การพัฒนาการจัดการระบบสินค้าคงคลัง

ในธุรกิจชิ้นส่วนอะไหล่รถยนต์

นางสาว สุวดี สมุทรธนานนท์

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิศวกรรมศาสตรมหาบัณฑิต
สาขาวิชาการจัดการทางวิศวกรรม ศูนย์ระดับภูมิภาคทางวิศวกรรมระบบการผลิต
คณะวิศวกรรมศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย
ปีการศึกษา 2550

INVENTORY MANAGEMENT SYSTEM DEVELOPMENT IN AUTOMOTIVE SPARE-PART BUSINESS

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A Thesis Submitted in Partial Fulfilment of the Requirements
for the Degree of Master of Engineering Program in Engineering Management
The Regional Centre for Manufacturing Systems Engineering
Faculty of Engineering
Chulalongkorn University
Academic Year 2007

Thesis Title	INVENTORY MANAGEMENT SYSTEM DEVELOPMENT IN AUTOMOTIVE SPARE-PART BUSINESS
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Field of Study	Engineering Management
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การวิจัยมีวัตถุประสงค์เพื่อการพัฒนาการจัดการระบบสินค้าคงคลังในธุรกิจชิ้นส่วนอะไหล่รถยนต์ โดยได้มีการพัฒนาหลายประการด้วยกันอันได้แก่ การจัดการสินค้าคงคลังตกค้าง, การจัดการส่วนโกดังเก็บสินค้า, การพัฒนาระบบการบันทึกการซื้อสินค้า, การศึกษาและวิเคราะห์ปริมาณอุปสงค์ของอะไหล่รถยนต์ในแต่ละรุ่น โดยใช้อายุการใช้งานของรถเป็นเกณฑ์, การพยากรณ์อุปสงค์โดยใช้หลักสถิติศาสตร์, การใช้หลักการจัดการระบบคงคลังแบบประหยัดในการคำนวณหาจำนวนการสั่งซื้อสินค้าและจำนวนคงคลังที่เหมาะสม เพื่อแก้ปัญหาโกดังเก็บสินค้ามีพื้นที่ไม่เพียงพอ และเพื่อลดค่าใช้จ่ายในการจัดเก็บสินค้าอีกด้วย

จากการวิจัยพบว่า โกดังเก็บสินค้าได้ถูกจัดการให้มีสภาพแวดล้อมที่ดีขึ้นและมีการกำหนดกฎให้พนักงานทุกคนปฏิบัติตามเพื่อรักษาสภาพที่ดีของโกดังไว้ ระบบการบันทึกการซื้อขายสินค้าก็ได้มีการพัฒนาให้มีความถูกต้องและแม่นยำมากขึ้น ข้อมูลอุปสงค์ของอะไหล่รถยต์ในแต่ละรุ่นได้ถูกนำมาวิเคราะห์หาแนวโน้ม โดยพิจารณาอายุการใช้งานของรถยนต์เป็นเกณฑ์ จากนั้นได้มีการพยากรณ์อุปสงค์โดยใช้หลักการสถิติศาสตร์ และท้ายสุดได้มีการเสนอระบบการจัดการระบบคงคลังแบบประหยัดในการคำนวณหาจำนวนการสั่งซื้อสินค้าและจำนวนคงคลังที่เหมาะสม และสามารถประหยัดค่าใช้จ่ายคงคลังสำหรับอะไหล่ที่ยกตัวอย่างได้ถึง 64.7%

ศูนย์ระดับภูมิภาคทางวิศวกรรมระบบการผลิต
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ลายมือชื่ออาจารย์ที่ปรึกษา

4871647621 : MAJOR ENGINEERING MANAGEMENT
KEY WORD: INVENTORY MANAGEMENT SYSTEM

SUWADEE SAMUTHANANON : INVENTORY MANAGEMENT SYSTEM DEVELOPMENT IN AUTOMOTIVE SPARE-PART BUSINESS. THESIS ADVISOR : ASSOC PROF PARAMES CHUTIMA, PH.D., 125 pp.

The objective of this research is to improve the inventory management system in spare-part business.

The author studied how to improve inventory management in automotive spare-part business. Seven steps of inventory management system for this research are conducted to solve problems in ABC Company as poor storage space utilization, large number of stocks and high inventory costs. Warehouse management and inventory record system improvement are required for solving warehouse problems and more accuracy of stocks. Then, inventory policy is set to decide which part and when they should start to stocks. Trend of spare parts is another point to study trend of demand for demand forecasting. This research also presents how to select the suitable techniques for forecasting, and example of forecast demand in the next year. Optimal order quantity is also computed for appropriated replenishment order. Finally, dead stocks and sleeping stocks will be managed to improve storage space area and reduce inventory cost.

From the proposed systems, the result for inventory management system involves total inventory costs reduction of the example spare parts around 64.7% from actual system with trends of spare part demands analysis and more storage space area is also benefit from the system.

The Regional Centre for Manufacturing Systems Engineering
Field of study Engineering Management
Academic year 2007

Student's signature.....

Advisor's signature.....

ACKNOWLEDGEMENTS

I would like to express my gratitude to all those who gave me the possibility to complete this thesis. I want to thank my thesis advisor, Associate Professor Dr. Parames Chutima, for his guidance and helpful suggestions throughout the course of writing this thesis.

I have furthermore to thank Professor Dr. Sirichan Thongprasert and Associate Professor Jirapat Ngaoprasertwong for providing their invaluable time and support.

I also thank staffs in the Regional Centre for Systems Engineering for their help to process my thesis document during my working time.

Besides, I would like to thank my boss and colleagues for very kind assistance during my study leave period.

Thanks also to my friends for your help and encouragement.

Finally, I am very grateful for my mother, father and sister for their love and patience including great support and impressive encouragement during my master's degree study period.

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CHAPTER I

INTRODUCTION

1.1 Background of the Research

In the automotive spare-part business, an efficient inventory management is one of the key success factors. Because of the relatively low profit margins per unit on this business, poor inventory management can seriously undermine the business. The way that company can gain more profit is to reduce its cost and serve customers' demand as much as possible.

Regarding to the continuous growth of the automobile market in Thailand, there are many new car models were produced. As a result, a number of models in the market were increasing rapidly that affected the spare-part business. The more models the more variety of customers' demand. In this situation, efficient inventory management system play more important role than in the past.

1.2 Statement of Problem

ABC Company is an automotive spare-part dealer of X Company which is one of the well-known automobile brands with over 40-year history in Thailand. There are many car models have been produced under the brand of X Company.

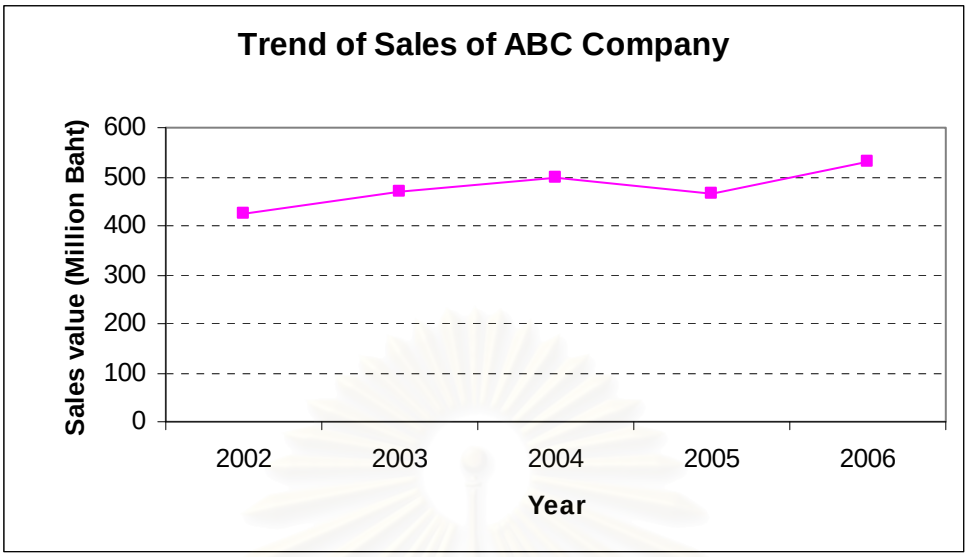
With a lot of vehicles under the umbrella of X Company in the market, the number of the spare parts is very large. Moreover, new car models are launched every year while average life time of Thai's vehicle is approximately 8-10 years, so the number of spare part is increasing every year. Therefore, it is much more difficult than the past to manage the inventory system.

In current situation, poor inventory system is one of important problem of ABC Company. Inventory management of ABC Company depends on an inventory staff that has experience for a long time in this business. Every decision are made base on the experience of him/her that sometimes may not be the proper way.

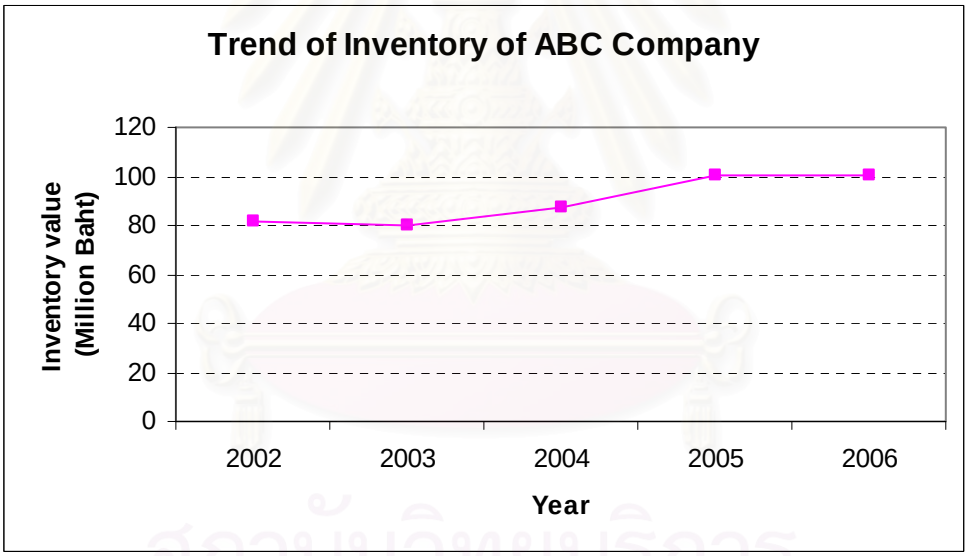
Due to increase of new car models and sales volume, since 1994, ABC Company has inventory level begun exceed the storage capacity. From that year, numbers of out-shelf items have increased every year. This affects many following problems occurring such as working environment, longer operating time for storing and finding parts, etc. Figure 1 shows example of current situation of inventory in ABC Company.

Figure 1.1 Current Situation of Inventory in ABC Company

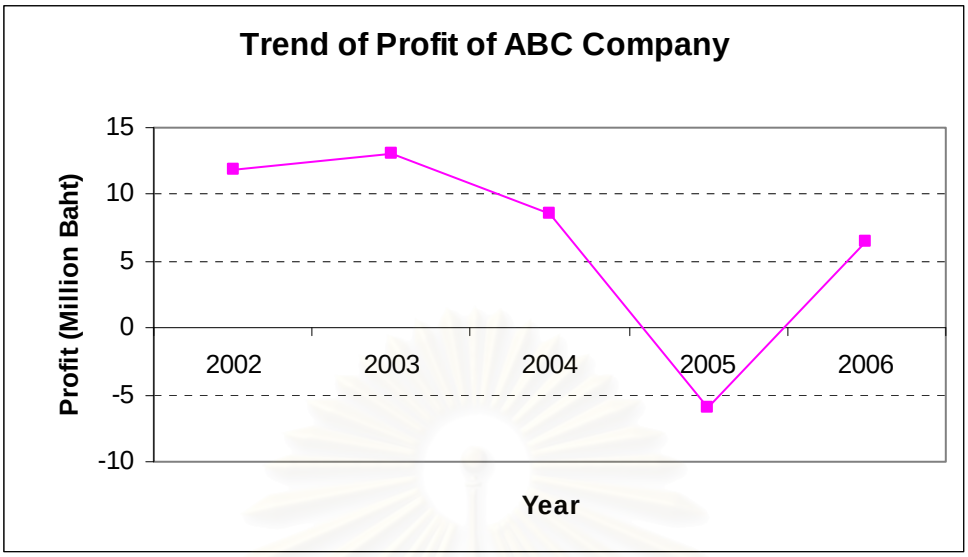
At the beginning of this problem, managers did not concern this situation because they considered in the point of view that sales increase means as more profit. Unfortunately, ABC Company has trend of profit decrease while sales volume has trend to increase. It can be implied that some costs are increase every year. Sales value and inventory value are shown in graph 1 and 2, while graph 3 shows about trend of profit during year 2002 to 2006.



Graph 1.1 Trends of Sales of ABC Company Year 2002 to 2006



Graph 1.2 Trend of Inventory Value of ABC Company Year 2002 to 2006



Graph 1.3 Trend of Profit of ABC Company Year 2002 to 2006

Causes of this problem could be assumed as:

- High level of dead stock and sleeping stock
- Inaccuracy in forecasting demand
- Stock data are not up-to-date and inaccuracy
- Customer purchasing condition
- Manager prefers the discount for the big lot size order
- High inventory cost
- There is no appropriate inventory management system

Above list causes might affect the inventory level and space utilization of company including cost and profit. Therefore, this research will focus on creating inventory management system for this company to be more efficient and appropriate to trend of demand for each category of car model based on period of model implementation and timing of model life.

1.3 Objectives

The purpose of this research is to develop an inventory management system for automotive spare-part business to improve efficiency of current situation of inventory.

1.4 Expected Benefits

This research will provide the solution, mainly focusing on inventory management system, for ABC Company to:

- Reducing inventory level for minimizing the problem about excess of storage space.
- Reducing related costs of inventory
- Gaining more profit by cost reduction
- Model as a guidance for inventory management system for forecasting spare part demand in other car models

1.5 Expected Results

The result of this research is the policy of inventory management system for ABC Company. This policy will improve the efficiency of inventory level and space utilization that can reduce out-shelf problem and cost of inventory to the company.

1.6 Scope of the Research and Assumption

This research will involve only the study of selected three car models from X Company's brand to analyze trend of demand of spare parts based on period of implementing time. For each car model, selected spare parts with different characteristic of demand will be analyzed to find the solution. The assumptions of this research may be listed as below.

1. This research focuses on one brand of car models from X Company
2. Historical data are reliable
3. There are no any external factors that might affect to demand-supply which are outside of those occurred in the period of historical data
4. Price of spare parts is remaining constant in considered period
5. All related costs are constant in considered period

6. Car sales volume of other car models of X Company have trend same as historical data

1.7 Methodology

This research will focus on creating the model of inventory management system by:

- Conducting dead stock management for better space utilization and inventory cost reduction
- Arranging warehouse system to improve for more efficiency of storage space utilization
- Improving inventory record system for more accuracy
- Analyzing selected three car models based on different period of implementing time which may affect to trend of spare part demand
- Selecting inventory control systems which are suitable for characteristic of spare parts

1.8 Research Procedure

1. Study and collect data of sections below:
    - Demand
    - Lead time of receiving parts from distributor
    - Sales volume
    - Quantity of inventory
    - Related cost: ordering cost, holding cost, etc.
2. Analyze data and summarize the problems of each section
3. Create the solutions of problem by utilizing the engineering management knowledge
4. Design and implement the inventory management system to the company
5. Arrange and collect the progressive of policy.
6. Summarize and evaluate the result of the policy.

7. Prepare the thesis report.
8. Attend the thesis examination

1.9 Research Schedule

The proposed schedule of this research is shown in table 1.1.

Table 1.1 Thesis Research Schedule

Year 2007	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
1. Study and collect data.								
2. Analyze data and summarize problems.								
3. Create solutions								
4. Design and implement the policy to the company								
5. Arrange and collect the progressive.								
6. Summarize and evaluate the result.								
7. Prepare the thesis report								
8. Thesis examination								

CHAPTER II

LITERATURE REVIEW

2.1 Definition of Inventory

Inventory is one of important part of the business for both products as goods and services. Raw materials, component parts, tools, stationary, finish goods, etc. are in the scope of inventory. Inventory of the business does not only express as things that are held in the warehouse, but it also presents in balance sheet and affects directly to profit.

2.2 Purpose of Inventory

There are several purposes for inventory in the business which can be described as below.

Minimizing fluctuations in demand: Customer's demand is difficult to accurately forecast. Inventory helps to keep goods enough for customer while the good inventory management should also concern on effective cost.

Unreliability in supply: Inventory prevents problems from unreliable suppliers in product receipt. In business, it is possible that company encounter to delay receive products from suppliers. To prevent late delivery to customers, most companies have stocks of goods.

Predictability: Production plan for manufacturing business is required the certain numbers of inventory. Raw material and component parts control are directly related to manufacturing plans. Buffer stocks or safety stocks is also important to prevent to stop the production process because of shortage of materials.

Lot size discount: Some suppliers may offer the more discount for big lot size purchase. It is necessary to concern carefully about comparing the profit from discount and carrying cost of inventory.

Ordering cost reduction: In addition to carrying cost of inventory, ordering cost is also needed to consider when buying products. One time ordering products have expenses which have to pay for purchasing products such as transportation fee. Lower times of order mean low cost of ordering as well.

2.3 Dead Stock or Obsolete Stock

Dead stock means stock items that remain in inventory for long period of time without any moving for sales. These stock can affect to company in several terms that can be clarified as below.

2.3.1 Effect of Dead Stock

It can be described the effect of dead stock to inventory as:

Effect in financial statement: In Balance Sheet, inventories have to be included to show in the sheet and computed for profit calculation.

Effect for space utilization: Other than effect in term of direct money of dead stock, space for keeping these stocks is also considered. It can be calculated to show in term of indirect money with two simple methods as:

- Term of area of utilized space – calculating in term of length and width of one item can be shown in occupied area of space.
- Term of volume of utilized space – calculating in term of length, width, and height of one item can be shown in occupied volume of space.

Effect in labor and machine utilization: Moving stock items or relocation to arrange space utilization for more efficient to keep other stocks have to concern to be cost. Labors and machines for operating relocation should be calculated based on labor wage and time, and maintenance fee and time to use machine. Then, indirect cost of dead stock in this term will be shown for cost calculation.

2.3.2 Method for Dead Stock Reduction

Several methods for eliminating dead stocks are proposed with many ways as:

- **Sales with discount**

  Discount is one of the most famous options to reduce dead stocks.

- **Convince salespeople with special commission**

  Special commission for salespeople can convince them to try to sales these stocks.

- **Use for promotion**

  It can be used for promotional purpose such as to be free sample for customers when they purchase other products or purchase big lot of products.

- **Return to supplier with lower value of initial**

  Some products can be returned to supplier in case of long time stock keeping, but the lower price will be paid for these items.

- **Donation**

  Donation is another option to reduce stocks. It involves the good image of company.

- **Auctions**

  The stocks will be converted to money by auctions, but it may have lower value than initial price.

- **Disposal**

  The easiest way to eliminate dead stocks is dispose them.

2.4 Warehouse Management

2.4.1 Space Utilization Concept

It is possible that concept of inventory for each company is different from each other, so there are many types of locator system for arrange stocks. Muller (2003) summarized main factors for consideration about locator system shown as below.

- Space availability
- Location system
- Product characteristics
- Storage methods

- Product dimension
- Shape of items
- Weight of items
- Labor availability
- Equipment
- Information system support

Muller also explained type of locator system that can be summarized as table 2.1.

Table 2.1 Type of Locator System

Type of Locator System	Concept	Impact on Space	Advantage	Disadvantage
Memory	▪ Record and manage stock with memory by human (stock keeper) ▪ No category for stock arrangement ▪ Use for limited variety, size and storage number of items	▪ Most complete space utilization ▪ Use small space area	▪ Simple ▪ Low cost ▪ Full space utilization	▪ System operating based on human ▪ Limited variety of stored items ▪ Possible to not find some items ▪ Possible to item lose
Fixed Location	▪ Fixed location for items	▪ Use large space area	▪ Easy to find items ▪ Easy to receive and stock replenishment ▪ Sequential stock arrangement ▪ Product category arrangement ▪ Short training time for new staff	▪ Honeycombing* ▪ Space planning calculation based on total volume of all items at that time ▪ Added new item or subpart storage affect to relocate all items (collapse of space)
Zoning	▪ Same as fixed location system but arrange based on product category	▪ Use large space area	▪ Suitable for special product characteristic ▪ Easy to find items ▪ Easy to receive and stock replenishment ▪ No collapse of space ▪ Flexibility of space planning	▪ Require efficient handling for complicated zoning utilization ▪ Honeycombing* ▪ Require update stock movement
Random Location	▪ Like memory system but more efficient management ▪ Apply record system to manage stock	▪ Complicated space planning (calculate based on volume of space)	▪ Maximization of space ▪ Know product location for all items	▪ Require constant update stock movement ▪ Complicated system
Combination	▪ Combine fixed and random system	▪ Some area for fix and some area for random arrangement	▪ Easy to find ▪ Maximization of space	▪ Complicated space planning system

* Honeycombing means that there are empty spaces in storage location which is involved from fixed location system. Those empty spaces occur from available spaces for around fixed location of each stock item.

2.4.2 Warehouse Improvement

One of the most popular methods for basic warehouse improvement is Japanese 5S concept. The 5S method has been developed in Japan at Toyota. 5S stands for five steps of improvement with Japanese language as Seiri, Seiton, Seiso, Seiketsu, Shitsuke. In English, it also stands for five steps as:

Sorting is categorizing remaining items as need or no need to use and eliminate unnecessary items.

Setting in Order is setting need items with systematical location.

Shining means cleaning the location and checks all equipment for keeping as good condition.

Standardizing is generating the standard for everyone to easy to remember and understand what should do to maintain good condition.

Sustaining is continuous improvement to how to keep the standard for everyone.

2.5 Forecasting

2.5.1 Demand Behavior

Demand can be found with main three types of demand behavior as trend, cycle and seasonal demand. Trend is the gradual movement with up or down in direction. Sometimes, random variation is included in this type of behavior, so it affects shape of graph. Cycle is movement of graph of demand with up-and-down and repeats its pattern. Some products have sales volumes depending on other factors such as the economy, the events, etc. Final type is seasonal pattern. Its sales volumes depends on the factors which occurring as the period such as weather, festival, holiday, etc. The below figures are shown types of demand behavior.

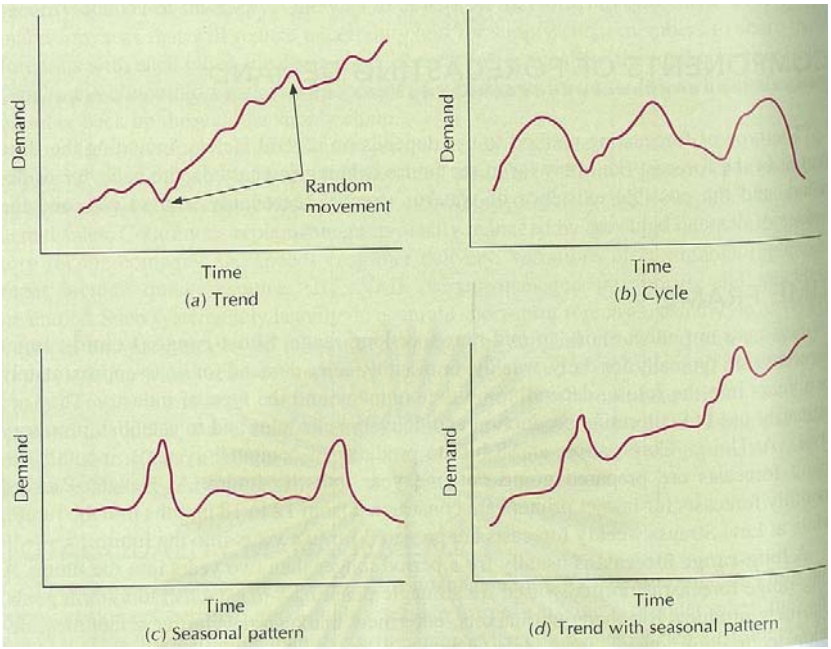


Figure 2.1 Types of Demand Behavior

2.5.2 Forecasting Methods

There are several techniques to forecast demand. Two basic types of forecasting methods will be discussed as:

2.5.2.1 Qualitative methods

This methods use judgmental approach and experimental approach. There are many techniques are applied for this method as:

- ❖ Market Research
- ❖ Historical Analogy
- ❖ Delphi Methods

2.5.2.2 Quantitative methods

This method is statistical techniques by using historical data of demand to predict the future demand. There are two main groups of forecasting techniques as *time series model* and *regression or casual model*.

Time Series Model

There are many techniques to forecast demand based on time period with historical data use. Below lists are examples of forecasting techniques.

- Moving Average
- Weighted Moving Average
- Single Exponential Smoothing
- Double Exponential Smoothing (Holt's Methods)
- Triple Exponential Smoothing (Winter's Methods)
- Etc.

Casual Model

Regression model or casual model is forecasting technique to find the relationship between demand and factor and convert in term of mathematical equation.

2.5.2.3 Moving Average

The moving average method is the simple demand forecasting. Forecast demand is computed from average actual demand for specific periods such as 3 months and 6 months. The longer the period, the more accurate forecast demand. The formula of moving average is:

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

where n = number of periods in the moving average
Di = demand in period i

2.5.2.4 Single Exponential Smoothing

This technique is also popular to forecast demand. It is to calculate demand by weighting the most recent data for strong effect. The weighted value is

called smoothing constant. It has normally value between 0 and 1 to give the weight for recent data. It means that if the last data is given much strong, the smoothing constant is closed to 1. The formula of singe exponential smoothing is:

$$F_{t+1} = \alpha D_1 + (1-\alpha)F_t$$

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

Dt = actual demand in the present period

Ft = the previously determined forecast for the present period

α = a weighting factor referred to as the **smoothing constant**

2.5.2.5 Double Exponential Smoothing

Double exponential smoothing or adjusted exponential smoothing is the techniques to use trend adjustment factor combining with single exponential smoothing method. The formula of double exponential smoothing method is:

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

where AF_{t+1} = the forecast from double exponential smoothing for the next period

F_{t+1} = the forecast from single exponential smoothing for the next period

T = an exponential smoothed trend factor

The trend factor can be computed from single exponential smoothing with use smoothing constant value for trend asβ.

$$T_{t+1} = \beta(F_{t+1} - F_t) + (1-\beta)T_1$$

where T_1 = the last period's trend factor

β = a smoothing constant for trend

The β factor has value between 0 and 1. It weights the most recent data with trend concern. β value and α value usually are not equal.

2.5.3 Forecast Accuracy

It is impossible that the forecast will be completely accurate, so the measurement of accuracy level is required to check error happen. Several measures of forecast error are proposed for calculation. The most popular technique with the simplest method is mean absolute deviation (MAD).

