	1,638	607	319	8,859	351	254
Mar-10	86	94	1,215	2,536	1,795	655	363	13,974	421	267
Apr-10	144	119	1,072	2,519	1,967	722	436	13,991	449	292
May-10	104	141	1,095	1,920	1,394	507	271	20,601	476	356
Jun-10	289	203	1,339	2,213	1,862	659	350	21,172	405	349
Jul-10	299	379	1,353	2,745	2,033	710	398	28,842	394	333
Aug-10	295	411	1,190	2,722	2,219	782	477	18,270	472	358
Sep-10	318	288	1,213	2,071	1,567	548	296	11,771	501	374
Oct-10	221	209	1,480	2,384	2,086	712	382	12,496	530	387
Nov-10	414	280	1,492	2,954	2,270	766	433	11,273	450	422
Dec-10	568	329	1,309	2,925	2,471	842	518	12,735	437	484
Jan-11	507	431	1,331	2,223	1,740	589	321	13,098	522	523
Feb-11	217	283	1,620	2,556	2,310	764	413	16,601	553	524
Mar-11	224	253	1,630	3,162	2,508	821	468	16,716	584	548
Total	5,972	7,183	34,464	71,333	49,354	19,612	10,727	272,220	12,897	11,022

3.5 Inventory Control Model Apply

3.5.1 As-is Inventory Situation Analysis

There is shortage of supply that occurs with the business unit of accessory parts of the TM Company because of the increasing of demand whether from market trends or campaigns and promotions of the company. Meanwhile, due to the limited capacity of the suppliers, distribution centers of TM Company have a double trouble to supply the goods to the dealers. Fortunately, lead time of the suppliers is quite constant so TM Company does not suffer much at this point. Each item has been supplied from the same supplier to DC#1, DC#2 and production lines of the TM Company. According to the Table 3.12, the suppliers of each item have allocated their own capacity per month to the TM Company. Meanwhile, they also have minimum order per each purchase.

Table 3.12 Capacity, Lead Time and Minimum Order of Suppliers

Item	Capacity of Suppliers / Month (unit)	Lead Time (months)	Minimum Order (unit)	Annual Demand 1st Year (unit)	Annual Demand 2nd Year (unit)	Annual Demand 3rd Year (unit)
Air Condition	500	3	100	1,247	1,202	3,750
Car Audio	500	3	100	2,512	1,293	3,700
Mud Guard	1500	0.5	300	7,114	**10,326**	16,932
Bed Liner	3000	0.5	1000	17,615	24,266	29,411
Floor Mat	2500	0.5	1000	9,384	14,972	25,041
Alloy Wheel	1000	0.5	300	5,337	5,933	8,319
Fog Lamp	500	0.5	100	2,708	3,264	4,741
Muffler Cutter	15000 / 20000	1	500	25,495	63,810	210,632
Air Purifier	1000	3	100	3,224	3,435	6,210
Back Sensor	1000	3	100	3,093	3,152	5,490

Since the demand of accessory parts increase continuously, the TM Company has to encounter with the shortage of supply. Table 3.13 summarizes the shortage number in units and the amount in Baht. There is a trend of shortage number that occurs with accessory part business unit of the TM Company.

Table 3.13 Shortage Number of Sample Items

	1st Year		2nd Year		3rd Year	
Item	**Shortage Number (unit)**	**Shortage Cost (baht)**	**Shortage Number (unit)**	**Shortage Cost (baht)**	**Shortage Number (unit)**	**Shortage Cost (baht)**
Air Con	19	38,532	0	0	3,904	7,917,312
Car Audio	0	0	0	0	1,509	2,716,200
Mud Guard	469	378,283	2,120	1,708,720	5,729	4,617,843
Bed Liner	1,220	890,843	4,855	3,544,393	9,936	7,253,037
Floor Mat	578	517,589	6,842	6,130,133	17,310	15,510,059
Alloy Wheel	150	109,107	204	148,716	1,485	1,082,565
Fog Lamp	138	102,534	283	210,269	1,354	1,006,022
Muffler Cutter	0	0	22,894	1,510,982	150,033	9,902,178
Air Purifier	0	0	0	0	2,453	2,528,699
Back Sensor	0	0	0	0	1,411	1,765,578
Total	2,574	2,036,888	37,198	13,253,214	195,124	54,299,492

For the period of study for 36 months, the TM Company lost their profit from the shortage supply because of the increasing demand of accessory parts. Demand of accessory parts has been increased continuously and dramatically although there was an economic downturn situation in 2009 as appears in the 2^{nd} year of this study.

3.5.2 Economic Order Quantity (EOQ) Approach

The objective of this approach is to determine the optimal level of cycle inventory that balance the costs of holding inventory with the benefit of economies of scale. This is a deterministic model in which all of parameters and variables are known and can be calculated. It is able to answer the questions of the business like how many orders to place to have optimal cycle inventory. The formula of EOQ can be written as:

EOQ of cycle inventory

$$Q^* = \sqrt{2SR}$$

H=Total unit inventory holding cost

S= Fixed Cost per Order

R= Annual demand or usage of the product (number of units)

Demand of air conditions in the first year is applied as the sample calculation of EOQ in order to have optimal cycle inventory:

$$\text{EOQ of Air condition at } 1^{st} \text{ year} = \sqrt{\frac{2 \times 350 \times 1{,}217}{673.60}} = 36 \text{ units per cycle order}$$

In order to have economies of scale in ordering, during the first year, the TM Company should place an order for air conditions at 36 units per order. The expected number of order per year of air conditions in the first year can be calculated as

$$\text{Expected number of Order} = \frac{\text{Annual Demand}}{\text{Order Quantity (EOQ)}}$$

$$\frac{1{,}217}{36} = 35 \text{ orders/ year or 3 orders/ month}$$

During the first year, the TM Company should place an order for air condition at 35 orders or 3 orders per month approximately. The equation to calculate the time between the orders of air conditions is expressed as follows:

$$\text{Time between order} = \frac{\text{Order Quantity (EOQ)}}{\text{Demand}}$$

$$\frac{36}{1{,}247} = 0.03 \text{ or every 11 days}$$

In a month, the TM Company should place an order of Air condition in every 11 days.

Table 3.14 is the summary of the results of EOQ, number of orders and time between orders of all selected items for this study.

Table 3.14 Summary of EOQ, Number of Order and Time between Order

	1st Year			2nd Year			3rd Year		
Item	**EOQ**	**Order per month**	**Time Between Order (days)**	**EOQ**	**Order per month**	**Time Between Order (days)**	**EOQ**	**Order per month**	**Time Between Order (days)**
Air Condition	36	3	11	35	3	11	62	5	6
Car Audio	52	4	7	37	3	10	63	5	6
Mud Guard	379	2	19	456	2	16	584	2	13
Bed Liner	256	6	5	300	7	5	330	7	4
Floor Mat	199	4	8	252	5	6	326	6	5
Alloy Wheel	141	3	10	148	3	9	176	4	8
Fog Lamp	108	2	15	118	2	13	143	3	11
Muffler Cutter	1356	2	19	2146	2	12	3899	5	7
Air Purifier	118	2	13	121	2	13	163	3	10
Back Sensor	126	2	15	127	2	15	167	3	11

Once Economic Order Quantity (EOQ) was applied to the selected sample items, it helps TM Company to have a systematic ordering to the suppliers. The TM Company will know how much quantity that should be purchased from the suppliers for each order. Meanwhile, from the expected demand, the TM Company also knows the quantity order per month and the interval of order placing to the suppliers.

3.5.3 Safety Inventory Level and Re-Order Point Determination

The assumption of EOQ model is that the stockout is not allowed and is not able to handle the uncertain demand. Therefore, the safety inventory is necessary to be considered as a buffer against the uncertain demand. There are two approaches on how to establish safety inventory. The first approach deals with known stockout cost and the second approach deals with unknown stockout cost.

In this case, the stockout cost is unknown. Thus, the service level should be set up to determine safety inventory levels and reorder points. The components for calculating safety inventory and reorder point consisting of:

<u>Demand</u>

- Demand (R) = the unit flow during a period of time
- Mean of Demand *(R)* = average value of demand in each year
- Standard Deviation of Demand (σR) = the variation of demand that deviates from the average value

<u>Lead Time</u>

- Lead Time (L) = the time between order is placed until the arrival of the order
- Mean Lead Time *(L)* = average value of lead time
- Lead Time Demand (LTD) = the total demand during replenishment lead time
- Mean Lead Time Demand *(LTD)* = Mean of Lead Time *(L)* x Mean of Demand *(R)*
- Standard Deviation of Lead Time Demand (σLTD) = $\sqrt{L} \times \sigma R$

Z Value = standard normal random variable

The sample calculation of above required components of air conditions in the first year can be expressed as:

Mean Demand *(R)* = $\frac{\Sigma \text{ Demand per week}}{52}$ = 23.51

Standard Deviation of Demand (σR) = 10.34

Mean Lead Time *(L)* = 12 weeks

Mean Lead Time Demand *(LTD)* = 23.51 x 12 = 282.12

Standard Deviation of Lead Time Demand (σLTD) = $\sqrt{12}$ x 10.34 = 35.82

The desired service level of the TM Company at 80% is determined to be the indicator to calculate the level of safety inventory and reorder point. It is measured by the probability that the actual lead time demand will not exceed the reorder point. Increasing Service level increases the required safety inventory.

The sample calculates the safety inventory and reorder point for a given service level at 80%, 85%, 90%, 95% and 99%. These probabilities provide a different Z value according to the Standard Normal Distribution table.

The formulae to calculate safety inventory and reorder point at a service level of 80% can be expressed as:

Safety inventory = Z x σLTD

= 0.85 x 35.82

= 30.45

Reorder point = (demand x lead time) + (Z value x I L)

= (23.51 x 12) + (0.85 x I12)

= 285.07

Table 3.15 illustrates the calculation of level of safety inventory and reorder point of Air conditions in the first year.

Table 3.15 Calculation of Safety Inventory and Reorder Point of Air condition

Service Level	Z Value	Safety Inventory	**ROP**
80%	0.85	30.45	285.07
85%	1.04	37.25	285.72
90%	1.28	45.85	286.56
95%	1.65	59.10	297.27
99%	2.33	83.46	290.19

It is a logical issue if the TM Company would like to have a high service level to supply the accessory parts. The safety inventory and reorder point has to be high respectively. The summary of safety inventory and reorder point of all items are demonstrated below.