Mean absolute demand (MAD) is an average of error which represent from the differences between forecast demand and actual demand. The formula of MAD is shown as:

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

where t = the period number
Dt = demand in period t
Ft = the forecast for period t
N = the total number of periods
| | = absolute value

In order to find the suitable forecasting technique for each group of data, the less MAD value means the less error. Therefore, the techniques that give the MAD value as the lowest value should be the most appropriated forecasting method.

2.6 Inventory Control System

Customer demand is important for inventory management. It is because to meet the demand, effective inventory control system should be conducted with accurate demand forecasting. Generally, demand for inventory items can be divided into two types as independent demand and dependent demand. Independent demand usually means the

finished products which do not depend on any internal factors. While dependent demand refers to materials or component parts which depends on demand of finished products and process planning.

2.6.1 Inventory Costs

The fundamental costs of inventory can be described as two types as:

Carrying Costs

Carrying costs are the costs of keeping items in inventory. Related items or issues which are related to hold stocks will be considered as carrying cost. The examples of carrying costs are composing of:

- Facility for storage of stocks such as building rental fee, electricity for lighting, security fee, insurance, tax, etc.
- Storage equipment
- Inventory labor cost
- Interest of loan

Carrying cost normally consider per unit on annual basis, so overall carrying cost can be found by multiplying the number of stocks by carrying cost for one unit.

Ordering Costs

It is the costs of order products from suppliers to replenishment. It is considered as per order of products. Examples of related issue for ordering costs are composing of:

- Transportation cost
- Communication cost of order such as telephone, fax, internet, etc.

Normally, carrying costs and ordering costs has relation in different direction. Low ordering costs involve high carrying costs. Large lot size of products purchasing means the company can decrease times of order. On the other hands, more times of purchasing products means smaller lot size will be bought, so fewer stocks are kept in the warehouse.

Total inventory costs can be calculated by summarize carrying costs and ordering costs. Total costs can be computed by using the formula as:

$$TC = \frac{C_o D}{Q} + \frac{C_c Q}{2}$$

where Q = optimal order quantity
Co = ordering cost per order
D = average annual demand
Cc = carrying cost per unit

2.6.2 Economic Order Quantity Models (EOQ)

Economic order quantity model or fixed-order quantity is the technique to find the optimal order quantity to balance carrying costs and ordering costs for minimum total costs. The assumptions for this model are:

- Demand is known and constant for concern period
- No shortage products
- Leadtime for ordering and receiving parts is constant
- Order quantity is receive at one time without backorder

Optimal order quantity is calculated from minimizing carrying costs and ordering costs by balancing them. The formula to find the optimal order quantity is:

$$\frac{C_o D}{Q} = \frac{C_c Q}{2}$$

$$Q^2 = \frac{2C_o D}{C_c}$$

$$Q_{opt} = \sqrt{\frac{2C_o D}{C_c}}$$

where Qopt = optimal order quantity

Therefore, the minimum total costs can be calculated by using optimal order quantity as:

$$TC_{\min} = \frac{C_o D}{Q_{opt}} + \frac{C_c Q_{opt}}{2}$$

2.6.3 Reorder Point

Optimal order quantity is known for how many the company should order products. And then, when the company should conduct the order for replenishment is also calculated to find the number of stocks indicating the point to order. The formula of reorder point is:

$$R = dL$$

where d = demand rate per period (daily)
L = lead time to receive order
SS = safety stock

Safety stock is the number of products in inventory for preventing stock out occurring. Safety stock can be computed with the formula as:

$$SS = z\sigma_d \sqrt{L}$$

where z = number of standard deviations corresponding to the service level probability (see appendix)
σ_d = the standard deviation of demand on the period (daily)

2.7 Journal and Other Literatures Review

There are many literatures were suggested about improvement of inventory management for more efficient. **Vitasek, Manrodt & Abbott (2005)** recommended the attribute of a lean supply chain for inventory can be identified as:

- Demand management capability
- Waste and cost reduction
- Process and product standardization
- Industry standardization adoption
- Cultural change competency
- Cross-enterprise collaboration

Topics of demand management, waste and cost reduction, industry standardization, and cultural change can be used to apply to distributor business to improve inventory management.

R. Crandall and W. Crandall (2007) provided several methods for physical inventory reduction for cost reduction in addition to inventory management system. It was focused into three types of area as reducing inventory used for making products, reducing indirect material, and using computer program for cost reduction. It can be summarized as:

Direct material reduction

- Lean production can reduce work-in-process but it is complicated to change process for improvement
- Modular product design can involve reducing the component parts but it can increase cost of development
- Mass customization can decrease finished goods but it requires system maintenance
- Inventory system with planning, forecasting and replenishment can reduce cost of transportation

- Record errors can be reduced by using accurate record system, but new record system with design and maintenance are required
- Supply chain management is very popular to improve all inventory management system, but it is necessary to have knowledge to manage complexity
- Reverse logistics can reduce waste, but it requires additional complicated processes
- Total quality management can decrease defects, but implementation cost may be high

Indirect material reduction

Several items of indirect materials can also affect to company's cost as inventory cost. Examples of reduction management can be described below.

- Using more efficient equipments, often checking vehicle performance, planning new routing of delivery and using TV conference for less traveling are reduction methods for reduce fuel consumption, but some costs of investments and maintenance may occur instead
- Facilities control is another method can decrease power consumption, but the investment cost is also needed to concern

Computer program use

There are many items can be changed to use computer system to help for inventory reduction.

- Using computer system as e-mail, digital book, and instant message note can reduce cost of paper and post-it
- E-payment and electronics tax form including using CD replacing paper training manual can also involve paper useless
- Using digital camera instead of film camera
- Changing from clay model making and testing actual products to using computer programs for product design and testing, but total cost of development should be concerned

Hedrick, Barnes, Davis & Whybark (1999) suggested successful inventory management in small business that involving balancing costs of inventory with the benefits of inventory. Other concern points are also including as maintaining a wide assortment stock, increasing inventory turnover, keeping stock low, obtaining low price by making volume purchase, and having adequate inventory on hand. The business has to make purchasing plan to determine appropriated needs for each time period. Recently, two approached inventory management, which are applied in many businesses, are Material Requirement Planning (MRP) and Just-in-time (JIT).

In term of inventory control, they recommended that there are several methods such as visual control, tickler control, click sheet control, and stub control (for retailer) to create adequate inventory control over inventory on order and stock. Moreover, there are existing computer systems to help for more feasible inventory control with point-of-sale terminal and off-line point of sales terminal.

Westwood (1999) suggested the appropriated inventory control system improvement for retail business as fashionable cloth with 40 retail outlets covering the North-West of England and the Midlands for case study. The retail's problem is about large number of stocks requests from their outlets, so he recommended four steps of problem solution as:

1. Forecast – exponential smoothing method was used to forecast the demand
2. Calculation of excess and requirement – the cover level as the ratio of present stock level to forecast demand for the following week was applied to calculate each shop's requirement and total requirement for overall shops
3. Planning the transfer – the characteristics of transfer for each shop was analyzed as an outgoing transfer, an incoming transfer, or no stock movement, and decided to set the system based on minimum transport cost
4. Making the transfer – implement the system to minimize the cost

Metersky & Kilgore (2004) suggested that total cost which is needed to be considered is composed of inbound transportation costs, outbound transportation costs, fixed and variable facility costs, and inventory carrying costs. Then, they advised four-step approach to improve inventory management as:

1. Analyze the root cause
2. Decompose the item data
3. Apply serious Math: demand variability, supplier lead time, fill rates
4. Continually refresh strategies

Krajewski & Ritzman (2002) explained about the inventory control system by comparing the advantages between P system (fixed-order period) and Q system (fixed-order quantity). The advantages of one system are implicitly disadvantages of the other one.

The primary advantages of P-systems are the following:

- Administration of the system is convenient.
- Order for multiple items from the same supplier may be combined into a single purchase order that could reduce ordering and transportation costs and may result in a price break from the supplier.
- The inventory position needs to known only when a review is made (not continuously, as in a Q system). However, this advantage is moot for firms using computerized record-keeping system, in which a transaction is reported upon each receipt or withdrawal.

The primary advantages of Q systems are the following:

- The review frequency of each item may be individualized. Tailoring the review frequency to the item can reduce total ordering and holding cost.
- Fixed lot sizes, if large enough, may result in quantity discounts. Physical limitations such as truckload capacities or materials handling methods also may require a fix lot size.
- Lower safety stocks result in saving.

In conclusion, the choice between Q and P systems is not clear cut. Which one is better depends on the relative importance of its advantages in various situations. Management must weigh each alternative carefully in selecting the best system.

In additions, 2 hybrid systems, control systems that merge some but not all the features of the P and Q systems, are introduced:

1. Optional replenishment system. A system used to review the inventory position at fixed time in intervals and, if the position has dropped to a predetermined level, to place a variable-sized order to cover expected needs.
2. Base stock system. An inventory control system that issues a replenishment order, Q, each time a withdrawal is made, for the same amount of the withdrawal.

They stated that regardless of the inventory system in use, record accuracy is crucial to its success. One method of achieving and maintaining accuracy is to assign responsibility to specific employees. A second method is to secure inventory behind locked doors or gates to prevent unauthorized or unreported withdrawals. Cycle counting is the third method. Class A items are counted most frequently. A final method, for computerized systems, is to make logic error checks on each transaction reported and fully investigate any discrepancies.

These methods can keep inventory record accuracy within acceptable bounds. Accuracy pays off mainly through better customer service, although some inventory reductions can be achieved by improving accuracy. A side benefit is that auditors may not require end-of-year counts if records prove to be sufficiently accurate.

Buxey (2006) explained in his journal, *Reconstructing inventory management theory*, to consider the suitable inventory management method for each type of business with different characteristics of demand. Several techniques were considered such as economic order quantity model (EOQ), material requirements planning (MRP), enterprise resource planning (ERP) and just-in-time concept (JIT). Q-systems and P-system as

fixed-order quantity and fixed-order period were focused in his research can be described as below.

Q-system is suitable for:

- Ordering truckloads
- Obtaining vendor's quantity discounts
- Obeying fixed capacity constraints
- Expensive units
- Critical items
- Lumpy demand
- Low demand
- Goods with erratic demand patterns or ordered infrequently

P-system is appropriated for:

- SKUs that are difficult to count
- Economical record maintenance
- Cheap items that do not warrant proper record keeping
- Smoothing clerical workloads
- Joint orders from common suppliers, especially where this facilitates quantity discounts or full truckloads
- Orders delivered on suppliers' routine visits
- Situations where it pays to use regular transport
- High demand items
- Cheap goods in high demand
- Expensive or high usage SKUs, which merit frequent orders and more clerical manpower than a Q-system needs
- Units with stable demand and moderate to low usage value
- Products in danger of obsolescence
- Perishable items
- Seasonal goods

Buxey also summarized four businesses cases and presented appropriated inventory management methods. W H Smith, the company as retail business with sales of newspapers, books, stationary, records, tobacco, etc. with 319 shops and 89 bookstalls and large numbers of stocks use ABC Classification concept for inventory control. Repco, the automotive spare parts with 231 retail branches and 93 repair service outlets, use fixed-order period for inventory control system. FJ Walker Foods, production-distribution operation for McDonald's Australian stores, apply the fixed-order quantity for inventory management same as Amway of Australia.

Goonatilake (1984) recommended several tools for application of inventories control techniques. Ordering method with using Re-Order Level (ROL) which is a function of rate of usage and order lead time. In addition to ROL, ABC Analysis is still suggested from him for inventory classification to select inventory items to greater control.

Lines (1996) recommended the demand forecasting to use in the business for improvement of stocks, delivery, and production. Several methods of forecasting cannot be used in the same matter. Detail of products and manufacturing should be concerned. In logistics, two types of decision making can be described as medium term concern with locating and size of warehouse including sources of supply, and short term concern as manufacturing, transportation and stocks. The forecasting method should be started from clear purpose and statement. And then, current situation and condition should be considered such as manufacturing’s facility, because it is related to forecast as the leadtime. Next, suitable forecasting technique should be selected based on historical sales data, and acceptable level of forecast error should be concerned as well.

Winston & Albright (2005) explained that regression method was used to forecast a variable by estimating its relationship with other variables, and extrapolation method used past data of a time series variable-and nothing else to forecast future values of the variable. These are methods which are recommended to apply for forecasting demand.

Rahul Tyagi (2002) explained that the efficacy of any forecasting package is dependent on how well it can utilize the sales history to predict future demand. Because different items have different demand patterns, the package should support a sufficient number of forecasting algorithms that cover all possible sales data representations. Time-series methods are the most common category of forecasting algorithms. Time-series techniques include methods such as moving average and exponential smoothing. Rahul also recommended a few tips for selecting the right forecasting package.

1. Begin by clearly delineating what you need from a forecasting package. This requires specifying:
    - Types of items being forecast.
    - Demand stream used for forecasting.
    - Promotional strategy to be used.
    - Volume of forecasts, calculated as the number of stores times the SKUs.
    - Frequency of forecasts and where in the hierarchy they should occur.
    - Link with your planning and execution systems.
2. Perform a high –level market scan to create a shortlist of relevant packages.
3. Go through a rigorous request for information stage before selecting packages for demonstrations.
4. Drive the demonstrations by asking vendors to demonstrate your unique business needs on their package.
5. Elicit a future roadmap for package from the vendors and have them clearly explain their process for adding functionality to the package.
6. Once a package or a set of package has been selected, conduct a functionality validation exercise.

CHAPTER III

PROCESS FOR RESEARCH

3.1 Research Methodology

There are 7 parts of methodology of inventory management system for this research to solve problems that occurred in ABC Company with main problem as poor storage space utilization, large number of stocks and high inventory costs. First, warehouse management is required to improve for solving the warehouse problems. Although ABC Company has the inventory flow system to control purchase-sale and stocks data in the computer system, the stocks database in that system are not up-to-date and useless. Therefore, inventory record system is necessary to improve for more accuracy of stocks data and support the proposed inventory control system. After that, inventory policy is important to set to decide which part and when they should start to stocks.

Trends of spare parts are another point which is needed to concern to study the trend of demand for demand forecasting. There are many techniques of demand forecasting. This research presents how to select the suitable techniques for forecasting, and calculate forecast demand in the next year based on trends of demand. And then, forecast demand will be calculated for finding the optimal order quantity to indicate how many parts should be order for replenishment. Finally, dead stocks and sleeping stocks will be managed to improve storage space area and reduce inventory cost.

3.2 Warehouse Management

First step of inventory improvement for ABC Company is to improve warehouse for better condition. Many activities are applied to solve problems which occurring in the warehouse of ABC Company.

3.2.1 Current Situation of Warehouse in ABC Company

Main problem of ABC Company's warehouse is unsuitable space utilization. Many problems that the company encounters can be listed as below.

- No appropriate receiving area for supporting 3 times part receiving
- Only 2 staffs are responsible for loading, receiving, checking, and arranging products on shelf
- Not enough space area to keep stocks, so excessive items from shelf are kept with untidy on the first floor
- There are many part numbers for each type of product, so it cannot be certain indicated of storage area on shelf
- Many dead stocks involve occupied space area

3.2.2 Current Locator System

ABC Company use locator system with both memory system and fixed location system. Almost same items were kept by group in same area but there was no category arrangement for each zone. All locations for stock arrangement are known by stock keepers who are responsible of those items.

3.2.3 Warehouse Improvement

ABC Company improves their warehouse management with methods as below.

3.2.3.1 Japanese 5S

Normally, ABC Company conducts 2 times of 5S on February (Chinese New Year) and at the end of the year together with annual stock check, but for conducting warehouse improvement, they decided to do 5S even though that timing is not both Chinese New Year and stock checking period. Detail of 5S can be concluded as below lists.

Sorting Dead stock were removed from shelf and eliminated by sales with high discount rate and disposal (detail in dead stock management section).

Setting in Order All products were set the locations on shelf for each item. ABC Company divide product items based on shape of parts and find suitable storage area for keeping with conditions as:

- Keep quantity of products as many as possible
- No damage during keeping
- Easy to bring from storage area

Another problem of storage space area is because of a lot of variations of part number for one product item, it is difficult to do the fixed storage area based on part number. As a result, adjustable storage boxes are made for separate variations of product item.

Shining Cleaning the warehouse is a part of 5S, but all staffs have to do together.

Standardizing Standard to arrange products and bring the parts out is set like a rule for every staff. The rule is whoever takes the part from shelf but not use; he/she has to return that part back to the shelf.

Sustaining As above, standard are made to force all staffs to maintain the good conditions of warehouse. In case whoever operates out of standard, his or her assumed 100 points would be cut 1 point. And then, there is comparison of total highest point to get special reward at the end of the year.

3.2.3.2 Additional Employees for More Manpower

Manpower is another cause of problem for warehouse. There are only 2 staffs for receiving, loading, checking, and arranging purchased products on shelf. With 3 times of products receipt from X Company at 8:00 am, 2:00 pm and 5:00 pm and average products around 300 items with more than 300 units per day, they spend long time to complete all processes for all products. Therefore, ABC Company decided to employ more 2 staffs to work for these jobs.

3.2.3.3 Setting Receiving Area

Setting limited receiving area for receiving parts is another solution for scattered of products when they arrive. With more additional staffs for this

receiving, lead time of receiving and checking can be reduced, so it is possible to set the fixed location of receiving area.

Before improvement – arrival products are put on the pathway in front of the company.

After improvement – arrival products are put on the receiving area which is set with limit area in order to avoid keeping on the pathway.

Figure 3.1 Receiving Area before Improvement (arrival products kept on pathway)

Figure 3.2 Receiving Area after Improvement

3.2.3.4 Receiving Date Fix for Customer

The last important point which affects to warehouse is some storage areas are occupied by products waiting for customer receipt. Sometimes, some customers receive their reserved ordered products 1 day to 1 weeks after part arriving. It is one of causes to spend long time period of these product items. ABC Company set the new policy to solve this problem by informing customers to

receive their parts within 3 days after part arriving. Unless customers have not yet received products within 3 days, those parts will be sold to other customers or kept as stocks.

3.3 Inventory Flow System

ABC Company has the computer system to control part purchase and sale, but there are many problems such as late input purchasing data and no inventory control system to be guideline for order quantity. It involves that not enough storage space to keep products and high inventory cost. The function of computer system is shown as below.

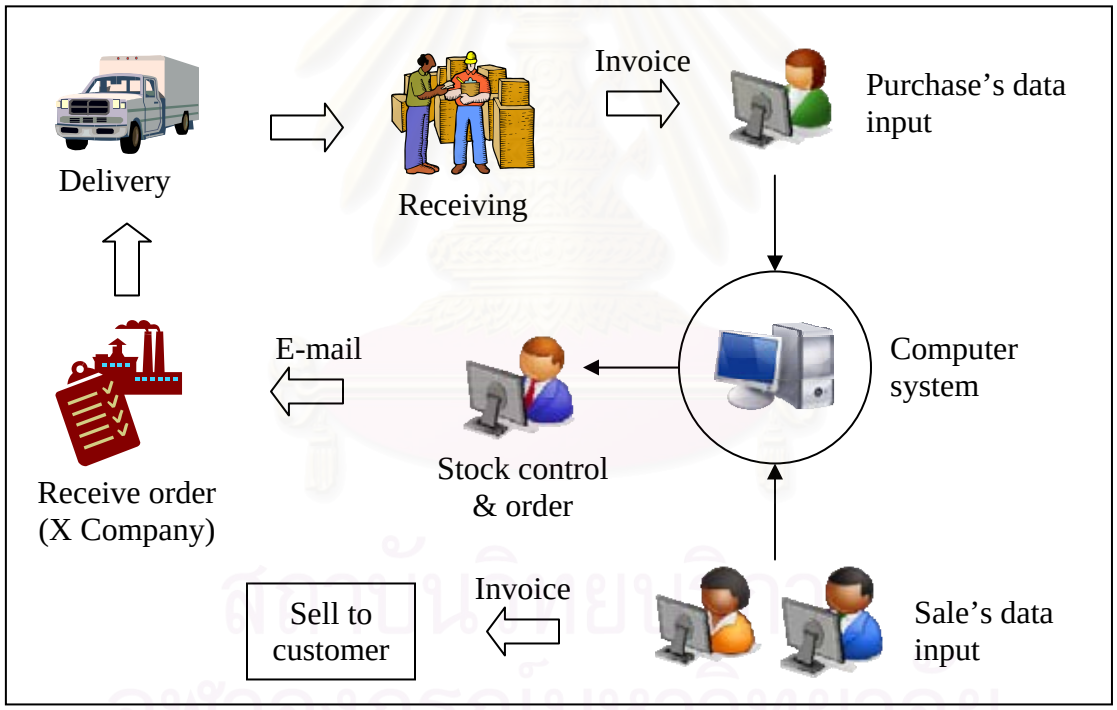


Figure 3.3 Function of Computer System of ABC Company for Inventory Control

Purchase data, stock control and sales data are in the same computer system. It can be checked these data by accessing in the computer program. Therefore, new computer system is not required for new inventory control system application. The staff

who controls stocks can conduct forecasting demand, ordering suitable number of products and ordering when stocks level reaches reorder point.

New computer system is now considering implementing for inventory improvement. In order to support the inventory control system for stocks checking, numbers of stocks at important point for inventory control such as reorder point are required to show to remind inventory control staff for replenishment order. In additions, new computer system as calculation of inventory control system is also necessary for the application.

3.4 Inventory Record System Management

3.4.1 Record System in ABC Company

ABC Company has 2 parts of record system of stocks as purchasing from X company and selling to customer. The first part is purchase of products. Ordered products which are bought from X company are delivered three times at 8:00 am, 2:00 pm and 5:00 pm. Numbers of product items are fluctuated for each day with 20 items for minimum and 700 items for maximum. There are 2 types of ordering products as stocks order and daily order. Stock order has leadtime 3 days for receiving, while daily order has 1 day leadtime. Stock order items will be delivered to ABC Company at 8:00 am. The daily order items will be delivered at 2:00 pm and 5:00 pm.

Data of purchased items are filled in the computer system by only 1 staffs; it is difficult to finish filling all data in one day. Moreover, invoice documents, which contain the data, are often sent to these staffs lately around 1-2 days. It is because there are only 2 staffs for receiving and checking all parts, and they use those documents for checking product items when customer received parts. This is one of important causes of inaccurate number of stock.

The second part is sales of products. Causes, which affect to stocks, are return of products and products with wrong part number. For return of products, several customers

sometime sell parts return to the company with the reason as customer of ABC Company's customer wants to cancel or does not want to buy that product anymore. In spare part business in Thailand, good service is the most important point to meet customer satisfaction, so all part can be sold back when those products are not needed and those parts have no any damage. And then, ABC Company will receive and send back to X company. This affects to number of stock that is different stock's number between record and actual number. It is because the product is actually not in ABC Company's warehouse during returning process. Some customers sell part return after purchasing over 3 months.

Another cause of problem for sales is ordering wrong part. There are many car models launched with full major change and minor change, and there are 2-3 specifications with different options and different prices in each model. Therefore, many customers confuse about specification of spare part for maintenance and order the wrong part number. And then, customers send that wrong part back to change for correct part.

3.4.2 Causes of Problems for Record System

As above information, it can be concluded main causes of inaccurate stocks record system with two major points as late data filling of purchased items and return items from customers. ABC Company investigated these causes and solved the problem based on cost consideration with detail below.

Late data input of purchased items

1) After checking part when receiving, invoice documents of product purchase were often sent to fill data lately around 1~2 days for daily order products because sale staff almost use the documents to check and take products to customers when selling those items. Current system for checking, loading, and selling products are as below flow chart.

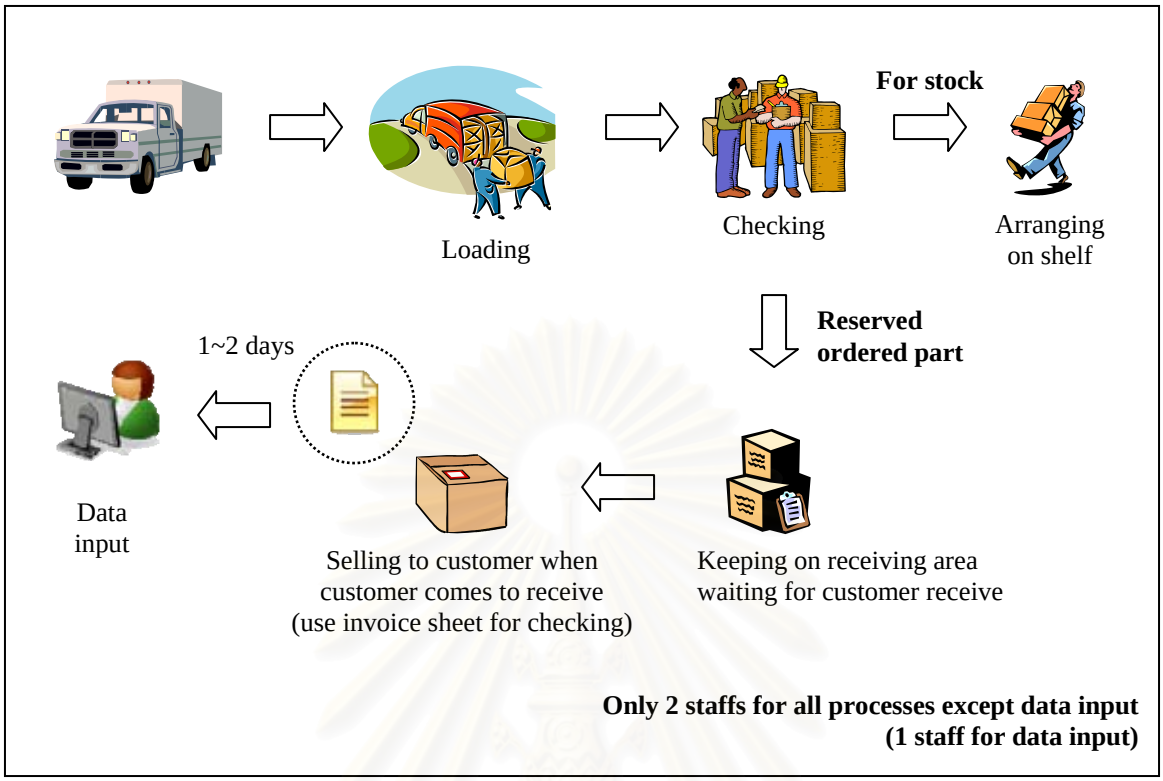


Figure 3.4 Current System of Receiving and Recording of Stocks for Daily Order Items

As above explanation, there are 2 groups of purchased products as first group is to be kept for stocks as stock order. Another group is product items that no stocks in the warehouse. When ABC Company receives order from customers, they will buy those items from X Company as daily order. When these product items were received, the staffs usually keep them on the receiving area and waiting for customers to get them including attach invoice on those package. Sometimes, it spends more than 2 days for waiting customers to receive the products. It is the reason why invoice sheets are usually sent to fill data much late. However, if these parts are kept for waiting customers over 2 days, the invoice sheet will be copied and send for data input and use that copy for customer.