Table 3.16 Summary of Safety Inventory and Reorder Point

	1st Year		2nd Year		3rd Year	
Item#	Safety Stock	ROP	Safety Stock	ROP	Safety Stock	ROP
Air Condition	30	285	49	280	87	868
Car Audio	60	572	29	301	72	857
Mud Guard	38	270	36	398	82	652
Bed Liner	115	666	128	935	180	1132
Floor Mat	62	355	123	577	152	964
Alloy Wheel	47	203	40	229	63	321
Fog Lamp	24	103	25	127	34	184
Muffler Cutter	294	1926	1792	4910	2053	16050
Air Purifier	40	733	44	796	67	1436
Back Sensor	54	703	45	730	100	1270

3.6 Inventory Cost Measurement

Safety inventory and reorder point numbers were determined and put into the Microsoft Excel which is selected as a simulation tool for calculation of the inventory level. Inventory costs should be provided to measure the performance of this simulation. This study is concerned with shortage and carrying cost that is to be compared to trade-offs. The calculation of To-be inventory carrying cost of air conditions during the first year is illustrated as follows:

Carrying cost = Average Inventory x Unit Cost x Annual Carrying Cost per unit

= 312 x 13,472 x 5%

= 4,410,281 baht

Table 3.17 Summary of Inventory Carrying Cost

	1st Year		2nd Year		3rd Year	
Item	As **Is Holding Cost (baht)**	**To Be Holding Cost (baht)**	**As Is Holding Cost (baht)**	**To Be Holding Cost (baht)**	**As Is Holding Cost (baht)**	**To Be Holding Cost (baht)**
Air Con	3,989,953	4,410,281	6,857,551	4,289,966	9,754,769	10,582,582
Car Audio	3,388,291	3,511,355	7,942,313	5,005,029	4,660,247	4,550,236
Mud Guard	82,166	138,587	272,160	298,327	337,958	479,415
Bed Liner	3,608,300	3,339,928	1,461,651	1,732,567	458,755	436,241
Floor Mat	1,689,122	2,395,843	347,921	397,044	2,218,931	2,359,186
Alloy Wheel	1,282,158	957,315	1,152,305	1,034,280	738,786	914,440
Fog Lamp	386,697	296,998	394,379	252,979	378,529	543,848
Muffler Cutter	473,161	433,051	434,711	644,023	481,751	433,398
Air Purifier	1,112,312	1,486,519	1,098,450	1,708,527	1,155,966	1,629,319
Back Sensor	814,904	998,056	815,182	924,972	809,205	950,418
Total	16,827,063	17,967,932	20,776,623	16,287,714	20,994,897	22,879,083

The calculation of shortage cost will be calculated per order cycle. The shortage of air conditions in the first year of As-is situation can be described with a formula as below:

Shortage cost = Average shortage number per order cycle x profit per unit

= 19 units x 2,028 baht

= 38,532 baht

Table 3.18 Summary of Inventory Shortage Cost

	1st Year		2nd Year		3rd Year	
Item	As **Is Shortage Cost (baht)**	**To Be Shortage Cost (baht)**	**As Is Shortage Cost (baht)**	**To Be Shortage Cost (baht)**	**As Is Shortage Cost (baht)**	**To Be Shortage Cost (baht)**
Air Con	38,532	0	0	0	7,917,312	19,357
Car Audio	0	0	0	0	2,716,200	0
Mud Guard	378,283	15,234	1,708,720	0	4,617,843	0
Bed Liner	890,843	45,240	3,544,393	91,250	7,253,037	0
Floor Mat	517,589	16,520	6,130,133	0	15,510,059	0
Alloy Wheel	109,107	0	148,716	0	1,082,565	28,952
Fog Lamp	102,534	0	210,269	0	1,006,022	0
Muffler Cutter	0	0	1,510,982	1,498,146	9,902,178	4,942,278
Air Purifier	0	0	0	0	2,528,699	250,533
Back Sensor	0	0	0	0	1,765,578	0
Total	2,036,888	76,994	13,253,214	8,077,700	54,299,492	5,241,120

The last component of inventory cost is ordering cost which can be calculated from ordering cost per order multiplied by the number of orders.

Table 3.19 Summary of Ordering Cost

	1st Year			2nd Year			3rd Year		
Item	Order per month	Ordering Cost per order (baht)	Total Order Cost (baht)	Order per month	Ordering Cost per order (baht)	Total Order Cost (baht)	Order per month	Ordering Cost per order (baht)	Total Order Cost (baht)
Air Con	3	350	1010	3	350	992	5	350	1752
Car Audio	4	350	1419	3	350	1018	5	350	1723
Mud Guard	2	350	548	2	350	660	2	350	845
Bed Liner	6	350	2009	7	350	2358	7	350	2596
Floor Mat	4	350	1373	5	350	1734	6	350	2242
Alloy Wheel	3	350	1106	3	350	1166	4	350	1381
Fog Lamp	2	350	732	2	350	804	3	350	969
Muffler Cutter	2	350	548	2	350	867	5	350	1576
Air Purifier	2	350	800	2	350	826	3	350	1111
Back Sensor	2	350	719	2	350	726	3	350	958
Total			**10,264**			**11,150**			**15,151**

3.7 Result Analysis and Summary

Forecasting methodology is important to many functions in business especially in the inventory management in which the business has to predict the future demands in order to efficiently plan and control on hand and upcoming amount of inventory. The nature of forecasting could be in accurate but if the business is able to predict the demand as close as the actual, it will be benefit for the business to plan its further operation.

By focusing on the inventory management, an efficient forecasting helps the business to plan the inventory levels which benefits by low level of carrying costs and ability to use the saving cost to invest for further projects. This study focuses on the demand of selected items and applies the different forecasting models and finally selects the model that provides the lowest forecasting error. The result of applying these forecast model benefits the TM Company to reduce forecasting errors from 50-100% to 13-45%. Then the study proceeded to study the inventory planning to have the availability product for uncertain demand with an optimal inventory level. The approach as EOQ, safety inventory model and reorder point determination were applied in this session. The results indicated that the shortage cost is reduced. However, setting up the level of safety inventory makes the carrying cost of the company increase. At this point, the company has to consider the tradeoffs between the reductions of shortage supply number and increase of inventory levels.

CHAPTER IV

PRESENTATION AND CRITICAL DISCUSSION OF RESULTS

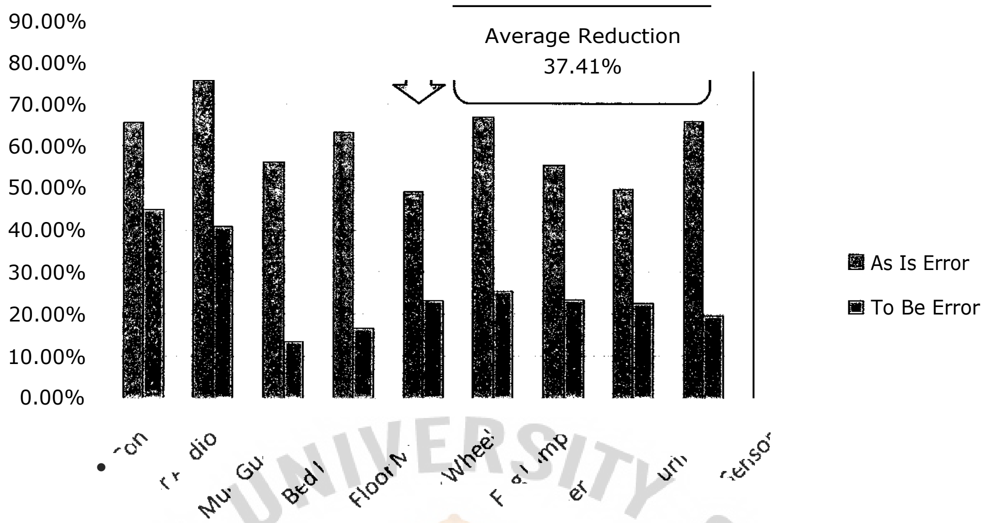
Basically, the questions of inventory planning are when to order and how many to order. The reorder point determination and economic order quantity are the answer to the above questions respectively. Meanwhile, in order to cope with the demand uncertainty, safety stock is an important factor that is a buffer against this situation. However, the efficient forecast model is also the important part that supports planning of inventory approach.

In Chapter III, demand of accessory parts of the TM Company was applied to the forecast models and Economic Order Quantity model (EOQ) to find out the solution to solve the problem of shortage supply. The different forecasting models were applied to ten items that were selected to be samples for this study. To serve the customer demand, product availability and manage inventory systematically, the calculation of EOQ and determination of safety inventory and reorder point are considered and studied in this case.

4.1 Applying Forecast Models

Demand forecasting is essential for the decision of business in order to consider future planning processes. This study illustrates how historical data of demand can be used as the input to the forecast models. The benefit of applying the forecast models in this study can be distinctly measured by the forecasting error approaches as MAD (Mean Absolute Deviation) and MAPE (Mean Absolute Percentage Error). The accuracy of forecasting was improved from current errors at 50-100% to only 14-45%. This is indicated in Figure 4.1.

Figure 4.1 Forecasting Error Comparison Between As-Is and To-Be

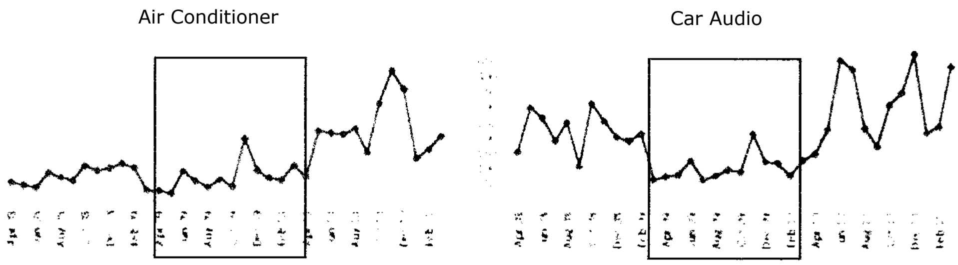


The average of reduction in forecast error of sample items is 37.41%. However, because demand patterns of each item is different; it is suggested to apply forecast models for each item individually. Although there is the suitable forecast model for each item where was selected, the forecast error had to be monitored occasionally to maintain the accuracy of forecasting.

Figure 4.1 indicates that although the forecast error of every item was obviously reduced, the errors of air conditions and car audios are still high. This situation can be analyzed by considering demand pattern of these items. Figure 3.3 indicates that demand pattern for these 2 items were dropped down at the same period of second year meanwhile, the demand pattern of the other items grow from the first year to second year and third year. This can be a limitation of the forecast model of time-series analysis which uses the historical data to make a forecast.

Figure 4.2 shows the period of demand turndown impact for the increase of forecast error of these two items