2) In case of stock order, the invoice documents for stock products are sent within receiving day. Because of large numbers of purchase items with more than 500 items, 1 staff could not fill all data into computer system in one day.

Return parts from customers

1) When customers cannot sell some products for a while but not over than 3 months, they can sell those products with no damage back to ABC Company. However, ABC Company can send them to sell back to X company, but there is penalty charge for total return value at the end of the year.
2) In case of wrong part number, customers can also send the products return to change to correct part number. As the same as above, they can be exchanged from X company as well.

These points are also causes of inaccurate stocks record. During return process, products have status as stocks in the company, but the products actually may be at the return parts area in warehouse or at the X Company to wait for return approve. They cannot be used for sale.

3.4.3 Record System Improvement

From above causes and problems, solutions for each problem were found to apply in the company.

3.4.3.1 Shorten Leadtime of Invoice Sheet Submission

ABC Company changed the system for receiving and record system by copy invoice sheet, and sent that copy to attach on the box which is kept to wait for customer receipt of daily order items.

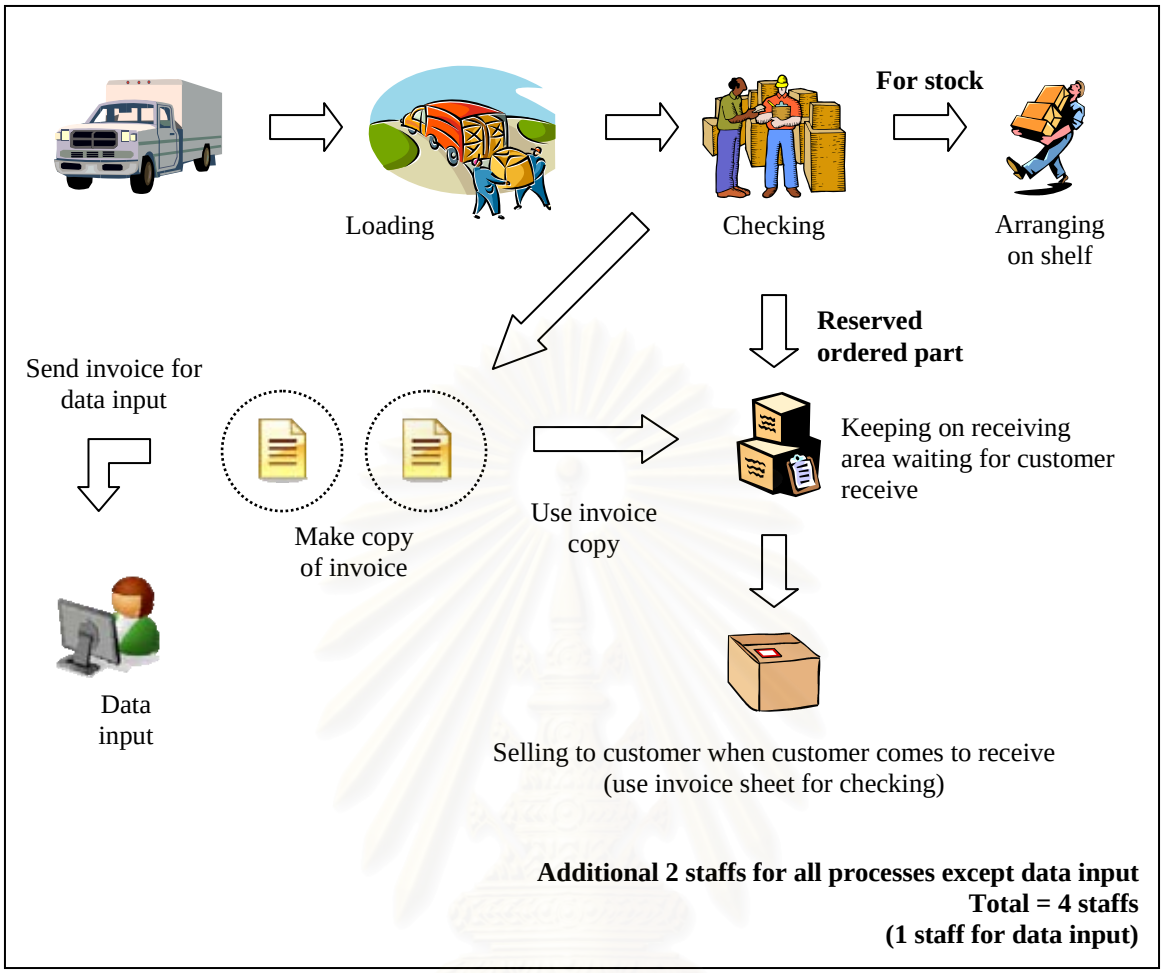


Figure 3.5 New System of Receiving and Recording of Stocks for Daily Order Items

In additions, 2 more staffs were employed for loading and checking received products to shorten leadtime for receiving process, so it involves that invoice sheet of stock order can be sent for data input earlier on that day.

3.4.3.2 Computer System Improvement

During filling data of purchased products into computer system, detail for filling as purchased date, item number, part number, part name, quantity, unit price, total price, net price, and percentage of discount. Normally, one person of staff can fill the data around 120 items for an hour. It means that maximum numbers of data input are 480 items a day. The new computer system contains format which is not needed to fill part name. Only filling part number, part name

is automatically showed in that format. This can reduce spending time for typing part name which is the longest part for data input. This new computer program can be created by setting the program to link with spare part database, which received from X company in form of computer file when new versions was updated.

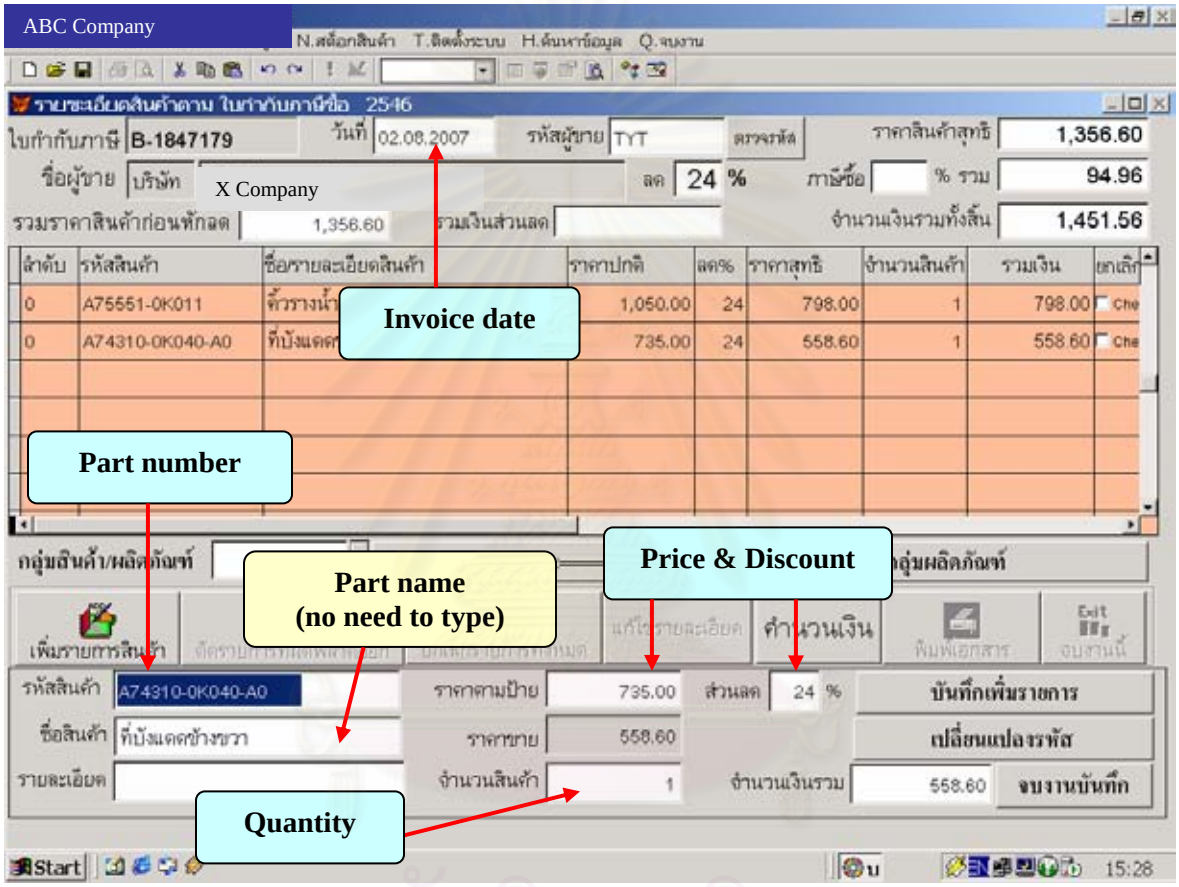


Figure 3.6 Format of New System for Purchase Data Input

3.4.3.3 Proposal of Bar Coding System

Bar coding system is one of the most popular for inventory management of business that have large numbers of products varieties. In case of ABC Company, all spare parts are delivered from X Company, and there is sticker of part number with barcode attached on every package. Therefore, it is not

necessary to generate new system of bar code symbol. Proposed routing of operation with bar coding system is created as in the figure.

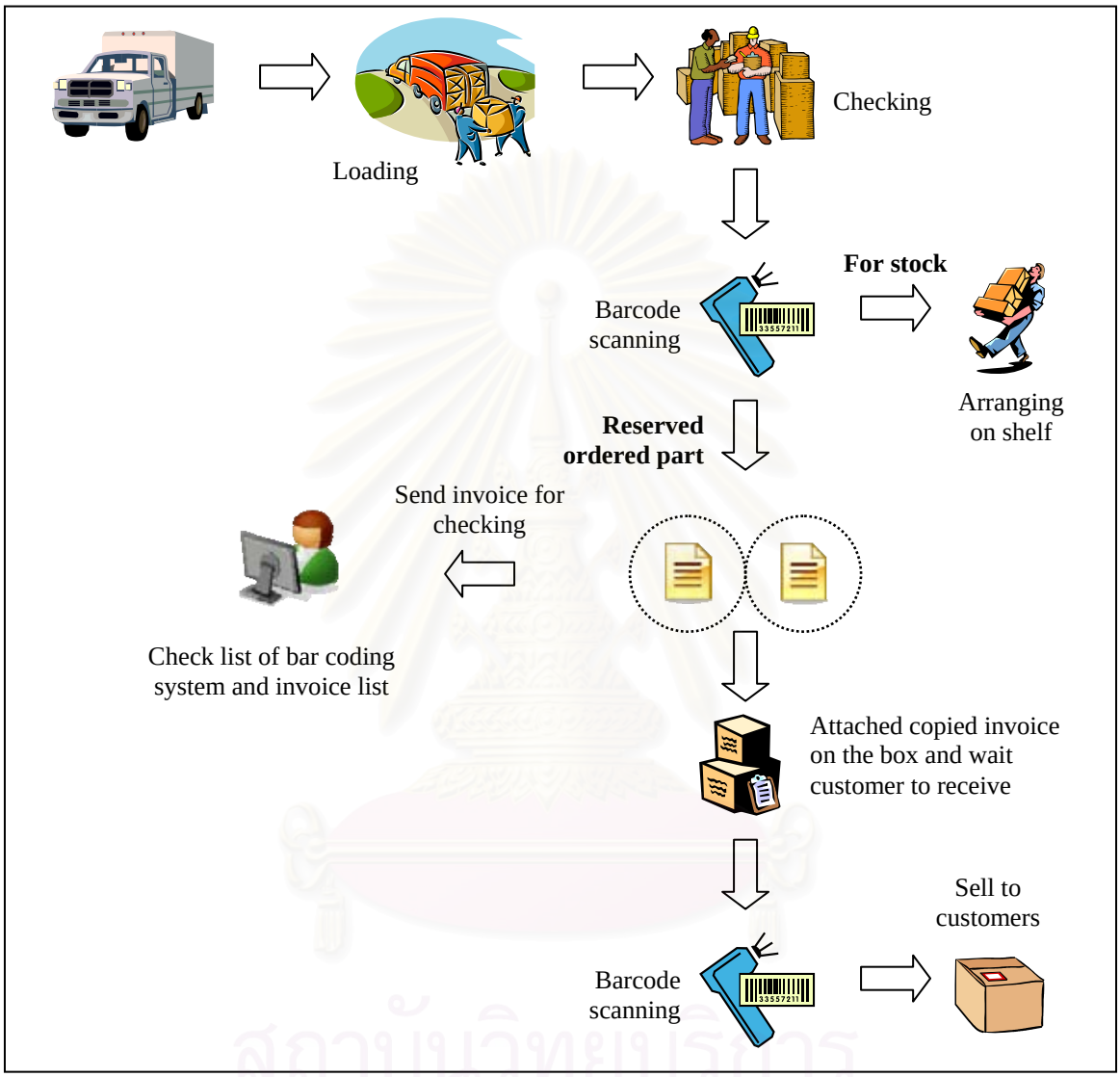


Figure 3.7 Operation Systems with Bar Coding System

The bar coding system is proposed to apply after part receiving for purchase data record and when selling products to customer for sales data record. This system can shorten leadtime of record system and it involves to accurate daily stocks database. For bar coding system investment, required equipment for this system are 2 wireless barcode scanners for part receiving and 3 laser barcode scanners for sales including computer software. Barcode printer is not required for

this system because all products have attached stickers of part number. Estimated total investment is around 100,000 Baht.

3.4.3.4 Separating Return Product Item

To prevent including return items to stocks in computer system, all return items are categorized into 2 groups as waiting to change and waiting to return which has 2 status as waiting to return to X Company as status 1 and status 2 for waiting for approve from X Company. For status 1, if other customers want to buy, it will be filled into stock system as return receive from customer. And then, it will be sold with normal method.

3.5 Inventory Policy

There are many car models launched under X Company's brand and there are also many sub-models for each model. It is impossible that ABC Company will keep stocks for all spare parts for all car models. Inventory policy to select parts for stocks keeping is necessary to the company. From spare part characteristics, spare parts can be classified into 3 groups for maintenance character as:

- Spare part for car maintenance
- Spare part for car accidents

With the testing standard of X Company's car part performance, minimum requirement for durability of most of parts are around 5 years, but sometimes, defect of products may occur during usage in that period. X Company has warranty policy for their products as warranty periods 3 years or 100,000 km. It means that customer is able to get free maintenance during warranty periods, so ABC Company realized that stocks of these spare parts are not necessary to keep in the first period of car model launching. After 3-year usage is timing that the company should start to keep stocks for this group of spare parts. Three cars models are considered to analyze spare parts demand after 3-year car model launching. The result is that all spare parts were sold for replacement for car

accidents in the first 3 years. On the 4th year after launching car model, some spare parts which are not for car accident replacing were sold. Detail of spare parts for maintenance is shown in table.

Table 3.1 Sales Volume of Spare Parts for Car Accidents and Car Maintenance

Car Model	Launched Year	Total Sales in 3rd year (Units)	Spare Parts for Car Accident		Spare Parts for Car Maintenance	
			Quantity (Units)	Quantity (%)	Quantity (Units)	Quantity (%)
No.1	2002	3,988	2,424	60.8%	1,564	39.2%
No.2	2001	7,757	6,162	79.4%	1,595	21.6%
No.3	2002	2,694	2,163	80.3%	531	19.7%

From above table, ABC Company should start to keep stocks of spare parts for car accident in the 1st year of car model launching and in the 3rd year for spare parts for car maintenance.

3.6 Trend of Spare Part Demand

According to inventory policy, types of spare parts are considered to select to conduct stock keeping based on car launching year. The company realized that trend of spare parts demand should also concerned to be guideline for number of stocks and part order management. In this research, focused car models and group of spare parts are considered to create trend of demand model to study movement of demand related to car usage time period.

3.6.1 Three Car Models Consideration

Three car models which were selected to reflect on sales volume are Model A, Model B and Model C with detail for each model as below.

Table 3.2 Information of Car Models for Spare Part Demand Consideration

MODEL	SUB-MODEL	ENGINE (CC)	PRICE	IMPLEMENT YEAR
Model A	Model A-1	1500	500,000 to 700,000 Baht	1997
	Model A-2			2002
Model B	Model B-1	1300, 1500	200,000 to 300,000 Baht	1992
	Model B-2	1600, 1800	400,000 to 600,000 Baht	1996
	Model B-3		600,000 to 1,000,000 Baht	2001
Model C	Model C-1	2200	1,000,000 to 1,200,000 Baht	1993
	Model C-2			1998
	Model C-3	2000, 2400, 3500	1,100,000 to 1,300,000 Baht	2002
	Model C-4		1,300,000 to 1,700,000 Baht (3500CC model 2,800,000 Baht)	2006

Model B has the most car sales volumes with medium market segment and first implementation. Actually, there are 2-3 sub-models of this model which were launched before Model B-1, but it is too old for consideration. Therefore, Model B-1 is the first sub-model in this model to be selected for analysis.

Model C has car sales volumes less than Model A because its market segment is high grade with high price, though first sub-model of Model C was launched in Thailand before Model A.

3.6.2 Focused Spare Part Consideration

According to more than 3,000 parts in one car, group of sample parts was focused to analyze trend of demand. ABC Company selected sample parts with high sales volume in year 2002 to 2006 for each model. Sample parts which were focused can be divided into two groups referring to inventory policy as:

Spare Parts for Car Maintenance

- Oil Seal
- Door Handle
- Timing Belt
- Insulator Engine Mounting

Spare Parts for Car Accident

- Bumper
- Cover Under Engine
- Front Fender Panel
- Rear Fender Panel
- Glass
- Outside Moulding
- Lamp and Lens
- Outer Side Mirror

3.6.3 Trend of Demand Summary

After ABC Company collected data of sales volume during year 2002 to 2006, trend of demand model can be summarized as graph below.

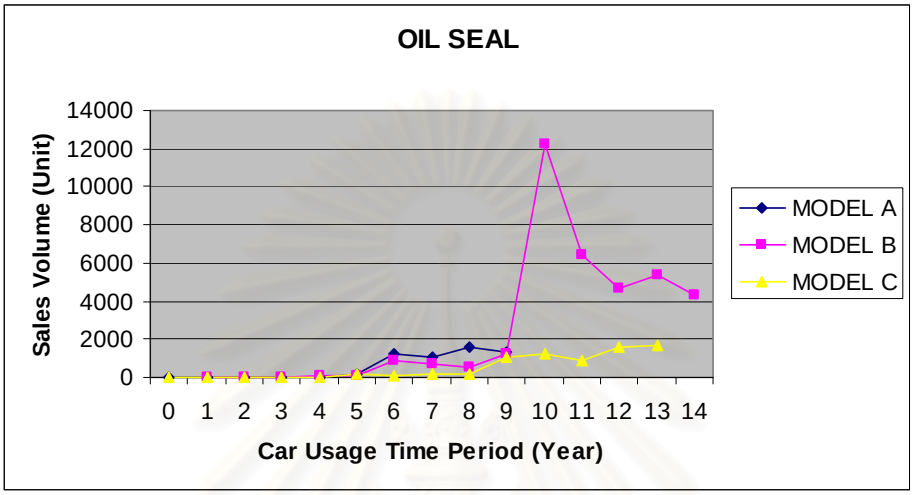
3.6.3.1 Spare Parts for Car Maintenance

3.6.3.1.1 Oil Seal

Description: This part is seal for oil leak prevention of transmission and transaxle case and shaft.

Figure 3.8 Oil Seal

Characteristics: Oil seals for transmission and transaxle have long period life time. They can be used over 5 years, so these parts are almost replaced a new one for the car with more than 5 years use.



Graph 3.1 Sales Volumes of Oil Seal

Demand Analysis: Number of sales volumes starts to increase around the 6th year of car use period. It slightly increases until the 9th year car use and extremely increases for 10th year for model B. It may be because that car model B has the largest car sales volume for that sub-model which was launched on that period.

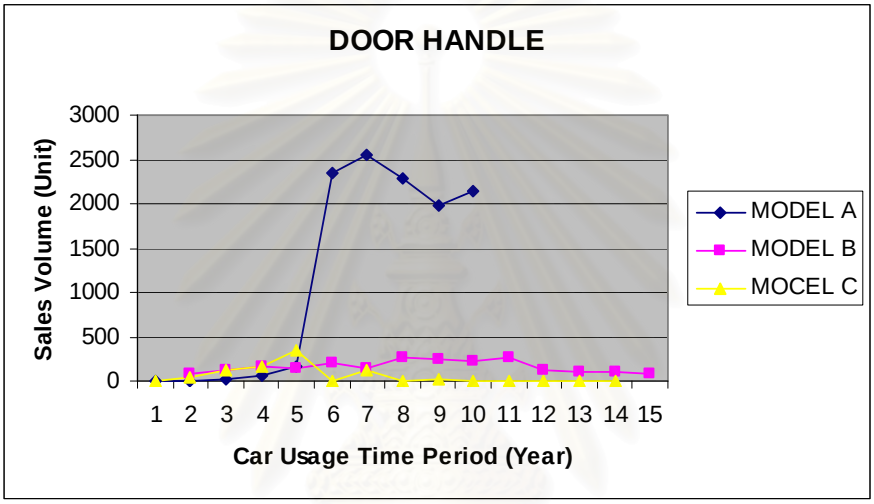
3.6.3.1.2 Door Handle

Description: This data set is door handle of car for both inside handle and outside handle set. For door handle outside has 2 types of shape while door handle inside has only 1 type as pictures below.

Figure 3.9 Door Handle Outside

Figure 3.10 Door Handle Inside

Characteristics: This part will be replaced when part broken.



Graph 3.2 Sales Volumes of Door Handle

Demand Analysis: From graph, demand of door handle does not trend to rapid change for each year, but only car model A has obvious high sales volumes starting on the 6th year car use. After investigation, it was found that door handle is defective part with poor design for model A-1 which was launched during 1996 to 2002.

3.6.3.1.3 Timing Belt

Description: Timing Belt is the part that is for controlling timing of engine's valves.

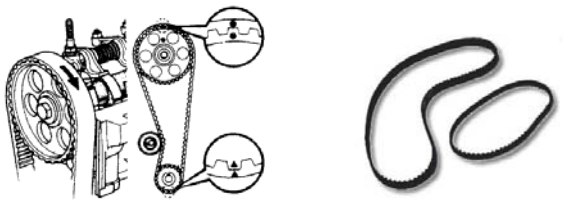
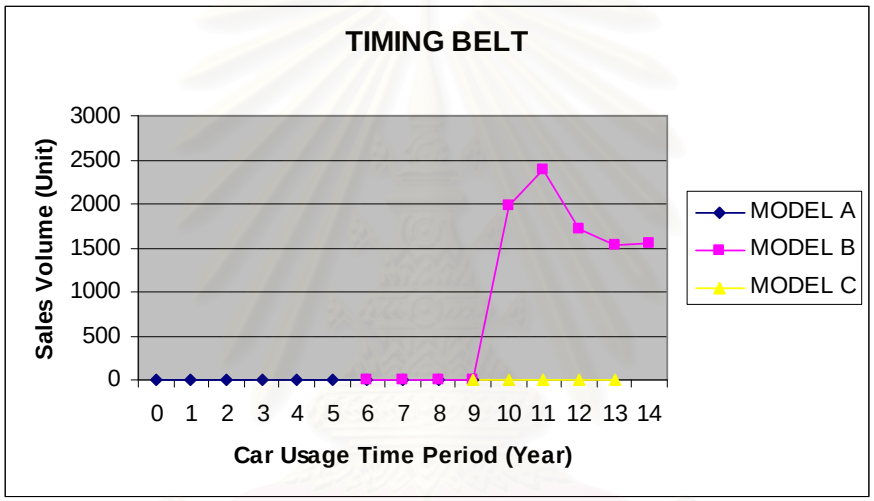


Figure 3.11 Timing Belt

Characteristics: Time period to change this part with new one in car is almost around after using every 100,000 km.



Graph 3.3 Sales Volumes of Timing Belt

Demand Analysis: Actually, car owners get their cars to check in service center after using reach 100,000 km. Almost cars are replaced this part during that maintenance in service center, so there is no any order of this part from customer. (Almost ABC Customers are spare part shops and small service shops.) Anyway, this part will have large number of sales volume on the 10^{th} to 11^{th} year of car use period for maintenance after driving 200,000 km.

Model A was launched 9 years ago. This timing is still not necessary to change this part with new one. While model C which was

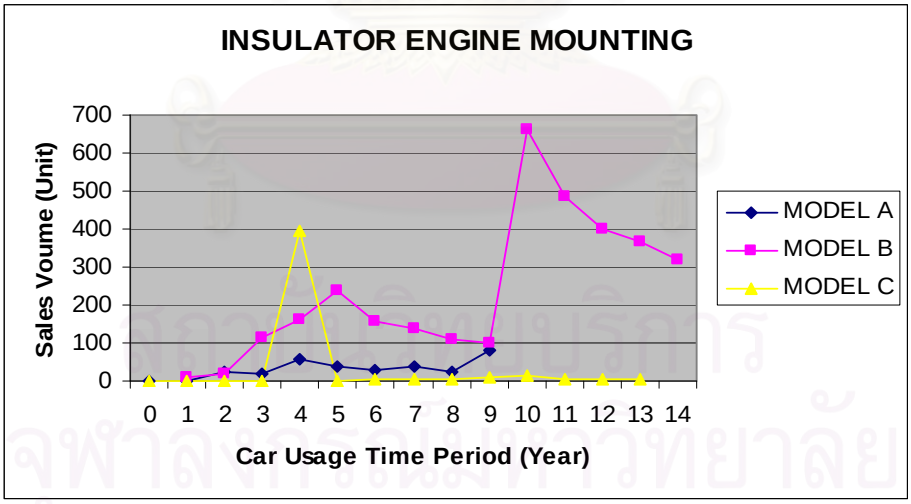
launched 9 to 13 years ago has not many sales volumes, sales volume of this part for model C is also small number.

3.6.3.1.4 Insulator Engine Mounting

Description: This is the part for absorbing the vibration from engine during operation. It is assembled under the engine.

Figure 3.12 Insulator Engine Mounting

Characteristics: Not being spare part which must be replaced often, so it will be changed to do maintenance for the car with 100,000 km used.