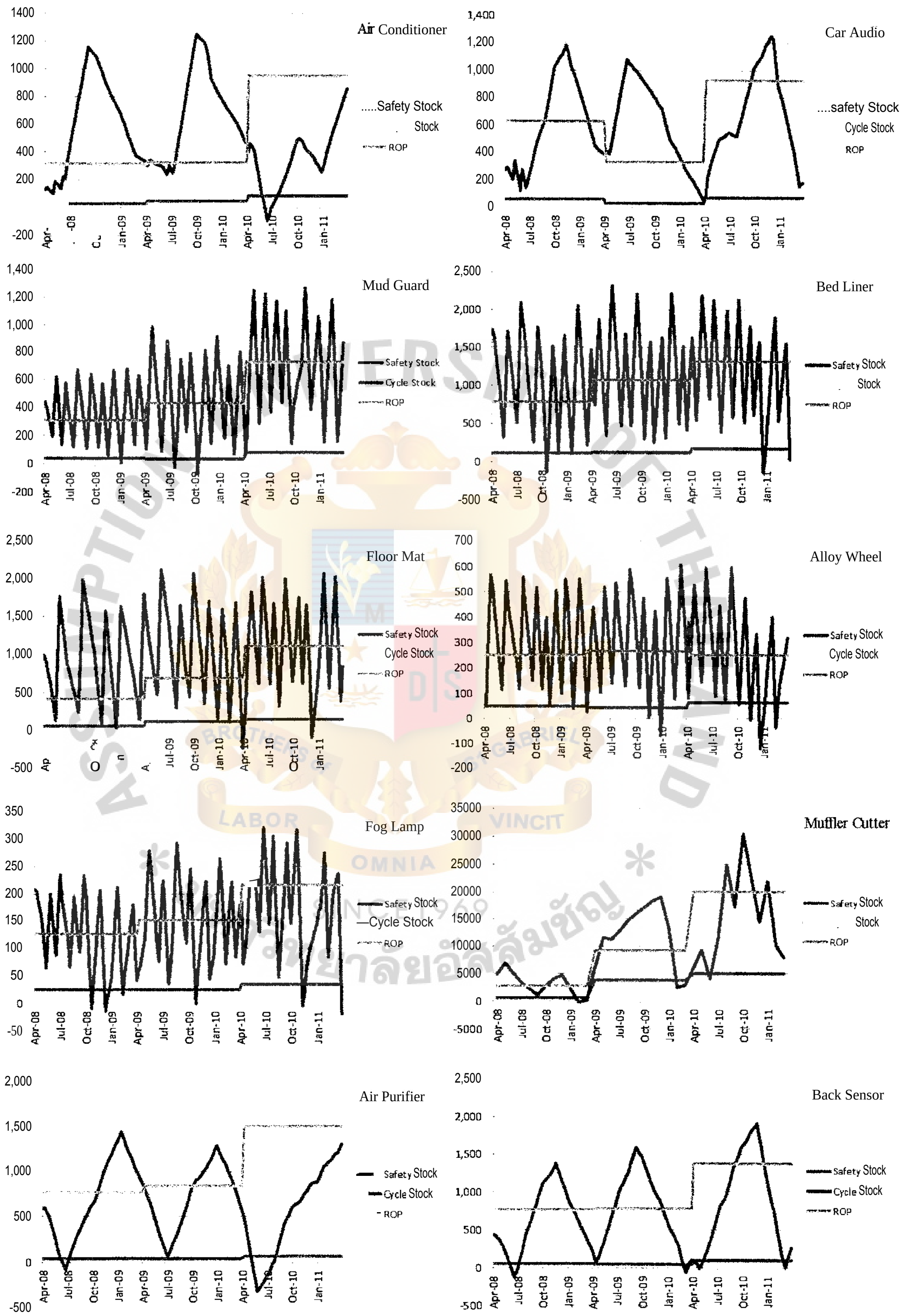
Figure 4.2 Demand Patterns of Air Condition and Car Audio



4.2 Safety Inventory and Reorder Point Determination

The determination of reorder point and safety inventory benefits the accessory part business unit of the TM Company because it helps to have systematic ordering and suitable safety inventory against the demand uncertainty. The key point of safety inventory determination is to apply the standard normal distribution table to the calculation. The number of service levels can determine the variable or Z Value to be applied in the calculation. The more service levels set up the more it affects the Z value and the number of safety inventories. Meanwhile, the reorder point calculation is applied to the result of safety inventory plus the demand that be expected to occur during lead time (lead time demand) of suppliers is also determined.

Figure 4.3 Safety Inventory Level and Reorder Point of each Sample Items



This study set the same service level for every sample items at 80%. Thus, it also means that the business might not able to have a hundred percent order filled rate for every order. Figure 4.2 illustrates the movement of cycle inventory during the period of the study. Upon the service level at 80%, air conditions, car audios and back sensors are the items that can have order filled rate at a hundred percent. Cycle stock of the remaining items fluctuates and often meets the safety stock level and eventually encounters the shortage situation. This result urges the business to set different service levels for each item which impacts to the increase of safety inventory to prevent the shortage supply.

One critical discussion would involve the reorder point determination of some items that are quite high when compared to the actual demand. Table 4.1 shows how the situation can be affect the long lead time of suppliers. Air conditions, car audios, air purifiers and back sensors are the items that have 12 weeks of lead time which impact the higher reorder point determination.

Table 4.1 Weekly Demand Compared to Reorder Point

	[redacted]		[redacted]		[redacted]		
Item	**Weekly Mean Demand**	**ROP**	**Weekly Mean Demand**	**ROP**	**Weekly Mean Demand**	**ROP**	**Lead Time (weeks)**
Air Condition	24	285	24	280	73	868	12
Car Audio	48	572	25	301	72	857	12
Mud Guard	135	270	199	398	326	652	2
Bed Liner	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Floor Mat	178	355	288	577	482	964	2
Alloy Wheel	[redacted]	203	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Fog Lamp	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Muffler Cutter	482	1926	1128	4910	4013	16050	4
Air Purifier	61	733	67	796	120	1436	12
Back Sensor	59	703	61	730	106	1270	12

4.3 Experiment of EOQ Model

The objective of applying EOQ model is to have the economic number of placing an order to suppliers. However, constrain of implementing EOQ model for this study is the result of EOQ number for some items is lower than the minimum order for suppliers.

Table 4.2 Minimum Order of Suppliers and EOQ Number

Item	Minimum Order	EOQ 1st year	EOQ 2nd year	EOQ 3rd year
Air condition	100	36	35	62
Car Audio	100	52	37	63
Mud Guard	300	379	456	584
Bed Liner	1000	256	300	330
Floor Mat	1000	199	252	326
Alloy Wheel	300	**141**	148	176
Fog Lamp	100	108	118	143
Muffler Cutter	500	1356	2146	3899
Air Purifier	100	118	121	163
Back Sensor	100	126	127	167

The disadvantage of the EOQ model is that the number of orders is fixed. This study is concerned with the limitations of EOQ model and attempt to apply the minimum order number of the supplier on those items.

4.4 Inventory Measurement

The result of setting up safety inventory benefits for the TM Company in terms of the availability of the goods and reduction of shortage cost are given table 3.18 and 3.19. The comparison of As-is and To-be shortage cost have been transformed into Bar Graph as given below:

Figure 4.4 Comparison of Shortage Cost

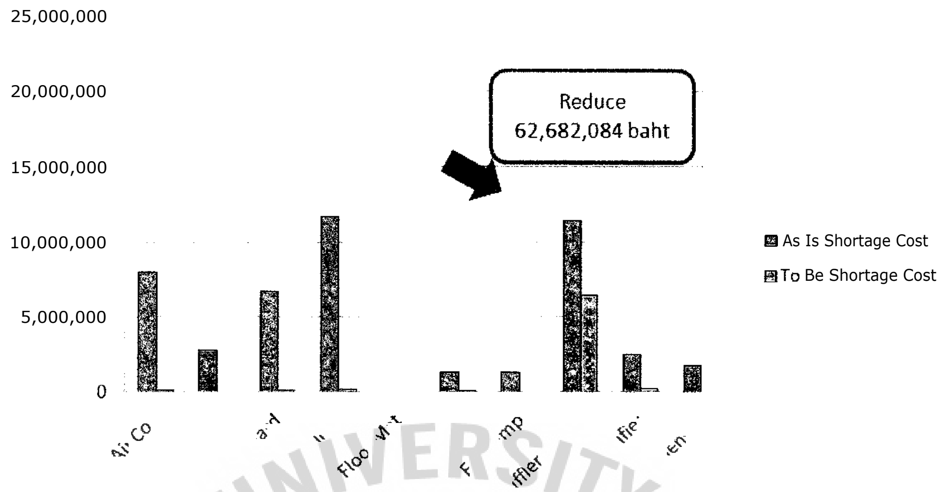
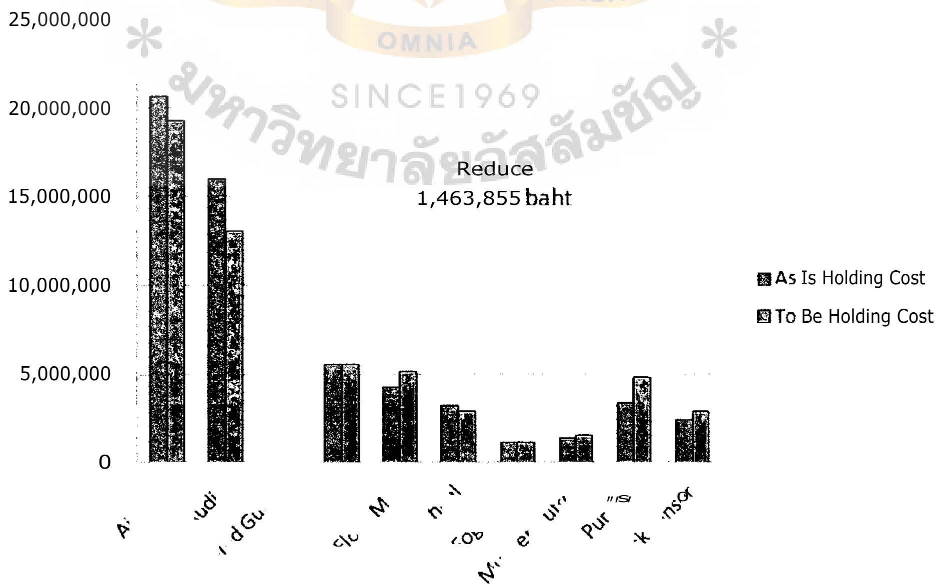


Figure 4.4 indicates the shortage cost of every item were reduced. There are only car audios, fog lamps and back sensors which do not have shortage number at all after the implementation. However, the total shortage cost of the sample items was reduced by 62,682,084 baht during the period of study. It means that TM Company have more available items for selling and have a chance to gain more profits. However, there are other considerations involving carrying more inventory which is the cause of the holding cost.

Figure 4.5 Comparison of Holding Cost



The implementation of inventory control in Microsoft Excel results shows the decrease of holding cost which is totally 1,463,855 baht. Every sample item does not result in the holding cost reduction. The high level of holding cost of air conditioners and car audios compared to other items could come from the high unit price of these two items. Those items are more expensive than the others.

4.5 Result Evaluation and Analysis

In conclusion, the results from implementing quantitative demand forecasting model shows that the percentage of forecast error was reduced in every sample item. This improvement makes the company formulate a better future plan not only in terms of inventory management but also for the other functions in the company.

The other objective of this study is to find out the solution to cope against the demand uncertainty. Implementing safety inventory, determination of reorder point and economic order quantity (EOQ) were applied to the historical data of demand to prove that these approaches are able to help the company to have a systematic inventory management whether in the point of ordering or storing the goods. The results were compared to the existing number of shortage and holding cost. The company can satisfy the demand of the customers by having available goods for them.

Microsoft Excel was applied as a simulation for running the inventory control, in some items of this study. Lead time of suppliers is a factor that affects the increasing inventory although order cycle was shortened. Long lead time from suppliers forced the company to store more inventories to prevent shortage supply as apparent in the higher holding cost of air purifiers and back sensors. The lead time of suppliers was 12 weeks. However, the result of tradeoffs between the shortage cost and inventory cost of these items could satisfy the company and the results could be accepted. Apparently, these approaches can answer the objective of this study on the inventory management.