Graph 3.4 Sales Volumes of Insulator Engine Mounting

Demand Analysis: It might be possible that this part is changed in the car used until 100,000 km around 4-6 years after purchased, so it is

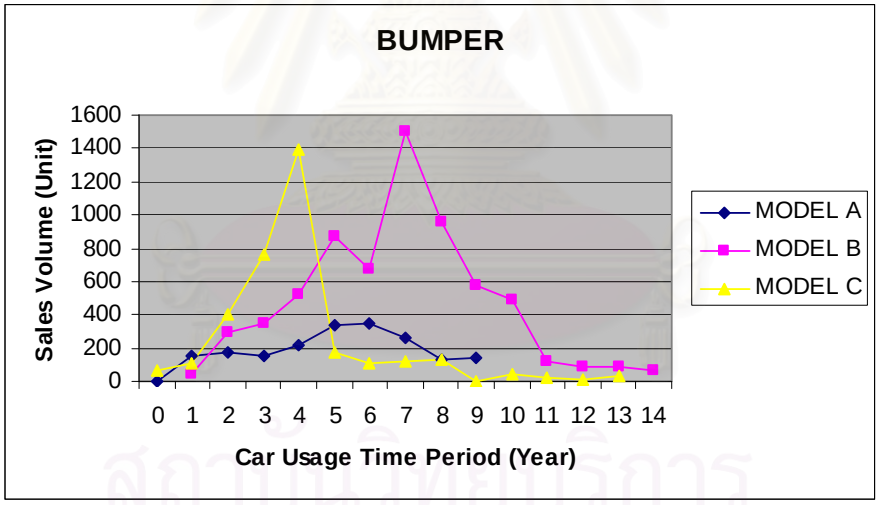
related to graph for high demand on that period. And then, it should be done re-maintenance again after using until 200,000 km.

3.6.3.2 Spare Parts for Car Accident

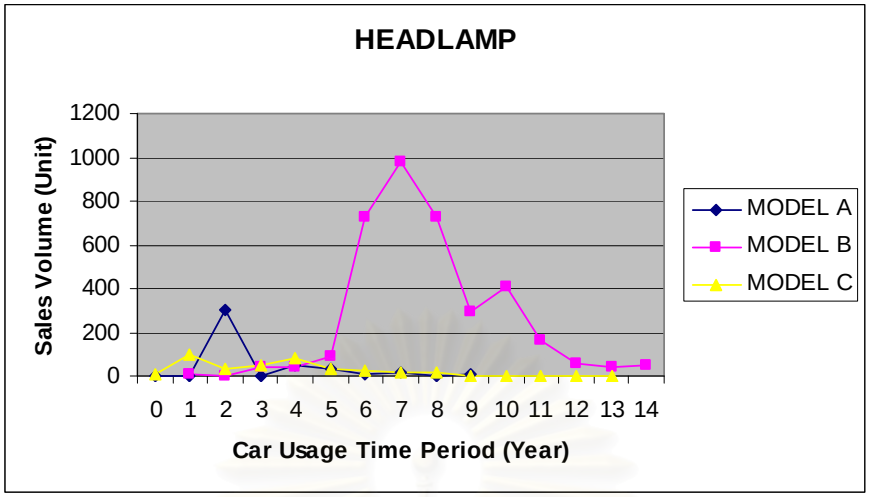
These spare parts have trends of sales volumes with fluctuation. It is difficult to analyze those trends based on certain factors because accident is unpredictable. However, trends of spare parts in this category can be summarized into 3 types of pattern of graph as shown below.

3.6.3.2.1 Demand Pattern 1

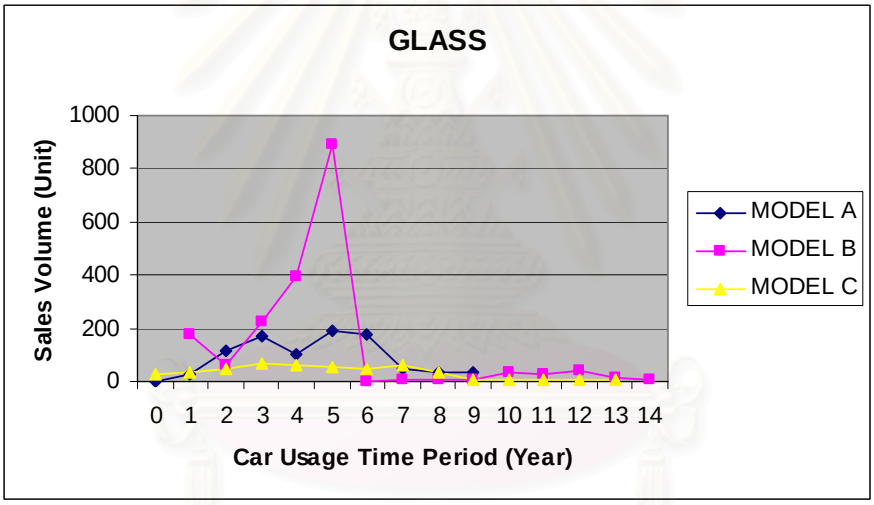
Parts which have graph of trend of demand as this pattern are bumper, head lamp, glass and outer mirror. Graphs of these parts are shown below.



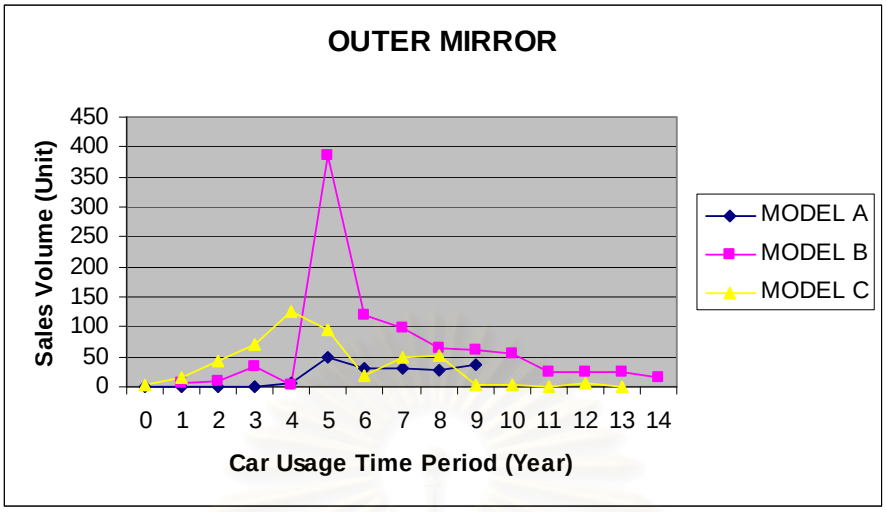
Graph 3.5 Sales Volume of Bumper



Graph 3.6 Sales Volume of Headlamp



Graph 3.7 Sales Volume of Glass

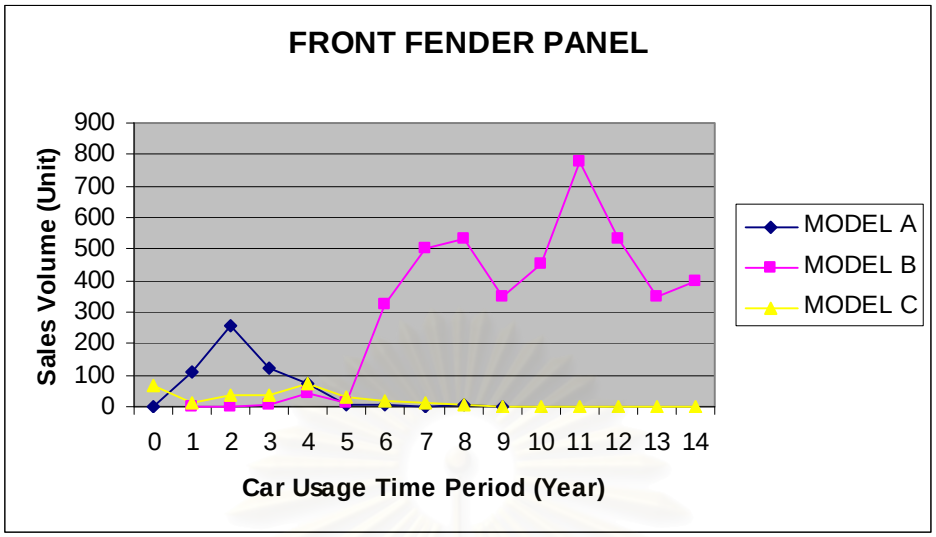


Graph 3.8 Sales Volume of Outer Mirror

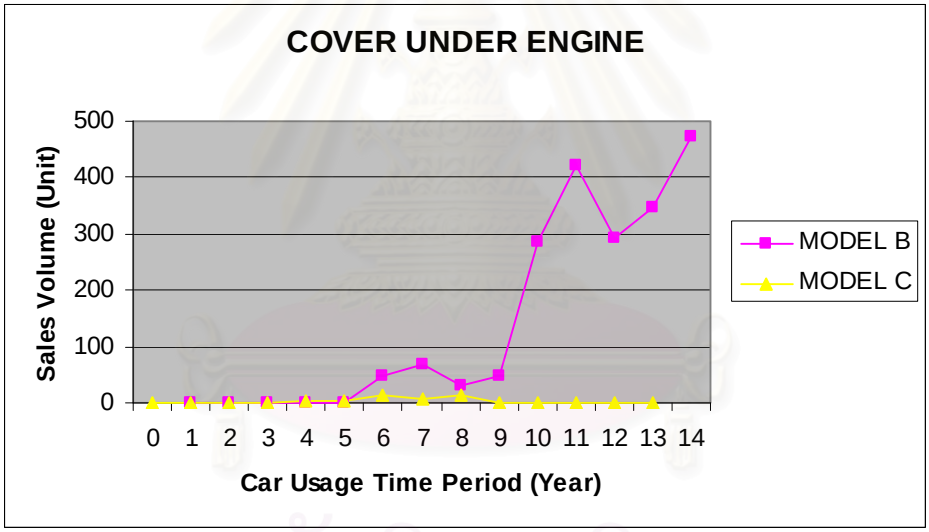
Demand Analysis: These parts have same pattern of sales volumes which slightly increases in the first period and rapidly increases for 1-2 years, and then rapidly decreases. In addition to obvious peak of demand, the car model which has the highest sales volume is model B. It may be because car model B has the largest car sales volumes.

3.6.3.2.2 Demand Pattern 2

Front fender panel and cover under engine have trend of demand with the same pattern. It might be possible that position of these two parts in car is near with each other. Graphs of sales volume of both parts are shown below.



Graph 3.9 Sales Volume of Front Fender Panel

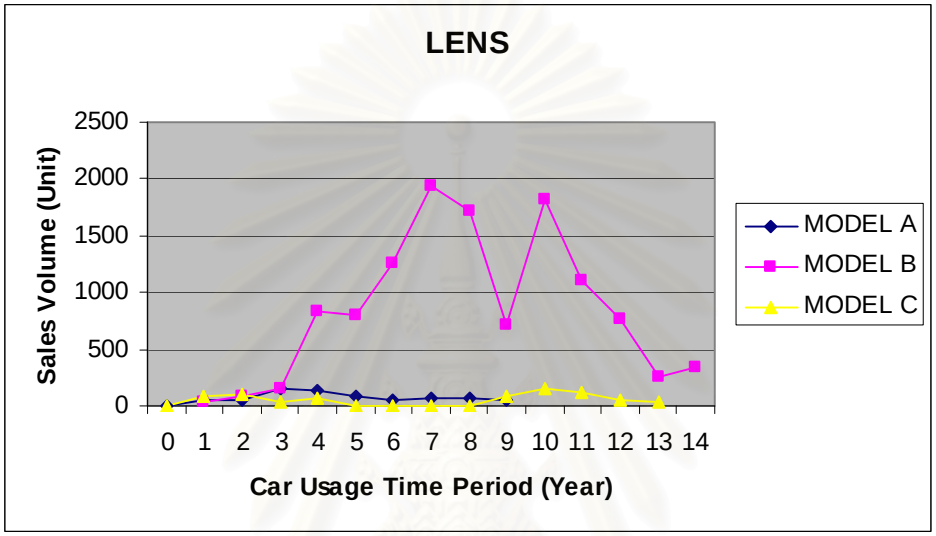


Graph 3.10 Sales Volume of Cover Under Engine

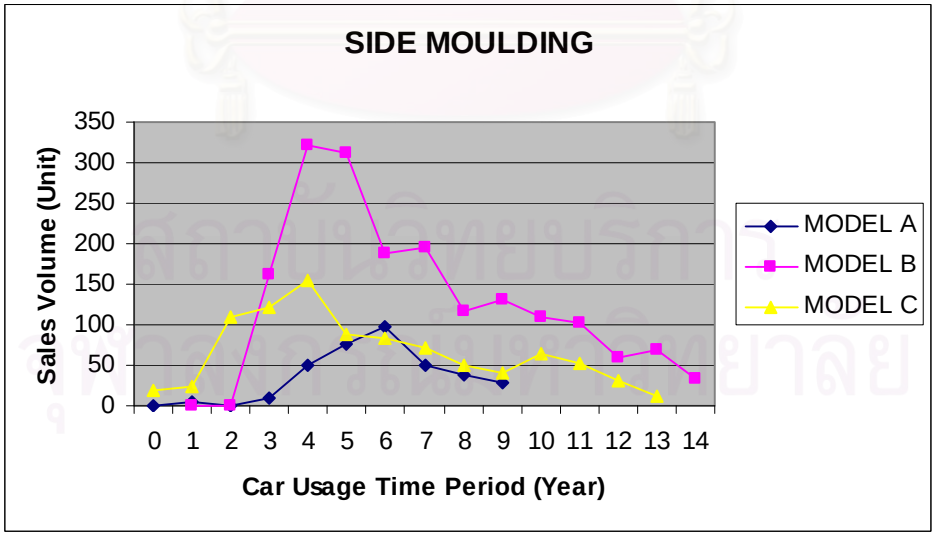
Demand Analysis: Parts which have this pattern of graph have trend of demand increase after car has been used for 5 years, and it trends to continuously increase after that. For cover under engine, there is no any order from customers for model A.

3.6.3.2.3 Demand Pattern 3

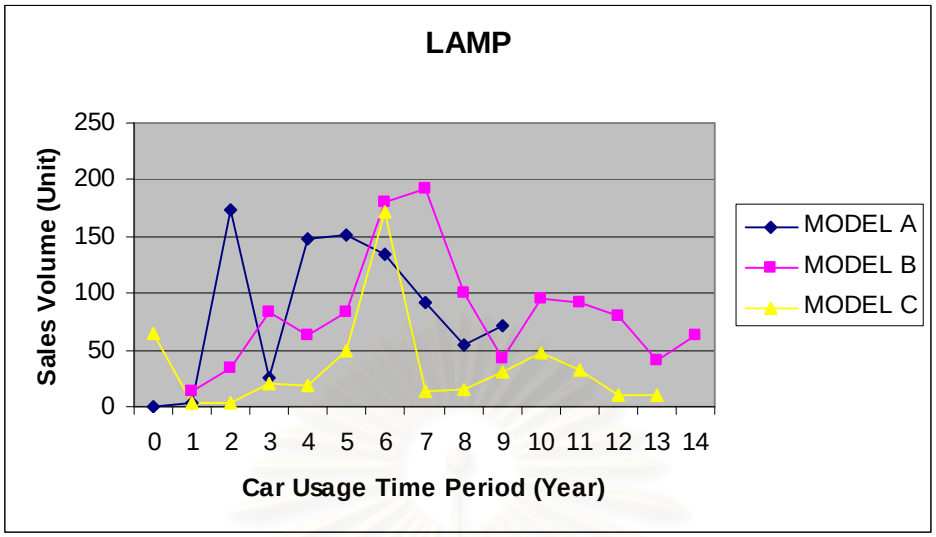
Another pattern of parts which are changed when car accident happened are lens, side moulding, lamp, and rear fender panel. They have graph of trend of demand with fluctuation, so it is very difficult to conclude the direction of graph.



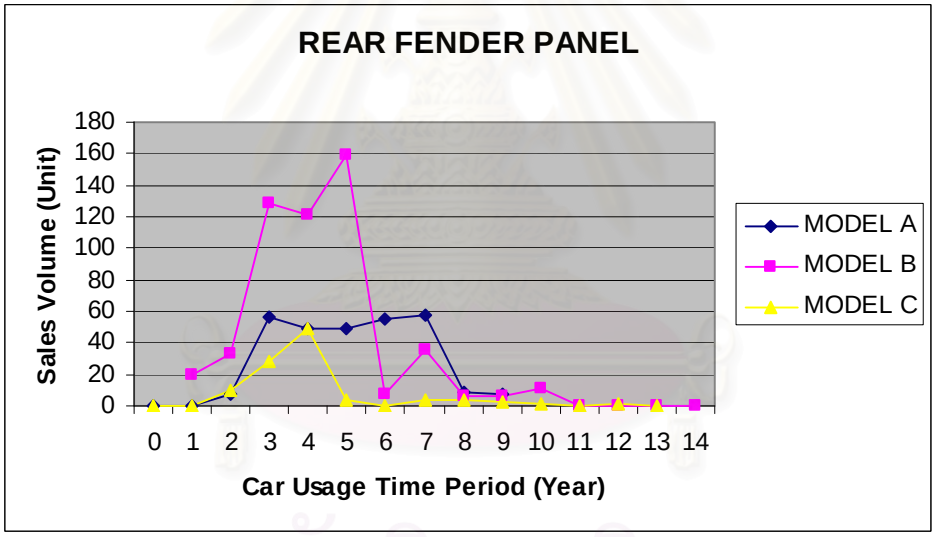
Graph 3.11 Sales Volume of Lens



Graph 3.12 Sales Volume of Side Moulding



Graph 3.13 Sales Volume of Lamp



Graph 3.14 Sales Volume of Rear Fender Panel

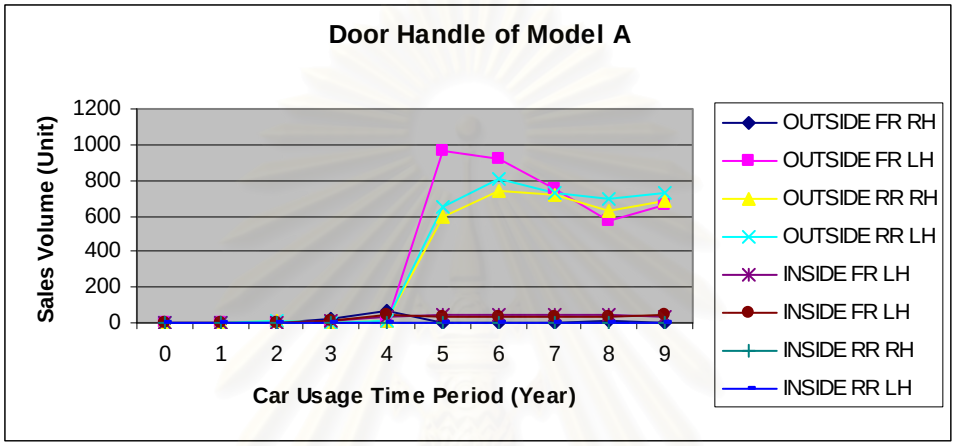
Demand Analysis: There is no any certain pattern to predict and explanation for parts in this group. However, it should carefully consider based on monthly actual demand for each part.

3.6.4 Detail of Part Demand Analysis

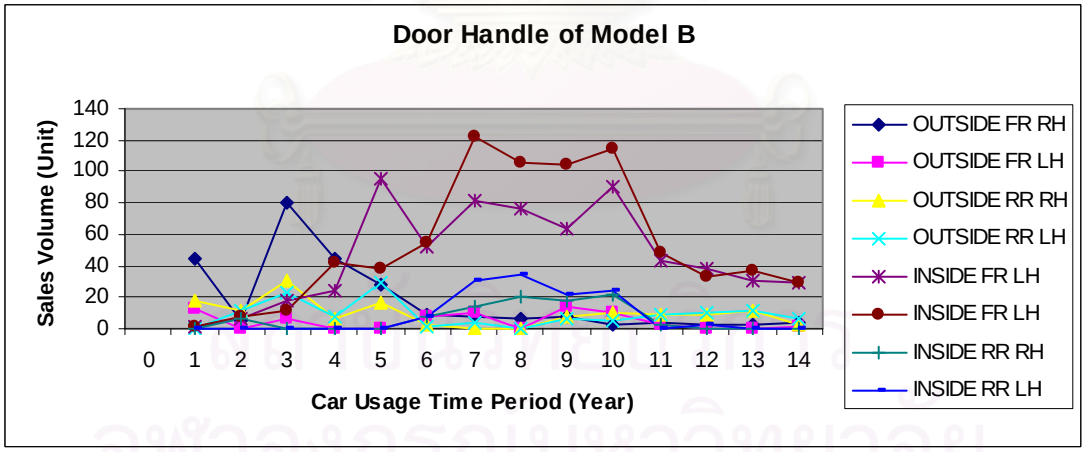
Above data of some parts as door handle and bumper, they are collected for part set to analyze overall trend of demand. In order to more accuracy in trend of demand

analysis, components of part set should be considered to be guideline for each component for management of stock and order.

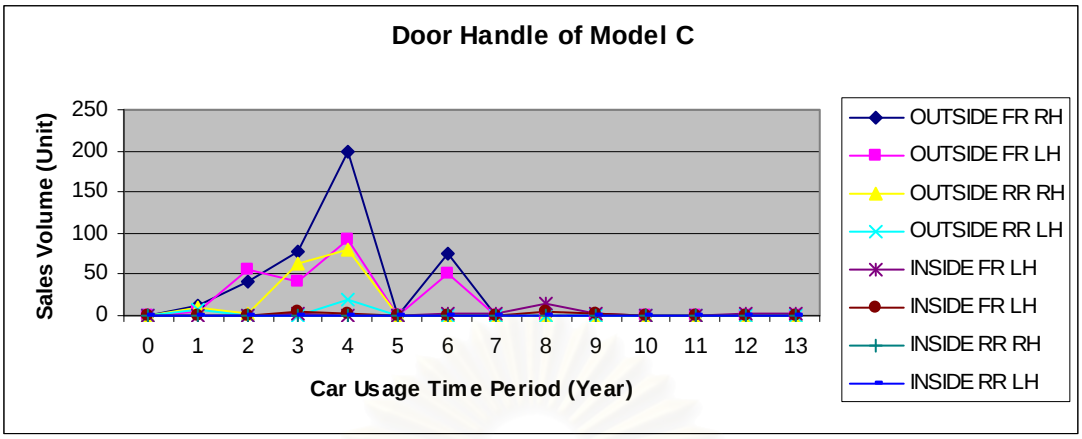
Door handle is example for showing detail of component parts. It can be divided into 8 components. Demand data for each component are collected and summarized based on car model as shown below.



Graph 3.15 Sales Volumes of Components of Door Handle of Model A



Graph 3.16 Sales Volumes of Components of Door Handle of Model B



Graph 3.17 Sales Volumes of Components of Door Handle of Model C

Demand Analysis: From Above graphs, it can be implied that ABC Company should arrange stocks by focusing on outside door handle front left and both rear left and right of model A-1. It is because these three parts have the largest volumes of demand and have trend in the same direction of overall door handle demand graph pattern.

3.6.5 Relations of Trends of Spare Parts Demand and Inventory Policy

According graph of trends of demand, demands of spare parts for car maintenance are starting to increase on the 3rd year of car usage time, while demands of parts for car accidents increase in the beginning year of car usage. It can support inventory policy to starting to keep stocks of spare parts for car maintenance in the 3rd year period and in the 1st year for car accidents. However, daily and monthly trends of demands should also be concerned to decide the numbers of stocks.

3.7 Demand Forecasting

Current situation for ABC Company is no any system or criteria for demand forecast. Staff who controls inventory usually order product based on outgoing quantities, so this is one of important point that involve many stocks remaining in warehouse. However, not enough products to supply customers are also another reason that demand forecast should be improved.

3.7.1 Demand Forecasting Method

There are several methods to conduct demand forecasting such as moving average, weighted moving average, simple exponential smoothing, double exponential smoothing, regression etc. For this research, 3 models, moving average, simple exponential smoothing, and double exponential smoothing are selected to apply and searched for the best fit model to use for demand forecast.

Oil seal is chosen to be example for concerning both demand forecasting and inventory system. It is because the largest number of demand among all focused products that are selected to study trend of demand in section 3.5. Actual demand of oil seal of car model A-1 is shown as calculation to find the most suitable demand forecasting techniques. Historical demand data for year 2006 are shown in below table.

Table 3.3 Historical Demand from Year 2006 of Oil Seal of Model A-1

Month (Year 2006)	**Demand (Unit)**
Jan-06	68
Feb-06	128
Mar-06	198
Apr-06	100
May-06	66
Jun-06	132
Jul-06	115
Aug-06	85
Sep-06	92
Oct-06	98
Nov-06	125
Dec-06	125

3.7.1.1 Moving Average

ABC Company selected to use moving average technique to forecast demand by using period as 3 months and 6 months.

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

where n = number of periods in the moving average

Di = demand in period i

Moving Average with 3 months period

From historical demand data in table 1 of oil seal of car model A-1, forecast demand on March 2002 by moving average method with 3 months period can be calculated as:

$$\text{F (Mar-06)} = \frac{\text{D (Jan-06) + D (Feb-06) + D (Mar-06)}}{3}$$

$$= \frac{68 + 128 + 198}{3}$$

$$= 131.3$$

Moving Average with 6 months period

From historical demand data in table 1 of oil seal of car model A-1, forecast demand on March 2002 by moving average method with 6 months period can be calculated as:

$$\text{F (Jun-06)} = \frac{\text{D(Jan-06)+D(Feb-06)+D(Mar-06)+D(Apr-06)+D(May-06)+D(Jun-06)}}{6}$$

$$= \frac{68 + 128 + 198 + 100 + 66 + 132}{6} = 115.3$$

3.7.1.2 Single Exponential Smoothing

Single exponential smoothing has the formula for calculation as:

$$F_{t+1} = \alpha D_1 + (1 - \alpha) F_t$$

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

Dt = actual demand in the present period

Ft = the previously determined forecast for the present period

α = a weighting factor referred to as the **smoothing constant**

Forecast demand of oil seal of car model A-1 can be calculated by using this method with α=0.18 as:

F (Apr-06) = α(D (Mar-06)) + (1-α)(F (Mar-06))

= (0.18)(198) + (1-0.18)(78.7)

= 100

The α value as 0.18 can be determined from trial-an-error to find the minimum error of forecast data.

3.7.1.3 Double Exponential Smoothing

The formula of double exponential smoothing method is:

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

where AF_{t+1} = the forecast from double exponential smoothing for the next period

F_{t+1} = the forecast from single exponential smoothing for the next period

T = an exponential smoothed trend factor

The trend factor can be computed from single exponential smoothing with use smoothing constant value for trend as β.

$$T_{t+1} = \beta(F_{t+1} - F_t) + (1-\beta)T_1$$

where T_1 = the last period's trend factor

β = a smoothing constant for trend

Forecast demand of oil seal of car model A-1 can be calculated by using this method with β=0.1 as:

T (Apr-06) = β(F (Apr-06) – F (Mar-06)) + (1-β)(T (Mar-06))
= (0.1)(100-78.71) + (1-0.1)(1.07)
= 3.09

So AF (Apr-06) = F (Apr-06) + T (Apr-06)
= 100 + 3.09
= 103.09

Actually, the best β value of oil seal of car model A-1 is 0. It can be computed by trial-an-error to minimize error of forecast. It means that the forecast demand from single exponential smoothing method has more accuracy than double exponential smoothing.

3.7.2 Forecast Accuracy

It is true that the forecast never has 100% accuracy. Forecast error is always found with the gab of forecast demand and actual demand. The indication of forecast accuracy is necessary to do for checking the level of error. There are several indicators which are for checking forecast error of each forecast techniques. In this research, mean absolute deviation is selected to use with the most popular and simplest to measure forecast error. The formula of mean absolute deviation is:

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

where t = the period number
Dt = demand in period t
Ft = the forecast for period t
n = the total number of periods

| | = absolute value

3.7.3 Demand Forecasting Method Selection

The selection of demand forecasting method is used by computing all above calculation methods with historical demand data of oil seal of car model A-1 since 2002 to 2006. Moving average with 3 months period, moving average with 6 months period, and single exponential smoothing are applied to consider for demand forecasting.

Table 3.4 Demands Forecasting with 3 Techniques and Forecasting Accuracy Checking of Oil Seal of Model A-1

Month	Demand	Moving average 3 months	Moving Average 6 months	Simple Exponential Smoothing	MAD (Moving Average 3 months)	MAD (Moving Average 6 months)	MAD (Single Exp smoothing)
Jan-06	68	-	-	-	-	-	-
Feb-06	128	-	-	68.00	-	-	60.00
Mar-06	198	131.33	-	78.71	66.67	-	119.29
Apr-06	100	142.00	-	100.00	42.00	-	0.00
May-06	66	121.33	-	100.00	55.33	-	34.00
Jun-06	132	99.33	115.33	93.93	32.67	16.67	38.07
Jul-06	115	104.33	123.17	100.73	10.67	8.17	14.27
Aug-06	85	110.67	116.00	103.27	25.67	31.00	18.27
Sep-06	92	97.33	98.33	100.01	5.33	6.33	8.01
Oct-06	98	91.67	98.00	98.58	6.33	0.00	0.58
Nov-06	125	105.00	107.83	98.48	20.00	17.17	26.52
Dec-06	125	116.00	106.67	103.21	9.00	18.33	21.79
					27.37	**13.95**	**30.98**

From table 1, the lowest mean absolute deviation value is 23.89, so it can be concluded that the moving average method with 3 months period is most suitable for demand forecasting for oil seal of car model A-1. However, the experimental is done for example of car models which have historical demand data of oil seal much enough to forecast the demand, and summarize as shown in below table.

Table 3.5 Demands Forecasting with 4 Techniques and Forecasting Accuracy Checking of Oil Seal of Model A-1, A-2, B-1, B-2, C-1 and C-2

Car Model	**MAD Moving Average 3 month**	**MAD Moving Average 6 month**	**MAD Single Exponential Smoothing**	**Conclusion of Forecasting Method Use**
A-1	27.37	**13.95**	30.98 (α=0.18)	6 month-moving average
A-2	4.00	**2.57**	2.98 (α=0.01)	6 month-moving average
B-1	284.70	342.88	**253.31** (α=0.07)	Single exponential smoothing
B-2	224.53	283.38	**215.87** (α=0.01)	Single exponential smoothing
B-3	**5.43**	5.88	8.17 (α=0.54)	3 month-moving average
C-1	**69.27**	111.86	93.92 (α=0.07)	3 month-moving average
C-2	**6.23**	8.00	7.46 (α=0.19)	3 month-moving average
C-3	**1.30**	1.74	1.54 (α=0.01)	3 month-moving average

From above table, it can be concluded that not only single exponential smoothing technique is suitable for all car model, but it depends on characteristic of demand. Therefore, different forecasting techniques should be selected to use for each model based on consideration of the lowest value of MAD.

After forecasting demand by using historical data of year 2006 for each model of oil seal, the summary of demand forecasting is shown in below table.

Table 3.6 Actual Demand and Forecast Demand of Oil Seal

	MODEL A-1		MODEL A-2		MODEL B-1		MODEL B-2		MODEL B-3		MODEL C-1		MODEL C-2		MODEL C-3	
Month	**Actual**	**Forecast**	**Actual**	**Forecast**	**Actual**	**Forecast**	**Actual**	**Forecast**	**Actual**	**Forecast**	**Actual**	**Forecast**	**Actual**	**Forecast**	**Actual**	**Forecast**
Jan	68	135	0	0	190	513	176	165	19	20	65	93	10	8	1	1
Feb	128	131	0	0	338	213	45	176	6	13	45	75	7	11	0	1
Mar	198	139	0	0	420	329	163	46	12	12	108	73	20	12	0	0
Apr	100	124	0	0	316	414	22	162	1	6	73	75	14	14	1	0
May	66	123	25	4	223	323	178	23	0	4	64	82	12	15	0	0
Jun	132	115	0	4	366	230	77	176	7	3	73	70	25	17	3	1
Jul	115	123	0	4	232	356	10	78	5	4	95	77	17	18	0	1
Aug	85	116	0	4	449	241	302	11	8	7	181	116	15	19	0	1
Sep	92	98	4	5	242	434	40	299	0	4	53	110	0	11	0	0
Oct	98	98	3	5	2124	255	1418	43	18	9	273	169	0	5	0	0
Nov	125	108	0	1	303	1993	14	1404	24	14	59	128	27	9	8	3
Dec	125	107	0	1	373	421	45	28	0	14	649	327	7	11	0	3

- Actual demand is from year 2006 demand.
- Forecast demand for months which is/or beginning of the year are computed from year 2005 demand.

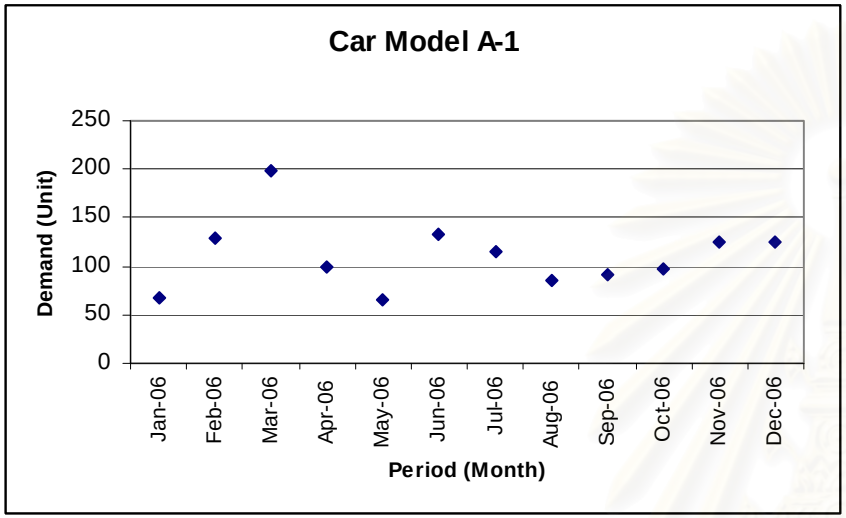
3.7.4 Variation of Demand

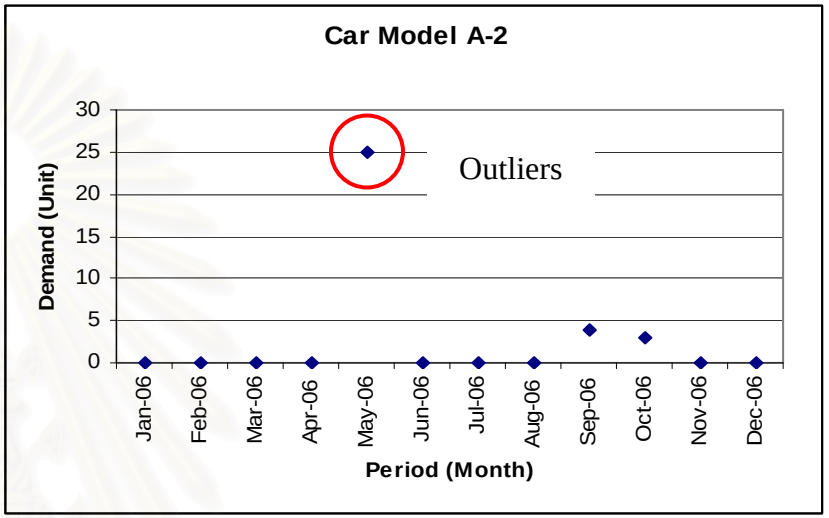
From above demand data, analyzing characteristic of demand is required to apply for finding the appropriate inventory control system. Coefficient of variation is the indicator to observe which has the formula shown below.

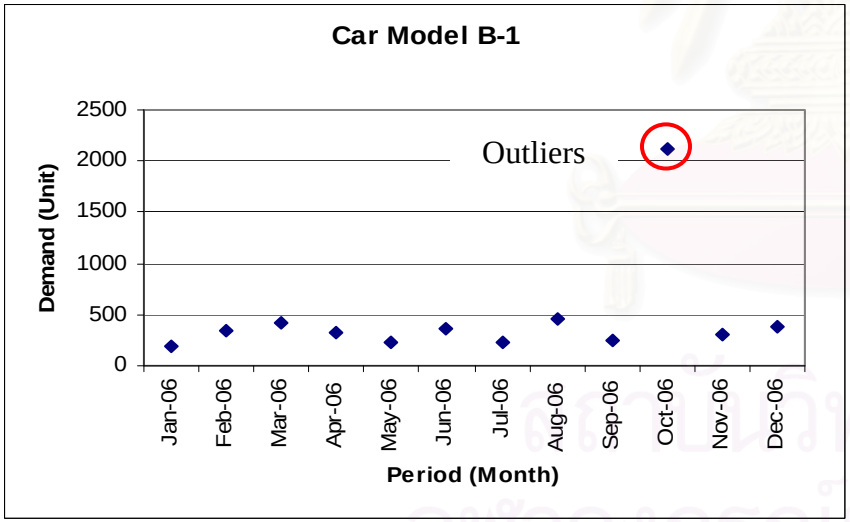
$$CV = \frac{SD}{Mean}$$

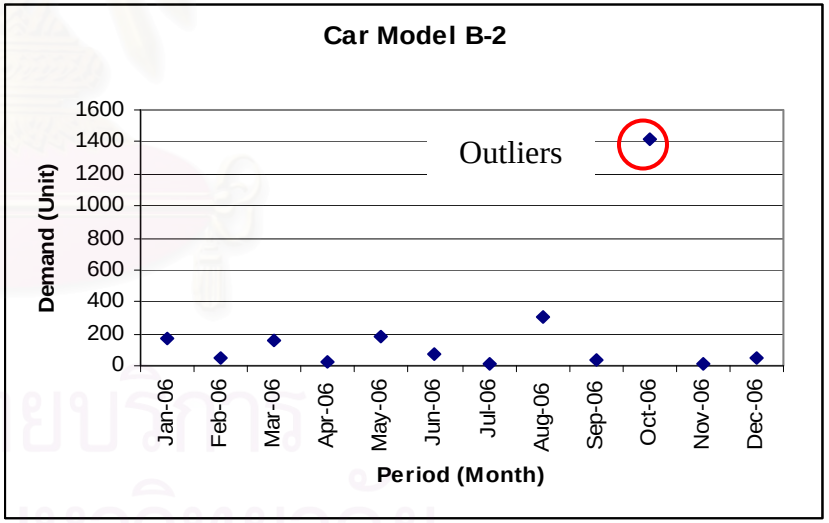
where CV = Coefficient of variation
SD = Standard deviation
Mean = Mean of data

In case of CV>1, it can be considered as high variation, but if CV<1 can be assumed as low variation. It means that if CV of demand data is lower than 1, the demand rate can be assumed as constant.

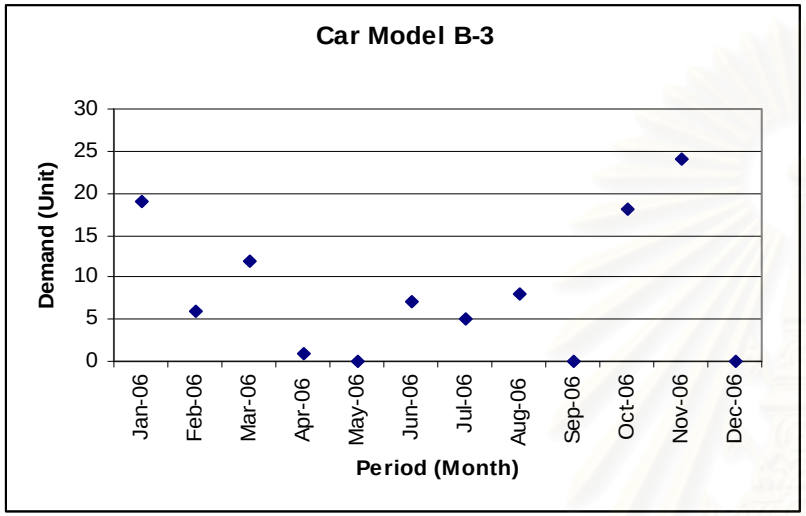


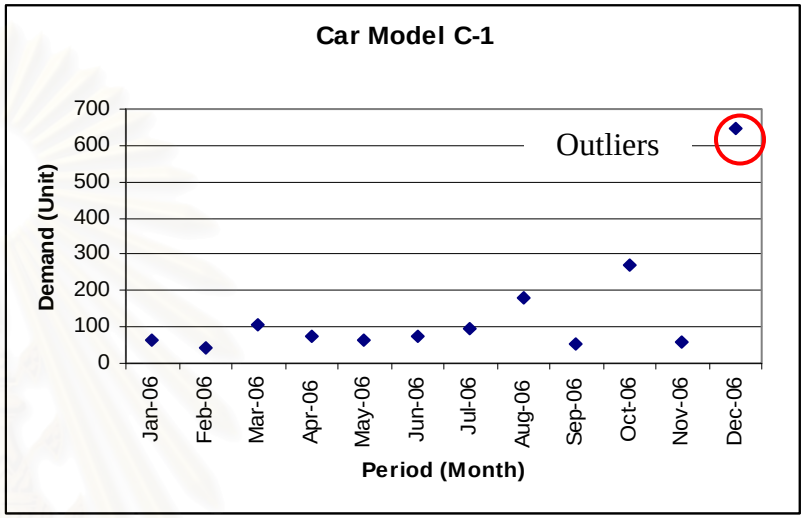


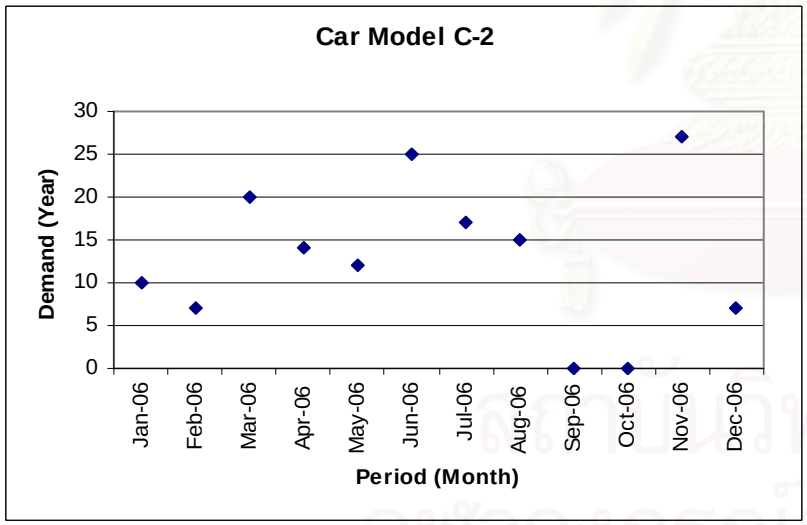


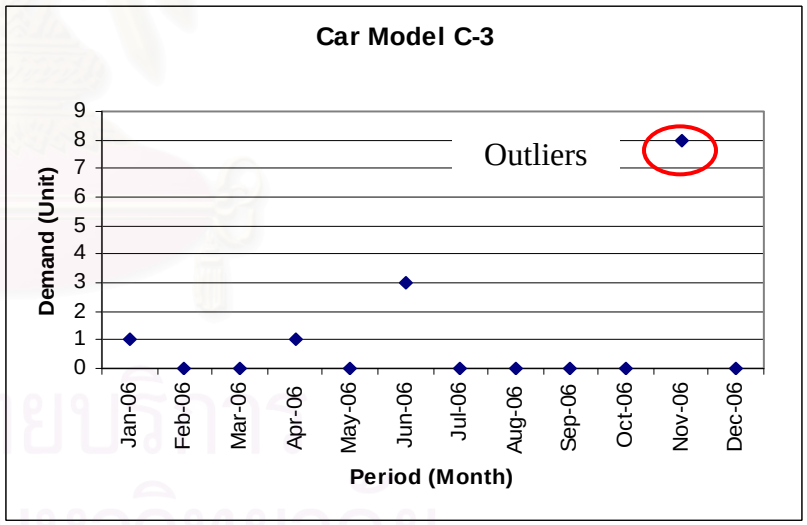


Graph 3.18 Year 2006 Demand of Oil Seal









Graph 3.19 Year 2006 Demand of Oil Seal (Cont.)

From the graphs, demand of oil seal of car model A-2, B-1, B-2, C-1 and C-3 have abnormal data. It is because there are export sales volumes on that month, so they are considered as outliers. The coefficient of variation for each car model is shown in below table.

Table 3.7 Coefficient of Variation of Year 2006 Demand

Car Model	Type of Demand	Standard Deviation (SD)	Mean	Coefficient of Variation (CV)
A-1	Actual 2006	3.0	111.0	0.32
	Forecast	1.1	118.1	0.11
A-2	Actual 2006	1.4	0.6	2.25
	Forecast	0.2	2.5	0.86
B-1	Actual 2006	84.8	313.8	0.27
	Forecast	98.5	339.1	0.29
B-2	Actual 2006	94.0	97.5	0.96
	Forecast	91.7	109.8	0.83
B-3	Actual 2006	0.7	8.3	0.99
	Forecast	0.5	9.2	0.59
C-1	Actual 2006	68.9	99.0	0.70
	Forecast	6.1	116.2	0.63
C-2	Actual 2006	0.7	12.8	0.68
	Forecast	0.4	12.5	0.34
C-3	Actual 2006	0.9	0.5	2.06
	Forecast	0.1	0.9	0.99

The coefficient of variation of demand data of almost car model for oil seal are less than 1, it means that demand rate can be assumed as constant. Except car model A-2 and C-3, the coefficient of variation is more than 1, so it cannot be assumed demand data as constant. However, demand rate of both car models are decided to be assumed as constant because of small number of sales volumes.

3.8 Inventory Control System

According to limitation of storage space area and no criteria or system of product order, high inventory cost is another important problem which the company encountered in addition to not enough space to keep stocks. It is necessary to improve order and stock keeping system to control number of product for ordering and keeping in warehouse with suitable standard.

3.8.1 Economic Order Quantity

To create the system for considering spare part quantity order, the suitable optimal number of order quantity is required to calculate based on balancing of carrying cost and ordering cost. Normally, carrying cost and holding cost has the relation in different direction, so the calculation to find order quantity should balance carrying minimum carrying cost and ordering cost.

3.8.1.1 Carrying Cost

Carrying cost of ABC Company can be described as lists below.

- **Electricity Fee**

  Electricity fee of ABC Company are around 20,000 Baht per month, so electricity fee is around 240,000 Baht per year.

- **Product Insurance Fee**

  ABC Company pays for fire insurance every year with the rate as 191,290.32 Baht.

- **Inventory Labor Cost**

  Staff's salary for who is direct related to inventory control is around 300,000 Baht.

- **Interest**

  Loan interest rate of the bank that is related to ABC Company in 2006 is around 8%, so total interest rate of inventory can be calculated as:

Inventory on the beginning of year 2006	100,890,572	Baht
Inventory on the end of year 2006	99,648,568	Baht
Average inventory of year 2006	100,269,570	Baht
Interest of year 2006	8,021,566.6	Baht

Total carrying cost per year can be calculated as:

Electricity fee	240,000.00	Baht
Insurance fee	191,290.32	Baht
Inventory labor cost	300,000.00	Baht
Interest of inventory	8,021,566.60	Baht
Total carrying cost per year	**8,752,856.92**	Baht
Total stock units for year 2006	378,316	Units
Carrying cost per unit	**23.14**	Baht

3.8.1.2 Ordering Cost

ABC Company has no transportation cost because all transportation cost for ordering is paid by X Company, so only internet system fee for ordering by e-mail is spent for ordering to product purchase.

Internet system fee (per month)	1,200	Baht
Internet system fee (per year)	14,400	Baht
Total working day per year	250	days

ABC Company usually has 3 time of order for 1 day so;

Ordering cost per order	**19.2**	**Baht**

3.8.1.3 Order Quantity

Optimal order quantity can be found by using the formula as:

$$Q_{opt} = \sqrt{\frac{2C_o D}{C_c}}$$

where Qopt = optimal order quantity
Co = ordering cost per order
D = average annual demand
Cc = carrying cost per unit

Assume average annual demand of product items in ABC Company is constant, so the average annual demands of oil seal are shown in below table.

Table 3.8 Average Annual Demand of Oil Seal

Car Model	Type of Demand	Average Annual Demand (unit)
MODEL A-1	Actual 2006	1332
	Forecast	1417
MODEL A-2	Actual 2006	32
	Forecast	30
MODEL B-1	Actual 2006	5576
	Forecast	5723
MODEL B-2	Actual 2006	2490
	Forecast	2612
MODEL B-3	Actual 2006	100
	Forecast	111
MODEL C-1	Actual 2006	1738
	Forecast	1395
MODEL C-2	Actual 2006	154
	Forecast	150
MODEL C-3	Actual 2006	13
	Forecast	11

The optimal order quantity of oil seal of car model A-1 can be computed by using 2006 actual average annual demand as:

$$Q_{opt} = \sqrt{\frac{2 \times 19.2 \times 1332}{23.14}}$$

= 47 units

For other car models, they can be calculated as shown in the table.

Table 3.9 Optimal Order Quantity of Seal Oil Based on 2006 Actual Demand

Car Model	Optimal Order Quantity (Actual Demand)
MODEL A-1	47
MODEL A-2	7
MODEL B-1	96
MODEL B-2	64
MODEL B-3	13
MODEL C-1	54
MODEL C-2	16
MODEL C-3	5

In case of calculation from 2006 forecast demand, the optimal order quantity can be computed and shown in the table.

Table 3.10 Optimal Order Quantity of Seal Oil Based on 2006 Forecast Demand

Car Model	Optimal Order Quantity (Forecast Demand)
MODEL A-1	48
MODEL A-2	7
MODEL B-1	97
MODEL B-2	66
MODEL B-3	14
MODEL C-1	48
MODEL C-2	16
MODEL C-3	4

3.8.2 Total Inventory Cost

The total annual inventory cost can be computed by using the formula as:

$$TC = \frac{C_o D}{Q} + \frac{C_c Q}{2}$$

Total annual cost of 2006 oil seal of car model A-1 can be calculated as:

Based on actual demand

$$TC = \frac{(19.2)(1332)}{47} + \frac{(23.14)(47)}{2}$$

$$= 1087.93 \text{ Baht}$$

Based on forecast demand

$$TC = \frac{(19.2)(1417)}{48} + \frac{(23.14)(48)}{2}$$

$$= 1122.23 \text{ Baht}$$

3.8.3 Reorder Point

Reorder point which is the indicator quantity number for order products to fill up stocks can be computed from the formula as:

$$R = dL + SS$$

where d = demand rate per period (daily)

L = lead time to receive order

SS = safety stock

Safety stock is the number of products in inventory for preventing stock out occurring. Safety stock can be computed with the formula as:

$$SS = z\sigma_d \sqrt{L}$$

where z = number of standard deviations corresponding to the service

level probability

σ_d = the standard deviation of demand on the period (daily)

Safety stock of oil seal of car model A-1 can be calculated by considering all parameters as:

Based on actual demand

- From table 1, the standard deviation of monthly demand of oil seal of model A-1 can be calculated is 36, so the standard deviation of daily demand is around 3
- ABC Company can accept the service level of 80%, the value of z is 0.87 (from the normal table in appendix)
- Leadtime to receive order from X Company is 3 days

As a result, the safety stock of oil seal of car model A-1 can be computed as:

$$SS = (0.87)(3)\sqrt{3} = 4$$

Therefore, the reorder point of oil seal of car model A-1 can be calculated as:

$$R = (5)(3) + 4 = 20$$

Based on forecast demand

- From table 1, the standard deviation of monthly demand of oil seal of model A-1 can be calculated is 14, so the standard deviation of daily demand is around 1.1
- ABC Company can accept the service level of 80%, the value of z is 0.87 (from the normal table in appendix)
- Leadtime to receive order from X Company is 3 days

As a result, the safety stock of oil seal of car model A-1 can be computed as:

$$SS = (0.87)(1.1)\sqrt{3} = 2$$

Therefore, the reorder point of oil seal of car model A-1 can be calculated as:

$$R = (5.6)(3) + 1.7 = \mathbf{19}$$

3.9 Dead Stock (Obsolete Stock) Management

In order to inventory improvement, dead stocks is important problem affects for both warehouse storage space area and inventory cost. Therefore, dead stock management is required to solve the problem in ABC Company.

3.9.1 Storage Space Area

According to storage space area of ABC Company, part of space area is focused on this research. Term of space utilization is calculated in term of volume because there are various types of shelf used in this company. Focused storage space area can be shown as below.

1st Floor;	total space volume is	53.45	m^3
2nd Floor;	total space volume is	115.87	m^3
Total volume quantity of focused storage space area is		169.32	m^3.

3.9.2 Current Situation of Dead Stock

According to type of business, dead stock is one of inventory problems that are difficult to avoid for ABC Company. Many car models and a lot of car parts for each model involve high level of stocks. It is possible that those stocks become to be dead stock if demand forecast is not managed with suitable way. For ABC Company, they have sales value around 40 to 50 Million Baht per month, but they have no any system of

demand forecasting. This affected to company to have many dead stock items keeping in the warehouse.

The cause of high level of dead stock of ABC Company can be investigated as:

- There is no any regulation in Thailand to determine vehicle's life, so over 10 year-vehicles are still used in Thailand. Spare part dealer should have stocks for those car models.
- Big lot size discount is also cause for ABC Company to have many dead stocks. ABC Company often order big lot size promotion with special rate discount, but some of those items are still keeping in warehouse as dead stock.
- Inappropriate demand forecast is another cause. There is no any suitable model for studying trends of customer's demand, so they usually reorder based on sales volume. For example, they ordered an item with 1 unit of quantity when they sold 1 unit of that item, or sometimes, they order double of sales quantity.