These processes were operated in the QM for Windows and the simple Microsoft Excel program. The company places orders according to the reorder point in the volume of economic order quantity and sets the safety inventory to be a buffer against uncertain demand. However, the company should often update the demand and on hand inventory in order to have more accuracy and respond to the changes of demand which can occur. The supply planning needs to be revised to the situation.

Meanwhile, because this is the initial step of systematic demand forecast and inventory planning the company should arrange a training course to the staff about the logic of this system and inventory management skills. The business of automotive industry is growing continuously. The business of accessory parts is important unit that boosts the sales of volume and help gain profit. The company should develop this business unit and consider investing the technology to support the inventory activity such as RFID, e-procurement, etc.

CHAPTER V

SUMMARY FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

This final chapter consists of the findings, conclusions, theoretical and managerial implications and also recommendations for this study.

5.1 Summary of Findings

The main objective of this research is to study and select the suitable models of demand forecasting to support the inventory planning for accessory parts to encounter growth and uncertain demand of the accessory parts of an automotive industry. The summaries of findings of this research are as follows:

1. The study started with collection and gathering historical data of demand. The existing forecast numbers are implemented to gather with order numbers and movement of inventory. Then the ten critical items of accessory parts were selected as the sample items for this study.

2. Demand of the selected items was analyzed and plotted to review the demand patterns. The demand data was used as the input to the forecasting module in software simulation called QM for window to find the result of forecast and to measure the error of each models. The models that result in the least error number for each item were selected to be the appropriate forecast model. Each item might be applied with different forecast model.

3. In the section of inventory planning, the collected data was applied to economic order quantity (EOQ) model. The calculation results showed different number of EOQ for each item which gave the economic ordering cost.

4. In order to have the available goods to respond to the uncertain demand, the determination of safety inventory and reorder point is needed. The calculation of safety inventory applied the standard normal distribution table as a key to determine the variant of calculation of safety inventory level. The result of safety inventory can be used to calculate the reorder point which is the summation of safety inventory and demand during lead time.

5. The inventory consideration for this study is the improvement of shortage supply and measurement of inventory cost. The results of shortage cost have been reduced for all selected items of this study. Meanwhile, although holding cost of every items has not been reduced the tradeoffs between shortage cost and holding costs is still satisfies the company. The reduction of shortage cost is more than the increasing of holding cost. This is the benefit for the company to implement the models in the study.

5.2 Conclusions

There is consistency between demand forecast and inventory management which is important for the business and the supply chain network. This study indicates that if the company conducts both these parts and monitors them in a good condition, it is able to achieve much benefits from the inventory they are possessing.

Forecasts are critical part of business's function. Demand forecasts drive the production, capacity and scheduling. Moreover, it affects many functions in the business as well. A good forecast can help the business to protect itself from the uncertain demand. This study improves the forecasting method of the TM Company which results in the reduction of forecasting error. This study identifies the components of a demand forecast which consists of levels, trends and seasonality. Level measures the current deseasonalized demand. Trend measures the current rate of growth or decline in demand and seasonality indicates predictable seasonal fluctuation in demand.

Inventory accumulates whenever there is imbalance between supply and demand. This study indicates that the key component to have an efficient inventory control starts from a suitable ordering policy whether it is fixed order or periodic order policy. That order policy should have proper reorder point and optimal safety stock level to support its operation. A good control of inventory benefits the company in terms of reduction of shortage cost and holding cost. As per this research, during the period of study, the overall shortage and holding cost is reduced to 62,682,084 baht and 1,463,855 baht respectively. It means that the company is able to gain more profit and have opportunity for selling from the less shortage supply. More assets are gathered because of the reduction of holding cost of inventory those assets can be used to invest in the other projects which might have more profit.

5.3 Theoretical Implications

This study applied two parts of theory as it appears in the forecasting approach and inventory management techniques.

On the forecasting side, the selected qualitative forecasting method is used time series models that were applied to this study are useful for the study. It helps the company to have a systematic forecasting method and now less error than the traditional models. This also helps the inventory function to have a better planning on the future orders to cope with uncertain demand.

Decisions about purchasing under economies of scale involve trading off the fixed costs of ordering with the cost of holding the cycle inventory. This study investigates the economic order quantity which determines how much to order and the reorder point which determine when to order. The risk of stockout occurs after the reorder point is reached before the next coming order is received. The reorder point consists of the mean lead time demand plus the safety stock. Safety stock levels can be obtained by the minimization of the expected cost of holding and shortage cost. Safety inventory is influenced by demand uncertainty, replenishment lead time, lead time variability. As any one of them increases, the required safety inventory also increases.

5.4 Managerial Implications

This study improves the company involved in the supply planning management issues according to follows:

1. Achieving more accuracy of demand forecast in this study can help the company to make a better future planning and management not only for inventory planning but also other functions in the business such as financial, marketing, etc.

2. The suppliers might also benefit from the reliable forecasting data of the company as they can make a plan for supplying the accessory parts to the company on time and at right quantity.

3. When there is efficient inventory management and controllable inventory cost, it is affects the financial status of the company. Then the financial section is able to manage the assets that can be saved from inventory cost to invest in other projects.

4. A better inventory management helps the company to improve the responsiveness to the dealers and finally increase the consumer satisfaction.

5. The company could monitor the inventory status in order to protect stockout situations that may occur from uncertainty demand.