3.9.2.1 Category of Stock

Car is the product which has medium period of lifetime. In addition to this factor, Thai people also use the car more than 10 years, so stock keeping lead time should be concerned period of model life as well. To arrange stocks which have long keeping period, ABC Company categorized group of part with two main types as:

- ***Dead Stock*** means product items keeping in warehouse over 18 years
- ***Sleeping Stock*** means product items keeping in warehouse over 10 years and not used in car model since previous model.

3.9.2.2 Dead Stock

First group of stocks affected to storage space problem of ABC Company is dead stock. As above paragraph, the company identified dead stock as items kept in warehouse over 18 years. After surveying, data of dead stock can be collected and shown as below.

Dead Stock on 1st floor

Table 3.11 Dead Stock Volume on the 1st Floor Storage Space

Part Name	Quantity (units)	Storage volume (cm3)
Fan	20	260,480
Insulator Engine	50	130,832
Gear	5	136,850
Switch	20	
Spacer Bearing	2	
Pad Kit	147	392,496
Garnish Luggage	20	360,000
Grille Radiator	21	
Lens Clearance	34	
Lamp	15	
Cylinder Kit	40	
	Total	**752,496**

Dead stock on 1st floor can be calculated in term of space as ***0.75 m^3***.

Dead Stock on 2nd floor

Table 3.12 Dead Stock Volume on the 2nd Floor Storage Space

Part Name	Quantity (units)	Storage volume (cm3)
Absorber Shock	490	1,720,400
Arm	18	156,400
Liner	32	144,670
Piston	130	293,250
Disc Clutch	22	64,515
Shoe Kit Brake	5	32,257
Switch	1050	494,615
	Total	**2,906,107**

Dead stock on 2nd floor can be calculated in term of space as ***2.91 m^3***.

Percentage of dead stock which is considered can be calculated as shown below.

1st Floor Percentage of Dead Stock on the 1st floor is ***1.41%***

2nd Floor Percentage of Dead Stock on the 2nd floor is ***2.51%***

Table 3.13 List of Dead Stock

Part Number	Price (Baht)	Quantity (Unit)	Total Cost (Baht)
A04479-XXXXX	1050	12	12,600
A04494-XXXXX	1880	28	52,640
A04495-XXXXX	1550	17	26,350
A04499-XXXXX	300	40	12,000
A04991-XXXXX	150	147	22,050
A11461-XXXXX	3190	32	102,080
A13103-XXXX1	1440	82	118,080
A13103-XXXX2	1500	48	72,000
A31250-XXXXX	1800	22	39,600
A45490-XXXXX	2000	18	36,000
A48531-XXXX1	650	110	71,500
A48531-XXXX2	635	160	101,600
A48531-XXXX3	645	160	103,200
A48531-XXXX4	845	10	8,450
A52159-XXXXX	4040	7	28,280
A53101-XXXX1	2720	6	16,320
A53101-XXXX2	2990	6	17,940
A53101-XXXX3	3310	1	3,310
A53101-XXXX4	3300	1	3,300
A53111-XXXXX	2030	7	14,210
A76801-XXXX1	6850	10	68,500
A76801-XXXX2	10600	10	106,000
A81610-XXXXX	2290	15	34,350
A81611-XXXX1	1740	7	12,180
A81611-XXXX2	1740	3	5,220
A81621-XXXXX	1740	24	41,760
A83510-XXXXX	2390	5	11,950
	Total	**988**	**1,141,470**

Total value of dead stocks which directly affected to inventory cost of dead stocks can be estimated around **1,141,470** Baht.

3.9.2.3 Sleeping Stock

Another group of stocks with long keeping lead time is sleeping stock. Because many Thai cars are still used though model life is more than 10 years, ABC Company considered classifying sleeping stock as over 10 year-keeping lead time and not used in car model since previous model.

3.9.3 Dead Stock Reduction

Dead Stocks are classified into two groups of parts which the first one is very old package and kept in the shelf very long time (more than 20 years). And the second one is parts that are kept in stocks more than 18 years to 20 years. For both groups, ABC Company had two main methods for eliminating these stocks with detail as sale and disposal.

Some models of more than 10 year-cars are still used but there are few cars which will use genuine or new spare part for maintenance. That is the reason why ABC Company decided to dispose almost parts. However, some parts were purchased from second-hand spare parts shop with 90% – 98% discount from original price. Detail of dead stock reduction is shown as below table.

Table 3.14 Dead Stock Reduction

Part Number	Quantity (Unit)	Keeping Year	Eliminate Method	Discount	Money Value (Baht)
A04479-XXXXX	12	25	Disposed	-	-
A04494-XXXXX	28	30	Disposed	-	-
A04495-XXXXX	17	>18	Sold	90%	2,635
A04499-XXXXX	40	>25	Dispose	-	-
A04991-XXXXX	147	>25	Dispose	-	-
A11461-XXXXX	32	24	Dispose	-	-
A13103-XXXX1	82	>25	Dispose	-	-
A13103-XXXX2	48	>25	Dispose	-	-
A31250-XXXXX	22	>25	Dispose	-	-
A45490-XXXXX	>18	>25	Dispose	-	-
A48531-XXXX1	110	>25	Dispose	-	-
A48531-XXXX2	160	>25	Dispose	-	-
A48531-XXXX3	160	>25	Dispose	-	-
A48531-XXXX4	10	>25	Dispose	-	-
A52159-XXXXX	7	>18	Sold	95%	1,414
A53101-XXXX1	6	>18	Sold	90%	1,632
A53101-XXXX2	6	>18	Sold	90%	1,794
A53101-XXXX3	1	>18	Sold	90%	331
A53101-XXXX4	1	>18	Sold	90%	330
A53111-XXXXX	7	>18	Sold	90%	1,421
A76801-XXXX1	10	>18	Sold	95%	3,430
A76801-XXXX2	10	>18	Sold	95%	5,300
A81610-XXXXX	15	24	Dispose	-	-
A81611-XXXX1	7	>25	Dispose	-	-
A81611-XXXX2	3	24	Dispose	-	-
A81621-XXXXX	24	24	Dispose	-	-
A83510-XXXXX	5	>25	Dispose	-	-
				Total	**18,287**

3.9.4 Sleeping Stock Arrangement

In addition to dead stock elimination, ABC Company realized that preventing more dead stock happened again is also important. Sleeping stock is type of stock which may be dead stock in the future, so the company considered group of sleeping stocks for categorizing them and created the small system to manage sleeping stocks as shown below.

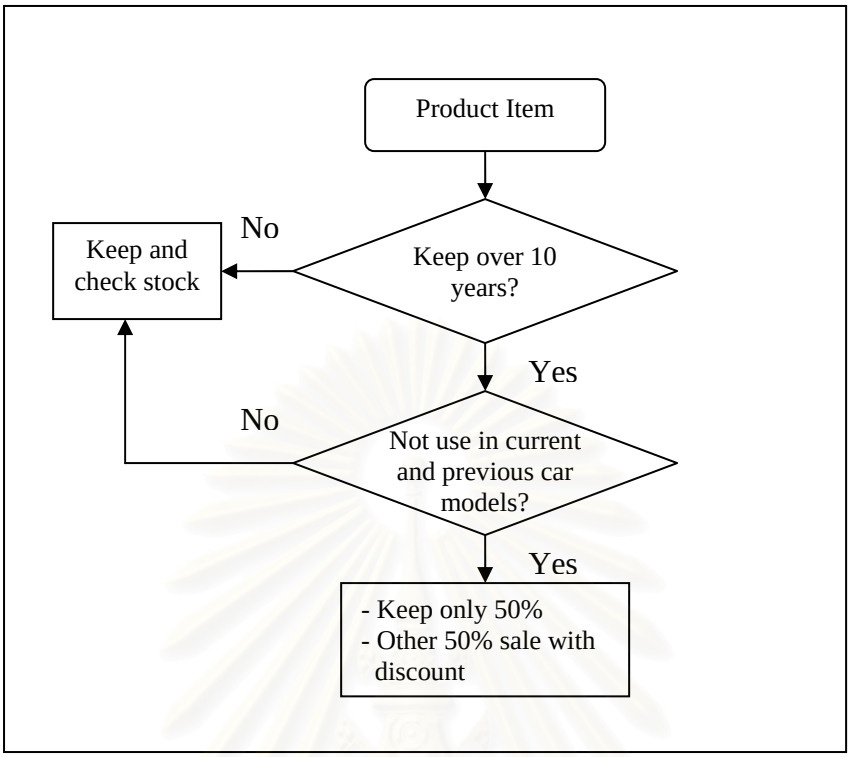


Figure 3.13 Flow Chart of Sleeping Stock Categorization

This flow chart shows the method to select parts for management. ABC Company set this policy to categorize sleeping stock to manage sleeping stock. The step of this system as:

Step 1 Considering product item that have been kept in warehouse over 10 years. If those items have not been kept for over 10 years, they will be kept in stocks.

Step 2 For product items with keeping over 10 years, they will be considered with criteria based on car model implementation period. If the item was used only for car model that was launched before previous model, it will be classified to be sleeping stock as shown in picture below.

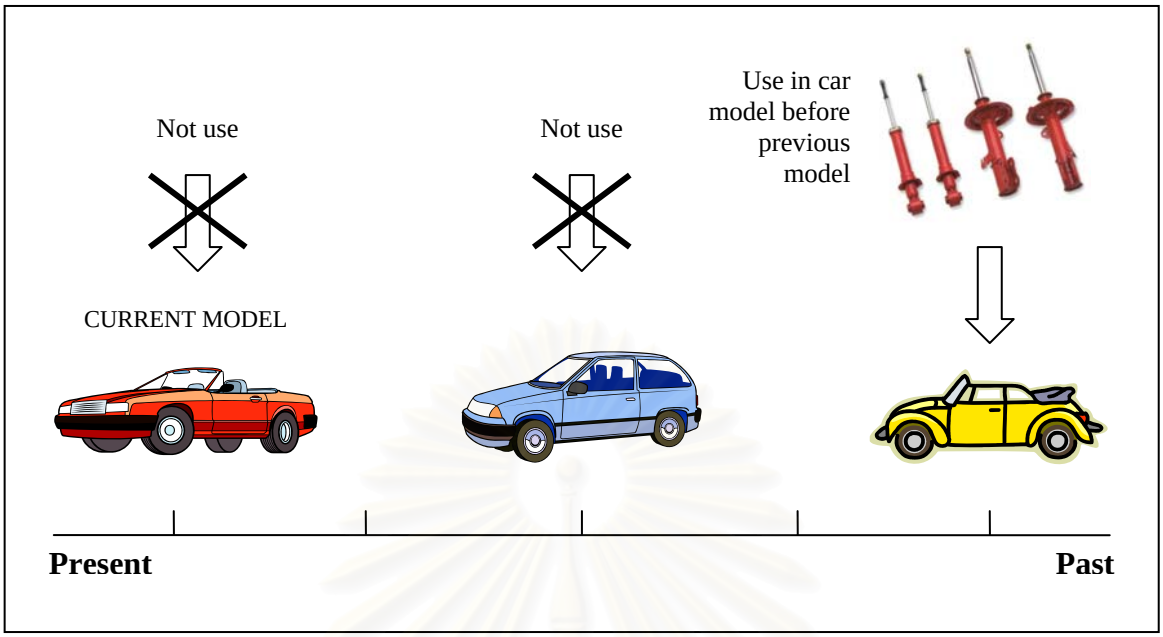


Figure 3.14 Identification of Sleeping Stocks

Step 3 After having list of sleeping stocks, ABC Company has plan to try to sell half of those items with 50% discount.

As a result, all above methodologies are proposed to solve inventory problems in ABC Company. Inventory control systems and demand forecasting will help the company to arrange suitable numbers of stocks and orders including reduce inventory costs. Moreover, sleeping stocks management is conducted for avoiding dead stocks problems as occurring in the past. Results for all proposed methodologies are shown in the next chapter.

CHAPTER IV

RESULT OF RESEARCH

4.1 Inventory Management System Improvement Result

Several proposed ways of inventory management system improvement as explanations in chapter 3 have the results can solve the inventory problems in ABC Company. In this chapter, results from those improvements are described in detail.

4.2 Result of Warehouse Management

After conducting warehouse improvement, the result can be found as below list.

- There is fixed receiving area for products loading when those items are arrival
- More storage area to keep product with many variations of part number by using adjustable box
- 2 additional staffs can help to shorten leadtime of loading, receiving, checking and arranging products to shelf
- More storage area to keep products that customers order (cycle time of keeping for waiting to customer receive products are 3 days maximum)

4.3 Result of Record System Improvement

4.3.1 Record System of Purchased Products

One of causes of problems of inaccurate stock record system is late data input for purchased items. It is because invoice document is sent for filling data much late. Several solutions for improvement can be concluded below.

1) 2 more staffs were employed for receiving, loading and checking received products.
2) Invoice sheet are copied and sent to data input, and using copy sheet for products checking when customers received.
3) Indicating time for deadline to submit invoice for data input at 2:00 pm for the 8 am-receiving and within that day for the rest.
4) New computer system to shorten data input leadtime by eliminating the part of part name typing.

The result of improvement can be described as below.

Table 4.1 Result of Stock Record System Improvement for Purchase Data Input

Item	Before Improvement	After Improvement
2 more staffs		
- Shorten leadtime for loading & checking parts	- Loading & checking parts 9:00~2:00 pm (4 hours) & 2:00~5:00 pm (3 hours) & 5:00~6:00 pm (1 hour)	- Loading & checking parts 9:00~12:00 am (3 hours) & 2:00~4:00 pm (2 hours) & 5:00~6:00 pm (1 hour)
- More time for data input	- Data input time from 2:00 pm and sometimes late around 1~2 days	- Data input time from 13:00 pm
	- Data input time 4 hours in case of invoice sheet on that day is sent immediately after finish products check 4 hours=(4x120=480 items)	- Data input time 6 hours in case of invoice sheet on that day is sent immediately after finish products check 5 hours=(5x120=600 items)
New computer system		
- Shorten typing time for data input	- Data input 120 items for 1 hour	- Data input 180 items for 1 hour
Total Performance	Data input time (max): ***480 items per day***	Data input time (max): 5x180 = ***900 items per day***

In case of proposed bar coding system, it involves shortening leadtime of purchase-sale record for stocks database. Estimated result of improvement can be shown in the table.

Table 4.2 Result of Stock Record System Improvement for Purchase Data Input with bar coding system

Item	**New Computer System Only**	**New Bar Coding System**
Improvement	Data input 180 items for 1 hour (20 second per item)	Data input 600 items for 1 hour (6 second per item)
Performance (comparing based on 5 hours)	Data input time (max): 5x180 = ***900 items per day***	Data input time (max): 5x180 = ***3,000 items per day***

From above table, bar coding system has more efficiency around 133%. In term of cost, comparison of bar coding system investment and employing more staffs to achieve same ability of data input is shown that the bar coding system is cheaper than staff employment.

Table 4.3 Cost Comparison between Staff Employment and Bar Coding System

	Staff Employment	**Bar Coding System**
Ability of data input	3,000 items per day	3,000 items per day
Requirement	3 persons	-
Cost (for 1 year)	Salary 12,000 Baht per month = 144,000 Baht/year/person = ***432,000 Baht/year***	Investment ***100,000 Baht*** (at the 1st year)

4.4 Model of Trend of Spare Part Demand

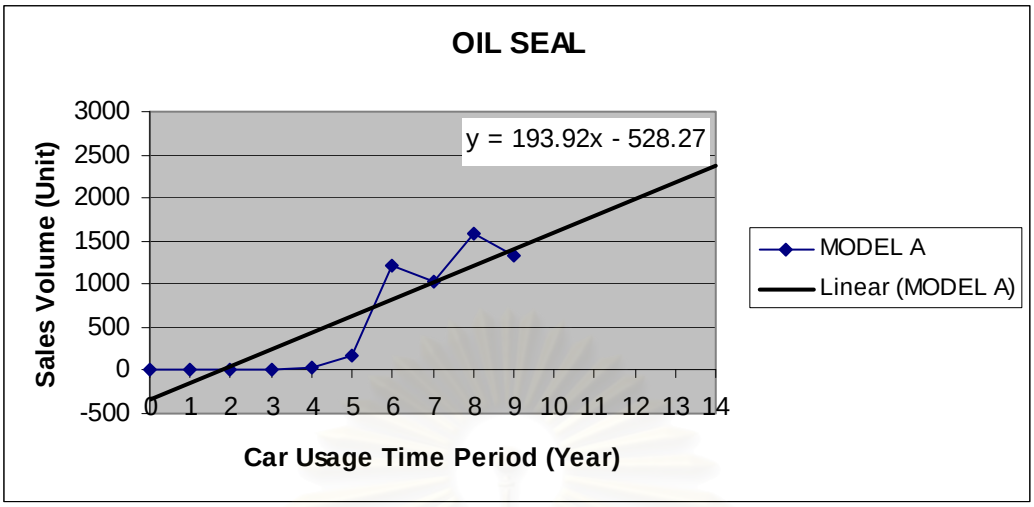
ABC Company collected data of sales volumes of focused group of spare parts to analyze trend of demand to be reference for forecast consideration. Trend of demand of each part is analyzed based on several factors which are related to characteristic of part and car model. From data of sales volumes in year 2002 to 2006 of three car models, factors for analysis can be summarized as below.

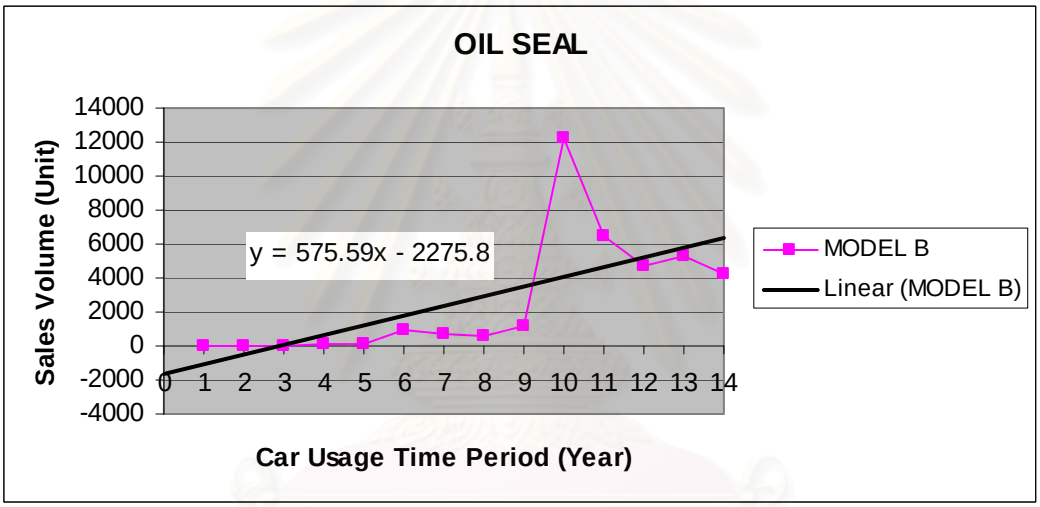
- Types of spare parts – spare part for car maintenance or for car accident.
- Design of part or shape of part (easy to damage)
- Special defective part for each model – it can affect to large number of sales volume of part for only one model.
- Number of car sales volumes

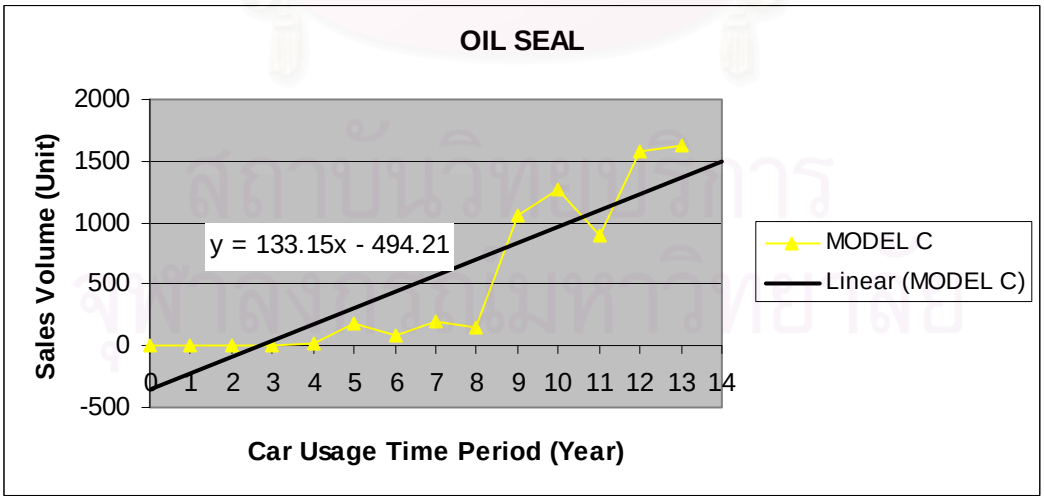
4.4.1 Trends of Demand Analysis for Demand Forecasting

As above explanation, there are many factors which can affect to demand of spare parts. Number of car sales volume and period of car usage time for each model are also important factors. From section 3.6.3, trends of spare part demand based on car usage time are collected to be guideline for reference to predict demand. As a result, in addition to concern daily and monthly demand of spare parts, these trends should be also applied for demand forecasting in the next year to concern the factor of car usage time. Oil seal is example to show trend of spare part analysis.

Firstly, usage time of car model is concerned to find the trend of demand. Linear equation from regression of trend of demand graph is shown in graph 1.







Graph 4.1 Trend Line and Linear Equation of Oil Seal Demand for Car Model A, B, and C

To consider demand forecasting in the next year, car usage time in 2007 has to be known at first. And then, forecast demand is predicted from those trends. Summary of trend of demand based on car usage time period and linear equation are shown in table.

Table 4.4 Period of Implemented Car Model and Trend of Demand

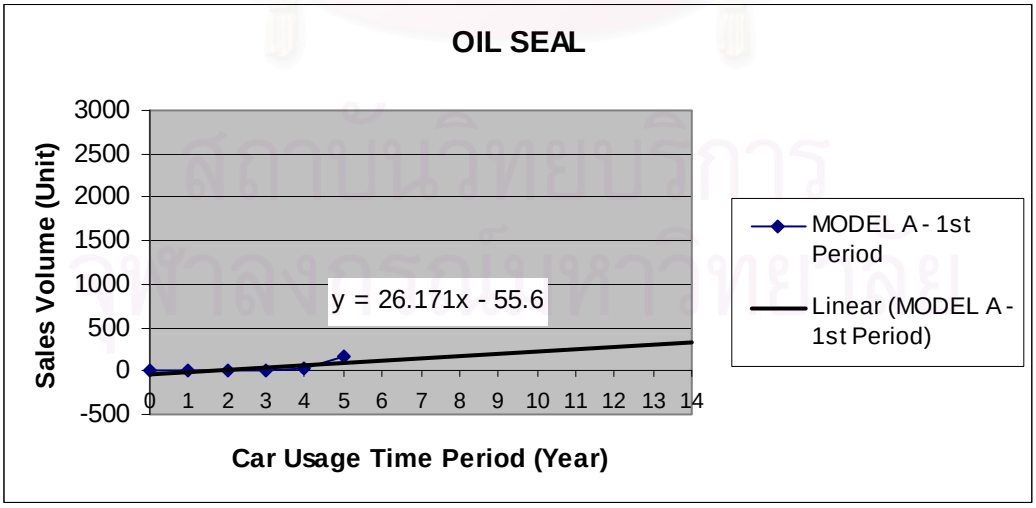
Car Model	Car Usage Time Period in 2006	Car Usage Time Period in 2007	Trend of Forecast Demand
A-1	9	10	Normal demand with equation; y = 193.92x - 528.27
A-2	4	5	
B-1	14	15	Normal demand with equation; y = 575.59x - 2275.8
B-2	10	11	Special demand concern with trend to decrease around 48%
B-3	5	6	Normal demand with equation; y = 575.59x - 2275.8
C-1	13	14	Normal demand with equation; y = 133.15x - 494.21
C-2	8	9	
C-3	4	5	

From trend of oil seal demand shown in graph 4.1, almost car models have trend as linear increase, so the linear equation from regression is used to forecast demand. Except car model B-2, demand tends to rapidly increase on the 10^{th} year and decrease on the 11^{th} year. It is possible that the 10^{th} year is timing to change oil seal for maintenance. Therefore, demand should be forecasted based on trend of the graph. After calculation, trend of demand forecasting can be predicted as shown in table.

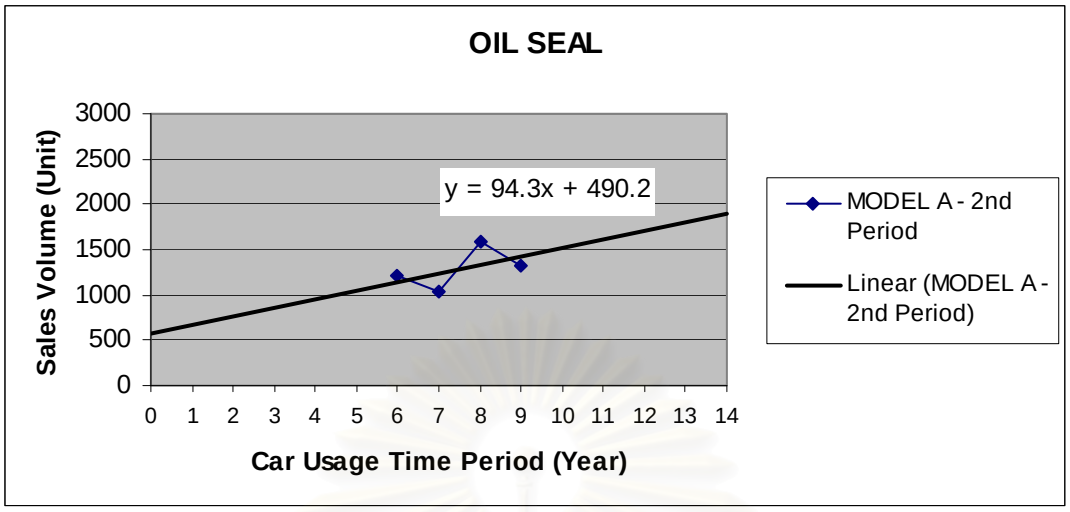
Table 4.5 Demand Forecasting from Trend of Demand

Car Model	Car Usage Time Period in 2007	Demand from linear equation on year 2006	Demand from linear equation on year 2007	Trend of Demand in 2007 based on Car Usage Time
A-1	10	1217	1411	+15.93%
A-2	5	247	441	+78.38%
B-1	15	5782	6358	+9.95%
B-2	11	Special forecast demand from data on 10th and 11th year.		-48.00%
B-3	6	602	1178	+95.59%
C-1	14	1237	1370	+10.77%
C-2	9	571	704	+23.32%
C-3	5	38	172	+346.84%

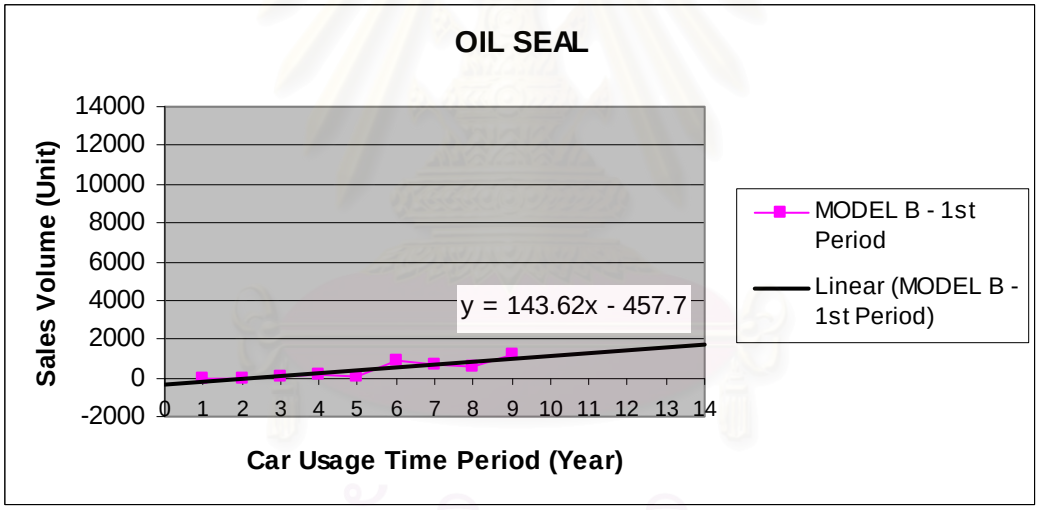
According to graphs of trend of oil seal demand, they are not completely linear in fact. The graphs are obvious separated into two periods of demand values. For more accuracy of demand forecasting, it should be better if linear equation will be separated to concern based on demand values as shown in below graphs.



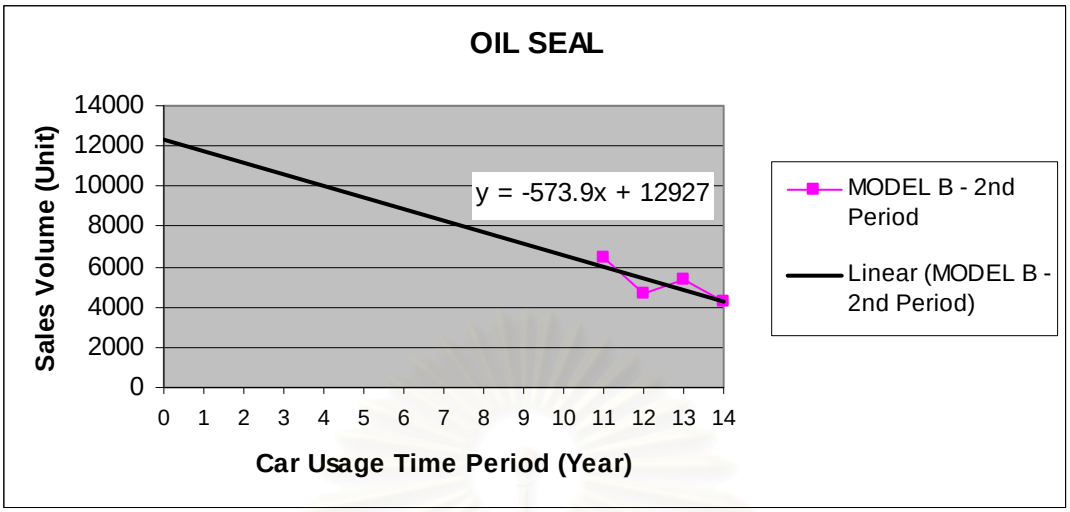
Graph 4.2 Trend Line and Linear Equation of Oil Seal Demand for Car Model A for 1st Period of Graph (1st year to 5th year)



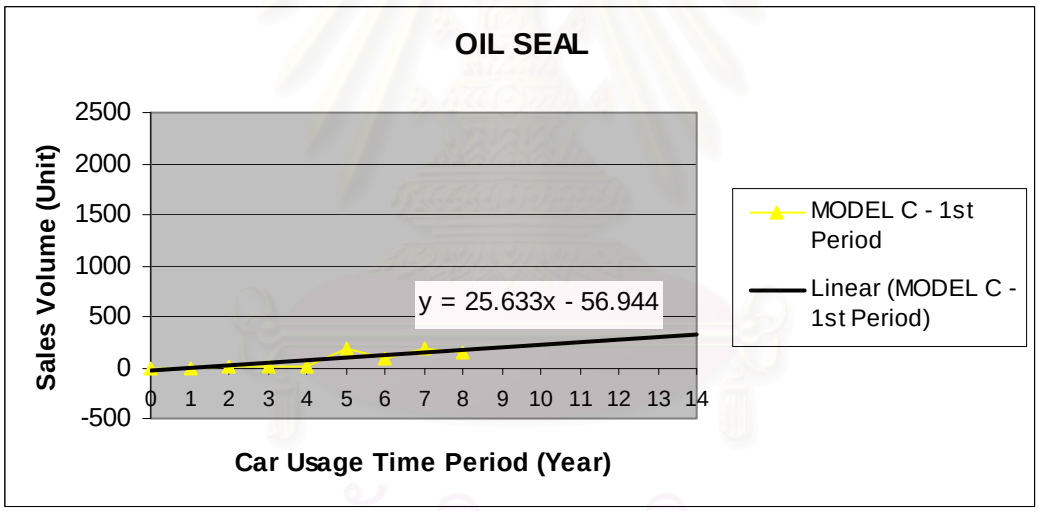
Graph 4.3 Trend Line and Linear Equation of Oil Seal Demand for Car Model A for 2nd Period of Graph (starting from 6th year)



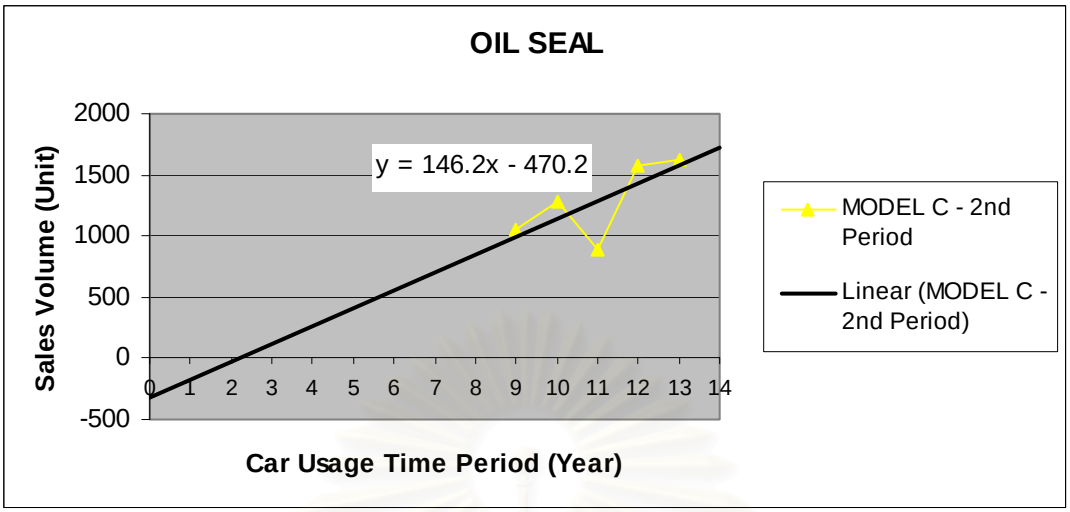
Graph 4.4 Trend Line and Linear Equation of Oil Seal Demand for Car Model B for 1st Period of Graph (1st year to 9th year)



Graph 4.5 Trend Line and Linear Equation of Oil Seal Demand for Car Model B for 2nd Period of Graph (starting from 11th year)



Graph 4.6 Trend Line and Linear Equation of Oil Seal Demand for Car Model C for 1st Period of Graph (1st year to 8th year)



Graph 4.7 Trend Line and Linear Equation of Oil Seal Demand for Car Model C for 2nd Period of Graph (starting from 9th year)

For demand of car model B, there is special demand on 10th year, so the value on this year will be separated to consider (not include to find linear equation). It can be summarized trend of demand after separated concerning data value in term of linear equation as shown in the table.

Table 4.6 Trend of Demand Concerning based on Separated Period of Graph

Car Model	Car Usage Time Period in 2006	Car Usage Time Period in 2007	Concerned Period of Graph	Trend of Demand
A-1	9	10	2nd	Normal demand: y = 94.3x + 490.2
A-2	4	5	1st	Normal demand: y = 26.171x - 55.6
B-1	14	15	2nd	Normal demand: y = -573.9x + 12927
B-2	10	11	-	Trend to decrease around 48%
B-3	5	6	1st	Normal demand: y = 143.62x - 457.7
C-1	13	14	2nd	Normal demand: y = 146.2x - 470.2
C-2	8	9	2nd	Normal demand: y = 146.2x - 470.2
C-3	4	5	1st	Normal demand: y = 25.633x - 56.944

New trends of demand forecasting can be calculated based on linear equation in above table as shown in next table.

Table 4.7 Demand Forecasting from Trend of Demand with Separate Period of Data Value Consideration

Car Model	Car Usage Time Period in 2007	Demand from linear equation on year 2006	Demand from linear equation on year 2007	Trend of Demand in 2007 based on Car Usage Time
A-1	10	1339	1433	+7.04%
A-2	5	49	75	+53.32%
B-1	15	4892	4319	-11.73%
B-2	11	Special forecast demand from data on 10^{th} and 11^{th} year.		-48.00%
B-3	6	260	404	+55.15%
C-1	14	1430	1577	+10.22%
C-2	9	148	174	+17.31%
C-3	5	46	71	+56.23%

4.4.2 Model and Guideline of Spare Parts for Car Maintenance

Trend of demand and demand analysis guideline of example parts for car maintenance can be summarized as below. The normal demands mean demand forecasting should be conducted by linear equation from graph.

Table 4.8 Model of Trend of Demand and Demand Analysis Guideline of Spare Parts for Car Maintenance

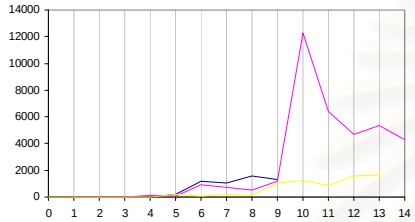
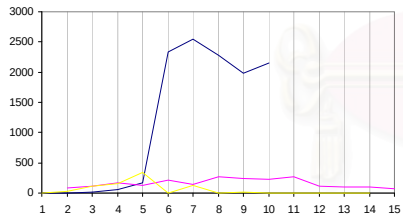
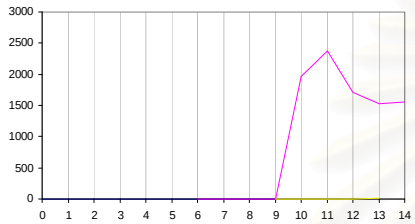
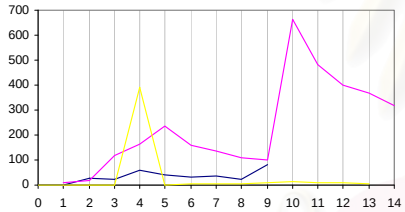
Spare Parts & Car Models	**Trends of Demand Forecasting Analysis based on Car Usage Time Period**		
	Model A	**Model B**	**Model C**
<u>Oil Seal</u> 	- Normal demands	- Normal demands - Prepare to increase on 10th year - Prepare to decrease on 11th year	- Normal demands
<u>Door Handle</u> 	- Normal demands - Special stocks for only sub-model launched during 1997 to 2002	- Normal demands	- Normal demands

Table 4.8 Model of Trend of Demand and Demand Analysis Guideline of Spare Parts for Car Maintenance (Cont.)

Part & Model of Demand	**Trends of Demand Forecasting Analysis based on Car Usage Time Period**		
	Model A	**Model B**	**Model C**
Timing Belt 	- No need stock	- Prepare large stocks on 10th year	- No need stock
Insulator Engine Mounting 	- Normal demands - Prepare to increase on 10th year	- Normal demands - Prepare to increase on 5th year - Prepare to increase double on 10th year	- Normal demands for all period - Not concern special order for export on 4th year

4.4.3 Model and Guideline of Part for Car Accident

As section 3.5.3.2, trend of spare part for car accidents can be categorized based on demand pattern as 3 groups. Trend of demand and demand analysis guideline of example parts for car accident can be summarized as below.

Table 4.9 Model of Trend of Demand Pattern 1 and Demand Analysis Guideline of Spare Parts for Car Accident

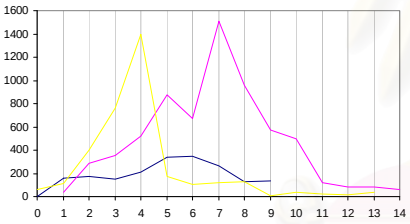
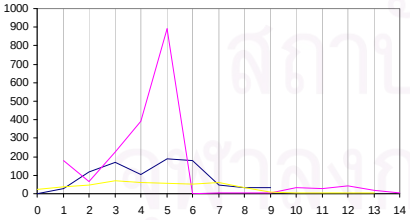
Part & Model of Demand	**Trends of Demand Forecasting Analysis based on Car Usage Time Period**		
	Model A	**Model B**	**Model C**
PATTERN 1 Bumper  Glass 	- Normal demands	- Normal demands - Prepare large stock when demand starting to increase but should be observe actual trend of demand monthly	- Normal demands

Table 4.9 Model of Trend of Demand Pattern 1 and Demand Analysis Guideline of Spare Parts for Car Accident (Cont.)

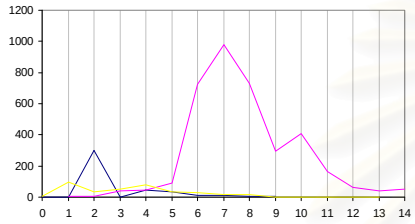
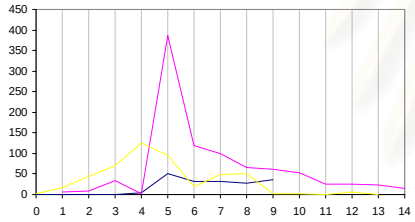
Part & Model of Demand	**Trends of Demand Forecasting Analysis based on Car Usage Time Period**		
	Model A	**Model B**	**Model C**
<u>Headlamp</u>  <u>Outer Mirror</u>  	- Normal demands	- Normal demands - Prepare large stock when demand starting to increase but should be observe actual trend of demand monthly	- Normal demands

Table 4.10 Model of Trend of Demand Pattern 2 and Demand Analysis Guideline of Spare Parts for Car Accident

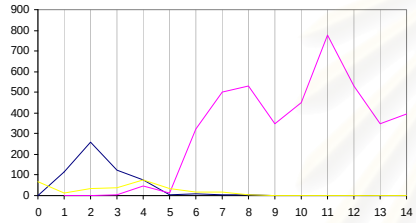
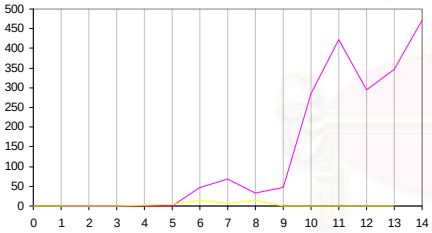
Part & Model of Demand	**Trends of Demand Forecasting Analysis based on Car Usage Time Period**		
	Model A	**Model B**	**Model C**
PATTERN 2 Front Fender Panel  Cover Under Engine 	- Normal demands	- Normal demands - Prepare large stock when demand starting to increase but should be observe actual trend of demand monthly	- Normal demands

Table 4.11 Model of Trend of Demand Pattern 3 and Demand Analysis Guideline of Spare Parts for Car Accident

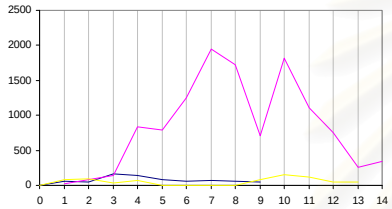
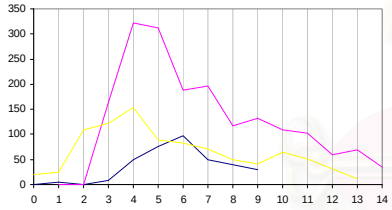
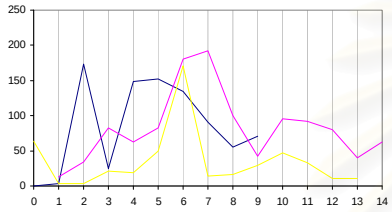
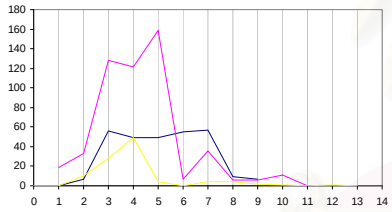
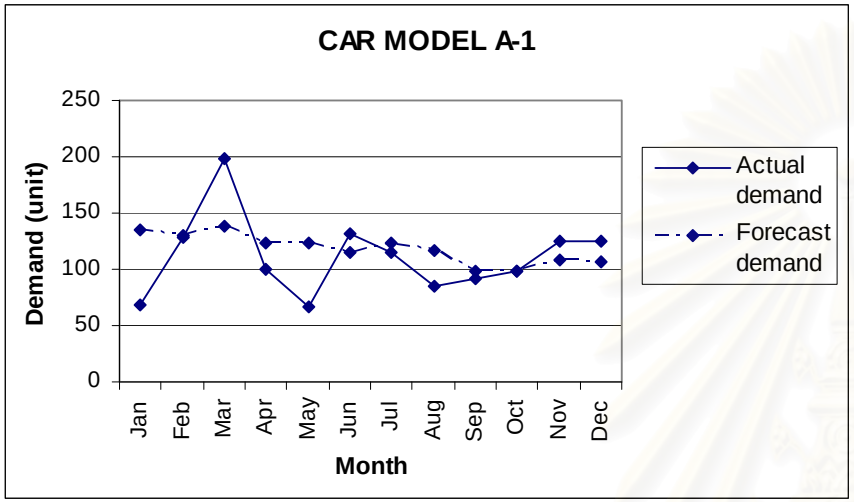
Part & Model of Demand	**Trends of Demand Forecasting Analysis based on Car Usage Time Period**		
	Model A	**Model B**	**Model C**
PATTERN 3 Lens  Side Moulding 	- Normal demands - Normal demands and increase number of stock when demand starting to increase	- Prepare large stock when demand starting to increase - Prepare large stock when demand starting to increase	- Normal demands - Normal demands and increase number of stock when demand starting to increase

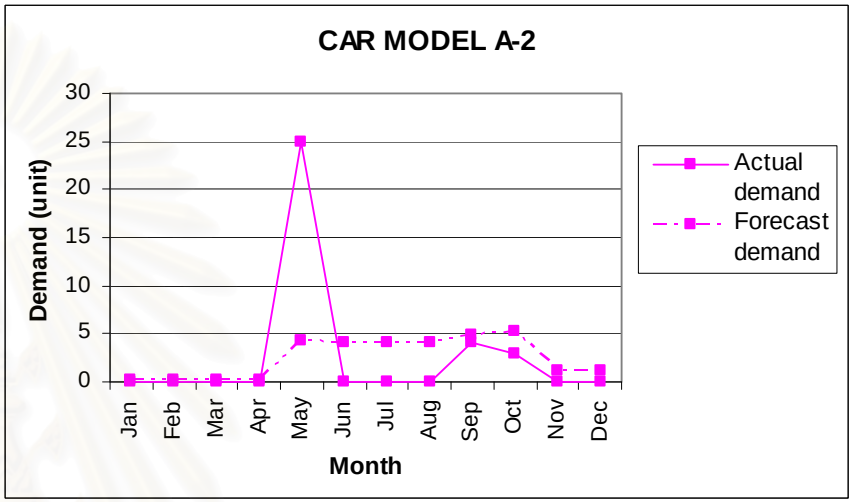
Table 4.11 Model of Trend of Demand Pattern 3 and Demand Analysis Guideline of Spare Parts for Car Accident (Cont.)

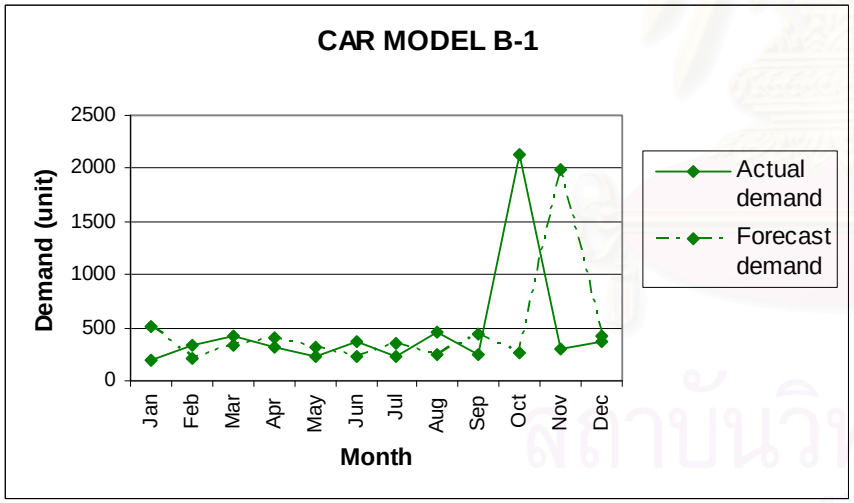
Part & Model of Demand	**Trends of Demand Forecasting Analysis based on Car Usage Time Period**		
	Model A	**Model B**	**Model C**
Lamp 	- Prepare large stock when demand starting to increase	- Prepare large stock when demand starting to increase	- Prepare large stock when demand starting to increase
Rear Fender Panel 	- Normal demands and increase number of stock when demand starting to increase	- Prepare large stock when demand starting to increase - Change to normal demands when demand starting to decrease	- Normal demands and increase number of stock when demand starting to increase

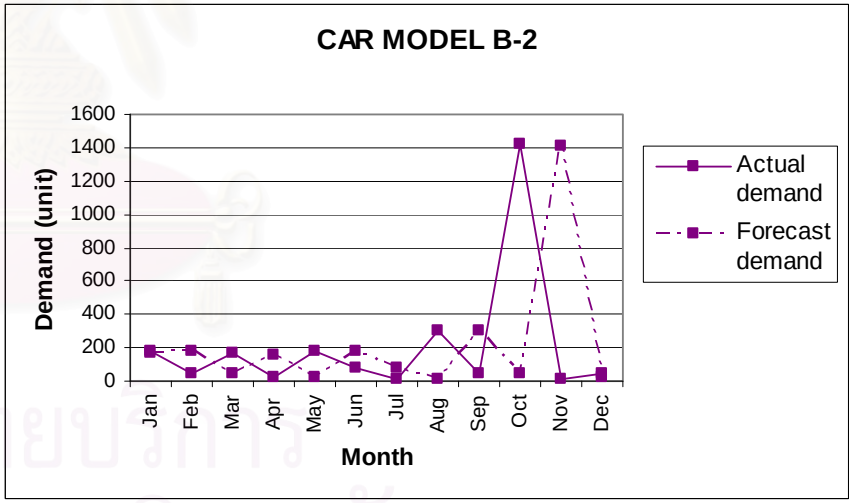
4.5 Forecast Demand

The calculation of forecast error measurement gives the result that different forecasting methods are suitable for each car model. As a result, each technique is selected to forecast demand with using year 2006 historical data. Oil seal is part to be example to show demand forecasting. Forecast demands of oil seal for each model are shown as:

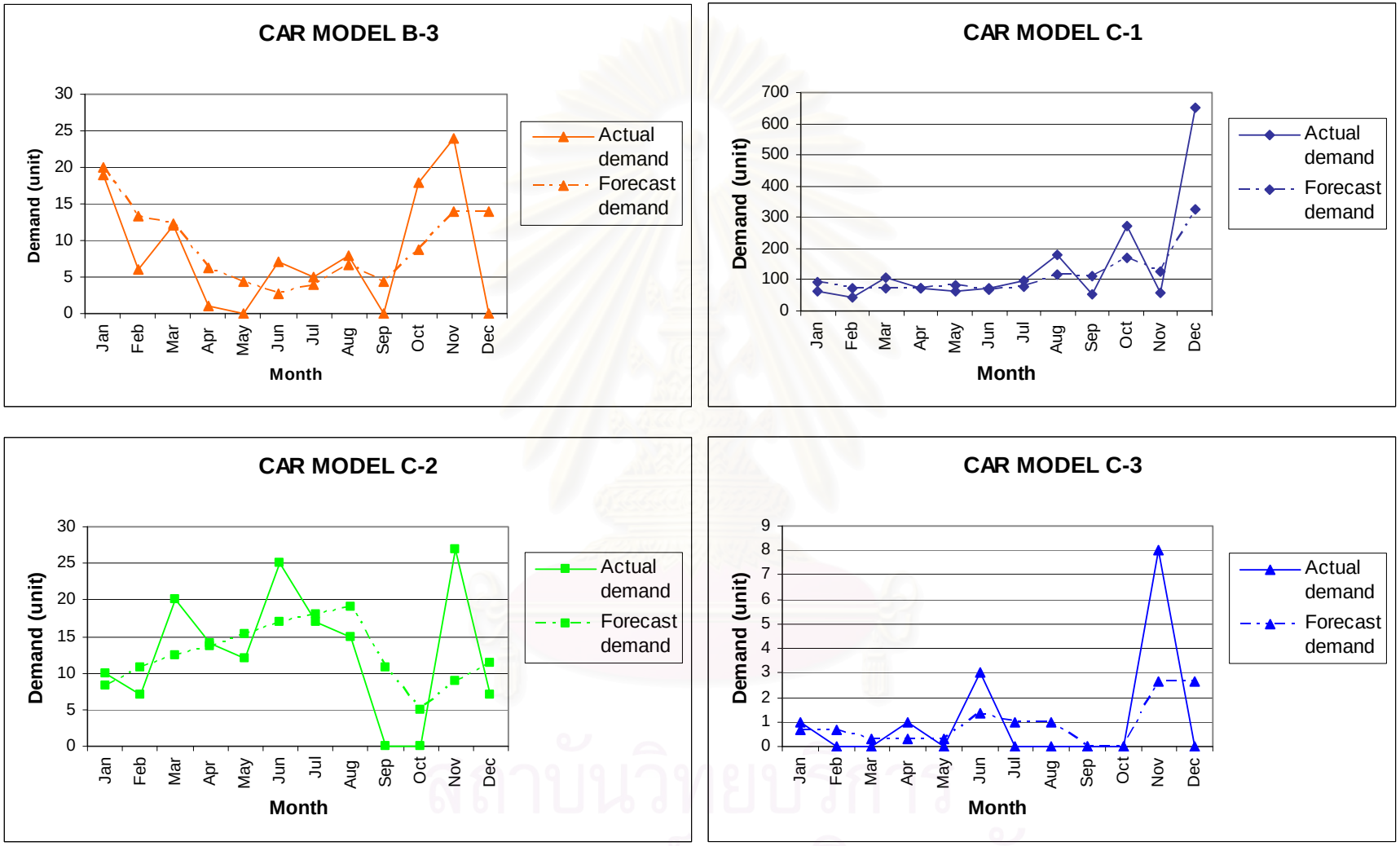








Graph 4.8 Actual Demand and Forecast Demand Data of Oil Seal



Graph 4.8 Actual Demand and Forecast Demand Data of Oil Seal (Cont.)