5.5 Limitations and Recommendations for Future Research

There are several future research opportunities to develop inventory approach and achieve more benefits from the efficient inventory management because of this study:

1. The company should be aware of the results of the forecast because the one important constrain of forecast is it is always wrong. However, the short term forecast can result in more accuracy than the long term forecast. Thus, when the forecast

model was applied to the item, the process of monitoring the actual demand should occur in order to adjust and revise according to the real situation.

2. Constrain of the supplier such as load size and pack size is needed to consider when applying EOQ model. These constrains were ignored from this study. To be ensured that that this model can be applied for more practical implementation, this issue should be added to the future study.

3. This study gathers the demand data of two locations of distribution center and one location of production lines. Then the consensus forecasting and the inventory approach is applied. Thus, the future studies should be concerned with the method to distribute the goods to each location. The expected model to be used for future studies is Distribution Requirement Planning (DRP). This approach can help the company to allocate and distribute the item according to the requirements of each location.

4. Due to the limitation of economic order quantity, periodic order policy should be considered for future studies. The results should be compared with the fixed order quantity policy in terms of fill rate and replenishment performance.

5. The company should monitor warehouse operations and movement of the goods beginning at receiving area, put away, storing, and issuing. Microsoft Excel or Microsoft Access is the interesting programs to be a tool for this purpose.

6. The issue of warehouse space utilization should be considered in case there is more inventory to be stored.

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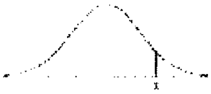
APPENDICES

APPENDIX A

The Standard Normal Distribution Table

Tables of the Normal Distribution



Probability Content from -oo to Z

Z	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	0.5000	0.5040	0.5080	0.5120	0.5160	0.5199	0.5239	0.5279	0.5319	0.5359
0.1	0.5398	0.5438	0.5478	0.5517	0.5557	0.5596	0.5636	0.5675	0.5714	0.5753
0.2	0.5793	0.5832	0.5871	0.5910	0.5948	0.5987	0.6026	0.6064	0.6103	0.6141
0.3	0.6179	0.6217	0.6255	0.6293	0.6331	0.6368	0.6406	0.6443	0.6480	0.6517
0.4	0.6554	0.6591	0.6628	0.6664	0.6700	0.6736	0.6772	0.6808	0.6844	0.6879
0.5	0.6915	0.6950	0.6985	0.7019	0.7054	0.7088	0.7123	0.7157	0.7190	0.7224
0.6	0.7257	0.7291	0.7324	0.7357	0.7389	0.7422	0.7454	0.7486	0.7517	0.7549
0.7	0.7580	0.7611	0.7642	0.7673	0.7704	0.7734	0.7764	0.7794	0.7823	0.7852
0.8	0.7881	0.7910	0.7939	0.7967	0.7995	0.8023	0.8051	0.8078	0.8106	0.8133
0.9	0.8159	0.8186	0.8212	0.8238	0.8264	0.8289	0.8315	0.8340	0.8365	0.8389
1.0	0.8413	0.8438	0.8461	0.8485	0.8508	0.8531	0.8554	0.8577	0.8599	0.8621
1.1	0.8643	0.8665	0.8686	0.8708	0.8729	0.8749	0.8770	0.8790	0.8810	0.8830
1.2	0.8849	0.8869	0.8888	0.8907	0.8925	0.8944	0.8962	0.8980	0.8997	0.9015
1.3	0.9032	0.9049	0.9066	0.9082	0.9099	0.9115	0.9131	0.9147	0.9162	0.9177
1.4	0.9192	0.9207	0.9222	0.9236	0.9251	0.9265	0.9279	0.9292	0.9306	0.9319
1.5	0.9332	0.9345	0.9357	0.9370	0.9382	0.9394	0.9406	0.9418	0.9429	0.9441
1.6	0.9452	0.9463	0.9474	0.9484	0.9495	0.9505	0.9515	0.9525	0.9535	0.9545
1.7	0.9554	0.9564	0.9573	0.9582	0.9591	0.9599	0.9608	0.9616	0.9625	0.9633
1.8	0.9641	0.9649	0.9656	0.9664	0.9671	0.9678	0.9686	0.9693	0.9699	0.9706
1.9	0.9713	0.9719	0.9726	0.9732	0.9738	0.9744	0.9750	0.9756	0.9761	0.9767
2.0	0.9772	0.9778	0.9783	0.9788	0.9793	0.9798	0.9803	0.9808	0.9812	0.9817
2.1	0.9821	0.9826	0.9830	0.9834	0.9838	0.9842	0.9846	0.9850	0.9854	0.9857
2.2	0.9861	0.9864	0.9868	0.9871	0.9875	0.9878	0.9881	0.9884	0.9887	0.9890
2.3	0.9893	0.9896	0.9898	0.9901	0.9904	0.9906	0.9909	0.9911	0.9913	0.9916
2.4	0.9918	0.9920	0.9922	0.9925	0.9927	0.9929	0.9931	0.9932	0.9934	0.9936
2.5	0.9938	0.9940	0.9941	0.9943	0.9945	0.9946	0.9948	0.9949	0.9951	0.9952
2.6	0.9953	0.9955	0.9956	0.9957	0.9959	0.9960	0.9961	0.9962	0.9963	0.9964
2.7	0.9965	0.9966	0.9967	0.9968	0.9969	0.9970	0.9971	0.9972	0.9973	0.9974
2.8	0.9974	0.9975	0.9976	0.9977	0.9977	0.9978	0.9979	0.9979	0.9980	0.9981
2.9	0.9981	0.9982	0.9982	0.9983	0.9984	0.9984	0.9985	0.9985	0.9986	0.9986
3.0	0.9987	0.9987	0.9987	0.9988	0.9988	0.9989	0.9989	0.9989	0.9990	0.9990