Above forecast demands are calculated from monthly demands in year 2006. In year 2007, forecast demand can be computed from using forecast demand in year 2006 including considering trends of demand based on car usage time period as from previous section. Calculation of forecast demand in year 2007 is shown in the table.

Table 4.12 Forecast Demand with Trend of Demand Concern

Car Model	Car Usage Time Period in 2007	Demand from linear equation on year 2006	Demand from linear equation on year 2007	Trend of Demand in 2007 based on Car Usage Time	Forecast Demand in Year 2006	Forecast Demand in Year 2007
A-1	10	1217	1411	+15.93%	1417	**1643**
A-2	5	247	441	+78.38%	30	**54**
B-1	15	5782	6358	+9.95%	5723	**6293**
B-2	11	2490	1295	-48.00%	2612	**1358**
B-3	6	602	1178	+95.59%	111	**216**
C-1	14	1237	1370	+10.77%	1395	**1545**
C-2	9	571	704	+23.32%	150	**185**
C-3	5	38	172	+346.84%	11	**49**

As separate period of demand value on trend of demand graph, new forecast demand can be calculated as shown in next table.

Table 4.13 Forecast Demand with Trend of Demand Concern from Separate Period of Data Value Consideration

Car Model	Car Usage Time Period in 2007	Demand from linear equation on year 2006	Demand from linear equation on year 2007	Trend of Demand in 2007 based on Car Usage Time	Forecast Demand in Year 2006	Forecast Demand in Year 2007
A-1	10	1339	1433	+7.04%	1417	**1517**
A-2	5	49	75	+53.32%	30	**46**
B-1	15	4892	4319	-11.73%	5723	**5052**
B-2	11	2490	1295	-48.00%	2612	**1358**
B-3	6	260	404	+55.15%	111	**172**
C-1	14	1430	1577	+10.22%	1395	**1537**
C-2	9	148	174	+17.31%	150	**176**
C-3	5	46	71	+56.23%	11	**17**

These forecast demand data is estimated to more accuracy because it computed by concerning with trends of spare part demand which also considering usage time period of car. The demand data will be used to calculate to find total inventory cost in the next section.

4.6 Inventory Control System

According to the high inventory cost problem, it is because there is no appropriate inventory control system for controlling the number of ordering products and keeping stocks. Therefore, inventory control system is created to consider order and stock keeping number based on company's current inventory conditions.

4.6.1 Economic Order Quantity and Total Inventory Cost

There are more than 10,000 specifications of spare parts which ABC Company has to control the inventory. Before improvement, the company order spare parts to X Company without any standard, so some products items are ordered with large number,

some products are ordered with small number but frequently. This involves the company has high inventory cost. The proposed system proposes suitable order quantity to minimize inventory cost by balancing carrying cost and ordering cost based on constant annual demand. This system is calculated by assumption as no remaining stocks. The below table shows the comparison for 2006 order number of oil seal and number of times order and proposed system.

Table 4.14 Comparison of Total Inventory Cost between Actual System and Proposed System of Oil Seal

Car Model	Actual Average Demand (Unit)	Actual System (Current)						Proposed System		
		Order Quantity per year (unit)	Number of order per year (times)	Order Quantity (unit)	Remain Stocks (unit)	Carrying Cost of Stocks (Baht)	Total Cost (Baht)	Optimal Order Quantity (Unit)	Number of order per year (times)	Total Cost (Baht)
A-1	1332	1299	156	8.3	0	0	3,167.63	47	28	1,087.93
A-2	32	32	4	8.0	0	0	169.36	7	4	168.63
B-1	5576	5490	431	12.7	0	0	8,552.21	96	58	2,225.92
B-2	2490	2482	69	36.0	0	0	1,745.25	64	39	1,487.47
B-3	100	-	-	-	0	0	0	13	8	290.54
C-1	1738	1802	145	12.4	64	1480.96	4,309.87	54	32	1,242.72
C-2	154	129	32	4.0	0	0	780.11	16	10	369.92
C-3	13	13	5	2.6	0	0	126.08	5	3	107.48
							18,850.52			**6,988.23**

Actual data are year 2006 data

From above table, if the company applies proposed system to order oil seal, they can reduce total inventory cost around **63%** for year 2006. And then, total cost of forecast demand which calculated from statistical forecasting techniques is computed as shown in the table.

Table 4.15 Total Inventory Cost of Proposed System of Oil Seal based on Forecast Demand from Year 2006

Car Model	Forecasted Average Demand (Unit)	Proposed System		
		Optimal Order Quantity (Unit)	Number of order per year (times)	Total Cost (Baht)
A-1	1417	48	29	1,122.23
A-2	30	7	4	163.27
B-1	5723	97	59	2,255.14
B-2	2612	66	40	1,523.43
B-3	111	14	8	313.59
C-1	1395	48	29	1,113.22
C-2	150	16	10	365.49
C-3	11	4	3	98.87
				6,955.24

It can be concluded that if proposed system is applied to use with forecast demand, total cost is also much cheaper than current system and quite equal to total cost from proposed system based on actual demand. In year 2007, estimated optimal order quantity and total inventory cost is computed and shown in the table.

Table 4.16 Estimated Optimal Order Quantity and Total Inventory Cost of Oil Seal in Year 2007

Car Model	Forecast Demand on Year 2007 (unit)	Optimal Order Quantity (unit)	Total Cost (Baht)
A-1	1643	52	1,208.34
A-2	54	9	218.06
B-1	6293	102	2,364.72
B-2	1358	47	1,098.56
B-3	216	19	438.56
C-1	1545	51	1,171.62
C-2	185	18	405.87
C-3	49	9	208.99
			7,114.72

Optimal order quantity for year 2007 is estimated by using combination of forecasting technique, EOQ concept, and trend of spare part demand based on car implementation period. Total cost calculated from these new estimated optimal order quantities is still cheaper than current system. It means that ABC Company can reduce inventory cost from year 2006 around 62.3% in case that demand in year 2007 is equal to year 2006.

For new forecast demand with trend of part concern based on separate linear equation calculation of data value, optimal order quantity, total inventory cost, and reorder point of oil seal in year 2007 can be estimated as shown in the next table.

Table 4.17 Estimated Optimal Order Quantity and Total Inventory Cost of Oil Seal in Year 2007 (based on separate linear equation calculation of data value)

Car Model	Forecast Demand on Year 2007 (unit)	Optimal Order Quantity (unit)	Total Cost (Baht)
A-1	1517	50	1,161.08
A-2	46	9	202.16
B-1	5052	92	2,118.75
B-2	1358	47	1,098.56
B-3	172	17	390.60
C-1	1537	51	1,168.73
C-2	176	17	395.85
C-3	17	5	123.57
			6,659.31

The total inventory cost of proposed system using forecast demand based on separate linear equation of trend of demand is less than using linear equation by considering overall demand data value around 6.4%. The summary of total cost computed based on different system is shown in the table.

Table 4.18 Comparison Total Cost for Different Forecast Demand and Optimal Order Quantity

Type of System	**Actual System (Current)**	**Proposed System**		
Type of Demand	**Actual demand**	**Normal forecast demand**	**Forecast demand with one linear equation trend of part**	**Forecast demand with separate linear equation trend of part**
Total Cost (Baht)	18,850.52	6,988.23	7,114.72	6,659.31
Total Cost Reduction (based on actual system)	-	**62.9%**	**62.3%**	**64.7%**

It can be concluded that the proposed inventory control system with using statistical forecasting techniques such as moving average or single exponential smoothing can reduce total inventory cost. However, the demand in spare part business is fluctuated; it can be affected from several factors such as characteristics and function of parts, car implementation year and number of car sales volume for each model. Therefore, it is better if demand forecasting will apply historical trend of demand based on car implementation period to find forecast demand on the next year. The result of proposed system is more total cost reduction than only normal forecasting demand. Moreover, if trend of demand data is considered to find the mathematical equation with realistic concern by grouping data value on the graph, the company can receive more cost reduction of total inventory cost.

4.6.2 Reorder Point

In addition to suitable order quantity, the proposed system also suggests the minimum number of stocks which the company should start to re-order parts to fill up stocks as reorder point. Normally, there are two types of product order from spare part dealer to X Company. Stock order is the first type which has 3 days of order leadtime, and another type is daily order that has 1 day of order leadtime. However, X Company's product's order rule is value of stock order should be more than 50% of total order value (stock order and daily order) per month. On the month that the company has stock order value more than 50% of total order, special reward money will be received from X Company by computed from total order value of that month. This rule involves ABC Company's order characteristics as:

- Stock order per month should be ordered as many as possible but it will affect to storage space area which requires very large area
- 1 day order leadtime for daily order means that customer can receive products which have no stocks in warehouse in 1 day
- 1 day order leadtime is not for some products which must imported from Japan but these types of parts have expensive price and low demand

From above information, 80% of service level is the level that is decided to use for ABC Company, so safety stocks and reorder point of oil seal are shown in below table.

Table 4.19 Safety Stocks and Reorder Point of Oil Seal

Car Model	Standard Deviation (daily)	Safety Stock (unit)	ROP (unit)
A-1	3.0	4	20
A-2	0.6	1	1
B-1	44.1	66	133
B-2	32.6	49	79
B-3	0.7	1	2
C-1	14.3	22	42
C-2	0.7	1	3
C-3	0.2	0	0

In case of calculation based on forecast demand, reorder point of oil seal is shown in the next table.

Table 4.20 Safety Stocks and Reorder Point of Oil Seal based on Forecast Demand

Car Model	Standard Deviation (daily)	Safety Stock (unit)	ROP (unit)
A-1	1.1	2	19
A-2	0.2	0	1
B-1	40.6	61	130
B-2	32.0	48	80
B-3	0.5	1	2
C-1	6.1	9	26
C-2	0.4	1	2
C-3	0.1	0	0

From above result, these data of ROP indicates when replenishment stocks should be ordered for preventing lack of parts. Not only ROP, but also all data of inventory control system are proposed to install in the computer system to control suitable number of stocks and orders. As explanation in previous chapter, ABC Company has plan to set

new computer system to support this control system, so it is believed that inventory problems in ABC Company will be solved by using this system of inventory management.

4.7 Result of Dead Stock Management

According to Chapter 3, dead stocks of ABC Company can be estimated in term of storage space area and cost as:

- 1.41% of dead stocks area from total storage space on the 1st floor
- 2.51% of dead stocks area from total storage space on the 2nd floor
- Total dead stocks value as 1,141,470 Baht

After improvement by dead stock elimination and sleeping stock management, ABC Company received benefits as cost reduction and unoccupied space area increase.

4.7.1 Dead Stock Elimination

Referring to dead stock reduction by sale and disposal, ABC Company gained benefit both in term of space usage and money value. It can estimate by consideration as below.

4.7.1.1 Storage Space Efficiency

After conducting dead stock elimination, additional storage space area is available for ABC Company. As Chapter 3, the company received more available space area about ***1.41%*** for the 1st floor and ***2.51%*** for the 2nd floor of warehouse.

4.7.1.2 Storage Opportunity

Storage space area of dead stock can be calculated to find profit in term of opportunity value. ABC Company estimated available space area value after removing dead stock by considering opportunity value from keeping high sales volumes of parts. From sales volumes of spare parts in 2004 to 2006, four top-ranked sales volumes of spare parts are four types of Oil Filter. Factors for the

estimation are composed of size of package and percentage for each spare part to order for stock. The percentage of stock is estimated sales number of each type of oil filter in 2004 to 2006 based on total sales number of four types in each year. Detail of four oil filters is shown below.

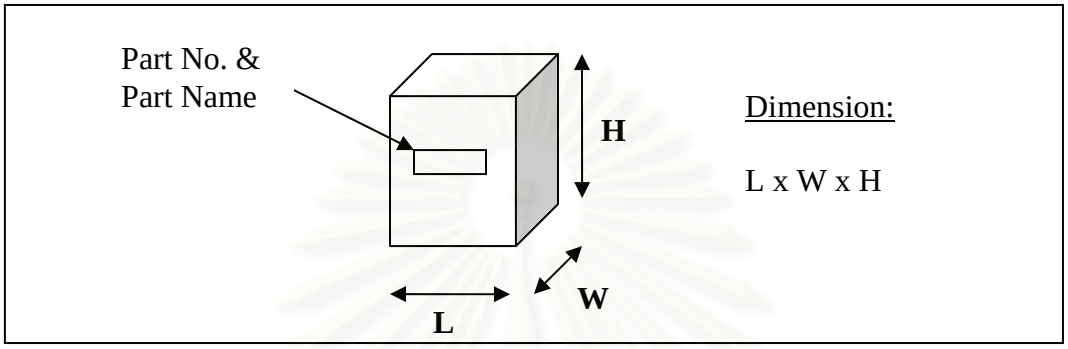


Figure 4.1 Oil Filter Packing Picture and Dimension

Table 4.21 Detail of Four Types of Oil Filter

Part Type (Oil Filter)	Dimension (cm)	Volumes (cm3)	Percentage of Stock	Unit Price or Sale price (Baht)
Type 1	10.2 x 10.2 x 14	1456.56	40%	135
Type 2	6.9 x 6.9 x 7.5	357.08	25%	165
Type 3	10.2 x 10.2 x 10	1040.40	20%	135
Type 4	7.7 x 7.7 x 9	533.61	15%	165

Then, estimate opportunity value from available area of dead stock elimination with calculation as:

$$F = (L_1*W_1*H_1)*N_1 + (L_2*W_2*H_2)*N_2 + (L_3*W_3*H_3)*N_3 + (L_4*W_4*H_4)*N_4$$

While; F = Available storage space (cm^3)

L = Length of package of part (cm)

W = Width of package of part (cm)

H = Height of package of part (cm)

N = Quantity of part

N_1, N_2, N_3 and N_4 are quantity of part, oil filter in this case, which are calculated to find the maximum value of $N_1+N_2+N_3+N_4$ to F value.

1st Floor available area

From available storage space 752,496 cm^3, it can be calculated as:

$$752496 = (10.2*10.2*14)*N_1+(6.9*6.9*7.5)*N_2+(10.2*10.2*10)*N_3+(7.7*7.7*9)*N_4$$

N_1 = 314 pieces (2.4% of average sales volume in 2004 – 2006)
N_2 = 196 pieces (2.3%)
N_3 = 157 pieces (2.2%)
N_4 = 118 pieces (2.6%)

While $N_1+N_2+N_3+N_4$ = 784 pieces (2.4% of total average sales volume of four parts in 2004 – 2006)

From above solution numbers, opportunity of space utilization for additional space in this floor can be estimated that ABC Company can keep more stock of highest sales volume of spare parts about ***2.4%***. In term of money value, opportunity value for the 1st floor can be calculated with sales price of each type of oil filter as ***114,048*** Baht. It means that ABC Company will have opportunity to use that space for keeping high sales moving rate of spare parts with money value as above.

2nd Floor available area

From available storage space 2,906,107 cm^3, it can be calculated as:

$$2906107 = (10.2*10.2*14)*N_1+(6.9*6.9*7.5)*N_2+(10.2*10.2*10)*N_3+(7.7*7.7*9)*N_4$$

N_1 = 1,211 pieces (9.4% of average sales volume in 2004 – 2006)
N_2 = 757 pieces (9%)

N_3 = 605 pieces (8.4%)

N_4 = 454 pieces (10%)

While $N_1+N_2+N_3+N_4$ = 3,027 pieces (9.1% of total average sales volume of four parts in 2004 – 2006)

Opportunity of space utilization for additional space in the 2nd floor can be estimated that ABC Company can keep more stock about ***9.4%.*** In term of money value, opportunity value for the 2nd floor can be calculated with sales price of each type of oil filter as ***440,450*** Baht.

4.7.1.3 Dead Stock Cost Reduction

After dead stock elimination, ABC Company can reduce dead stock cost which can be estimated as:

- Dead stocks value 1,141,470 Baht
- Carrying cost 23.14 Baht per unit

  (Calculation detail in section 3.7.1.1) 988 units

Total dead stocks cost reduction is 1,141,470 + (23.14*988) = **1,164,332 Baht**

4.7.1.4 Money from Dead Stock Sales

Actually, the company assumed dead stock as no value, but some dead stocks were sold to second-hand spare parts shop that made ABC Company got some money from dead stock elimination. ABC Company earned money from dead stocks sales as ***18,287*** Baht.

4.7.2 Sleeping Stock Management

Group of product items are which have status as sleeping stocks are collected to be proposed for sleeping stock control system. They should be controlled order and reduced quantity of these items to prevent being dead stocks. The list of product items

that have inventory status as sleeping stock and proposed control policy is shown in the table.

Table 4.22 List of Sleeping Stocks Needed to Control Order Policy

Part No.	Part Name	Number of Stocks	Price (Baht)	Proposed Control System	
				Keep (unit)	Sell (unit)
A04466-XXXXX	PAD KIT, DISC BRAKE	26	1610	13	13
A04495-XXXXX	BRAKE SHOE	76	2180	38	38
A11213-XXXXX	GASKET CYLINDER HEAD	18	365	9	9
A13041-XXXX1	BRG.CON.ROD MARK II	14	210	7	7
A13041-XXXX2	BRG.CON.ROD MARK II	14	165	7	7
A13101-XXXXX	PIST0N SUB-ASSY,W/P	24	750	12	12
A13103-XXXXX	PISTON (O/S 0.50)	16	680	8	8
A13285-XXXXX	BEARING SET	13	74	7	6
A13711-XXXXX	PISTON	14	345	7	7
A13715-XXXXX	VALVE, EXHAUST	19	495	10	9
A13753-XXXX1	SHIM	26	265	13	13
A13753-XXXX2	SHIM	14	265	7	7
A13753-XXXX3	SHIM	16	265	8	8
A13753-XXXX4	SHIM	23	265	12	11
A16363-XXXXX	MOTOR,COOLING FAN	44	5600	22	22
A16401-XXXXX	CAP SUB-ASSY,	30	385	15	15
A17179-XXXXX	GASKET,INTAKE	13	200	7	6
A17801-XXXXX	AIR FILTER	91	585	46	45
A19127-XXXXX	PACKING,DUST PROOF	18	87	9	9
A42323-XXXXX	RING	21	140	11	10
A47716-XXXXX	PLATE SUPPORT NO.01	20	205	10	10
A47717-XXXXX	PLATE SUPPORT NO.02	15	210	8	7
A48210-XXXXX	ABSORBER SHOCK FR,LH	18	930	9	9
A48331-XXXXX	BUMPER FR SPRING	33	420	17	16
A48633-XXXXX	SEAL	20	6	10	10
A48817-XXXXX	CUSHION STA.GLI ATM	14	140	7	7
A51441-XXXX1	COVER ENGINE RH	20	1220	10	10
A51441-XXXX2	COVER ENGINE RH	20	540	10	10
A53145-XXXXX	BRACKET, RADIATOR	21	89	11	10
A53217-XXXXX	SUPPORT SUB-ASSY,	23	1750	12	11
A53875-XXXXX	LINER,FR FENDER,RH	15	2150	8	7
A53875-XXXX1	LINER,FR FENDER,RH	120	395	60	60
A53875-XXXX2	LINER,FR FENDER,RH	30	1780	15	15
A53876-XXXX1	LINER FR FENDER LH	15	220	8	7
A53876-XXXX2	LINER FR FENDER LH	95	395	50	45
A65737-XXXXX	LOCK	18	190	9	9
A65739-XXXXX	PLATE RR WHEEL HOUSE	20	35	10	10
A67868-XXXXX	RETAINER DOOR W/S RH	20	2	10	10
A75474-XXXXX	PLATE RR NAME NO.2	28	275	14	14
A76911-XXXXX	MUDGUARD SIDE LH L/P	23	6100	12	11

Table 4.22 List of Sleeping Stocks Needed to Control Order Policy (Cont.)

Part No.	Part Name	Number of Stocks	Price (Baht)	Proposed Control System	
				Keep (unit)	Sell (unit)
A85110-XXXXX	MOTOR A/S,FR WIPER	40	1780	20	20
A85214-XXXXX	RUBBERWIPER BLADE,RH	25	350	13	12
A90080-XXXXX	GROMMET RADIATOR	14	48	7	7
A90099-XXXXX	CONDENSOR	20	120	10	10
A90113-XXXXX	BOLT, STUD	17	24	9	8
A90116-XXXX1	BOLT, STUD	70	90	35	35
A90116-XXXX2	BOLT, STUD	19	69	10	9
A90119-XXXXX	BOLT	34	28	17	17
A90170-XXXXX	NUT, CAP	28	46	14	14
A90189-XXXXX	GROMMET, SCREW	41	64	21	20
A90201-XXXXX	WASHER, PLATE	20	130	10	10
A90210-XXXX1	WASHER, SEAL	16	39	8	8
A90210-XXXX2	WASHER, SEAL	20	98	10	10
A90310-XXXXX	SEAL, OIL P/W STRG.	21	72	11	10
A90311-XXXX1	SEAL,PW/STRG.RACK	22	125	11	11
A90311-XXXX2	SEAL,PW/STRG.RACK	57	125	29	28
A90311-XXXX3	SEAL,PW/STRG.RACK	26	125	13	13
A90385-XXXXX	BUSH	31	120	16	15
A90520-XXXX1	RING	16	51	8	8
A90520-XXXX2	RING, SNAP	15	25003	8	7
A90564-XXXXX	SHIM	48	33	24	24
A90910-XXXX1	BOLT	13	145	7	6
A90910-XXXX2	BOLT	16	110	8	8
A90910-XXXX3	BOLT	19	115	10	9
A90913-XXXX1	SEAL, VALVE STEM OIL	18	255	9	9
A90913-XXXX2	SEAL, VALVE STEM OIL	16	280	8	8
A90913-XXXX3	SEAL, VALVE STEM OIL	38	155	19	19
A90916-XXXXX	THERMOSTAT	20	820	10	10
A90982-XXXXX	FUSE MINI	20	41	10	10
				953	**925**

All parts in this list will be carefully observed to prevent more replenishment order. Moreover, other spare parts which has trend to be sleeping stocks will be reconsider again every 6 months. Another cause which may involve occurring of sleeping stocks and dead stocks is big lot size order. However, there has not been any big lot size order since last 2 years. The reason is because there is no enough space to carry those parts. Anyway, if X Company offer big lot size sales with high discount, lot sizing technique will be considered before making decision to purchase them.

CHAPTER V

CONCLUSION AND RECOMENDATION

Not enough space for stocks keeping and high inventory cost are main problems of ABC Company with spare part business. They realized that improvements of inventory management system should be done to reduce these problems. Several proposed ways of improvement methodologies as explanation in chapter 3 has the satisfied results that expressed in chapter 4.

Warehouse improvement is the first that ABC Company operated with using 5S concept. Actually, this activity is usually done 2 times per year. But without standard and lack of attention to maintain warehouse with good condition, ABC Company's warehouse often encounter the problem as untidy warehouse. After setting the rules for warehouse management, the condition of good warehouse can be maintained. It involves that products are easy to find and good working environment. Moreover, additional staffs are employed for shortening leadtime of part receiving process.

Inventory record system is the next thing to improve for more accuracy of number of stocks. Additional staffs for receiving process and new computer program help purchasing record complete daily. This involves improving stocks record as well. Although employing more staffs for shortening leadtime of receiving process and apply new computer system to use for purchase data input were done to improve stock record system, barcode system is another suitable option for ABC Company. It is not necessary to create new system of barcode for each product item, because there is specific part number with barcode sticker attached on every box as of X Company database system. However, investment of barcode system is still needed to spend for setting up new system. Therefore, this matter is just a plan for next 3 years. Moreover, X Company has planned to force their all spare part dealer to operate online system with them in the next

8 to 9 years. The policy plan for spare part business of ABC Company and X Company is shown in below table.

Table 5.1 Future Plan of Computer System for Inventory Control

Year	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
X Company Policy Schedule	▽ Kick off order by e-mail						Kick off online system ▽				Deadline for online system ▽			
ABC Company Schedule				Launch order by e-mail ☆☆ Stock record system improvement				Launch barcode system ☆					Launch online system ☆	

Because of high investment for new system both barcode system and trading online system, it is very difficult to convince top management staff of old-family business like ABC Company to apply new system. As the result, slightly improvement is better way to solve the problems. If the result of improvement is going to be better and better, it may be easier to persuade top management staff to allow more improvement with higher technology.

In addition to improvement of above systems, the new system of inventory control are proposed to use for controlling order-keeping stocks. Inventory policy should be set to indicate types of part and starting time period for stocks. The result from policy is spare part for car accident should be stocks in the 1st year of car launching while spare part for car maintenance should be stocks in the 3rd year. However, trend of spare part demand should be concerned to find the suitable number of stocks as well.

Trend of spare part demand is studied to observe the characteristics of spare part demand based on year of car implementation. Main factors which affects to trend of demand are car sales volumes, defective car parts, and poor design of shape of car parts.

The next step is forecasting demand. After considering the suitable technique to forecast demand, the result is different techniques are appropriated for each demand of car model. Then, demand in the next year can be calculated b using forecast demand from statistical methods including with trends of demand concern. After that, the inventory control system is conducted to find the optimum number of order quantity with the minimum carrying cost and ordering cost. The result of this proposed improvement is inventory cost reduction. And then, reorder point is calculated to be guideline for part ordering based on customer's demand.

Finally dead stock management is operated to solve inventory problems. From this operation, ABC Company received benefit in term of more storage space area and in term of money. Inventory control system should be done to control number of stocks and order quantity to avoid dead stocks problem occurring again. Sleeping stock management is also another way to control keeping products items which tend to be dead stock. The result is possibility of dead stock occurring have a tendency to decrease. In additions, another cause of dead stock is big lot size purchase with discount, so in the next big lot size purchasing should be carefully considered before decision making to buy that product.

The results of proposed inventory management system have the satisfaction level of inventory. Numbers of stocks tend to decrease and total inventory costs can be reduced. It is believe that this system can solve inventory problems which occurred in ABC Company. Now, they are studying to decide to use proposed inventory system for demand forecasting and system of order-stock keeping control for suitable numbers of stocks and order for minimizing inventory costs. However, this system is very new and quite complicated for staffs. Therefore, it is necessary to have training about inventory knowledge before launching the new system. Anyway, ABC Company has planned of training and trial this system for some products starting next month and plan planned to apply this system within year 2008.

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APPENDICES

APPENDIX A
NORMAL CURVE AREA

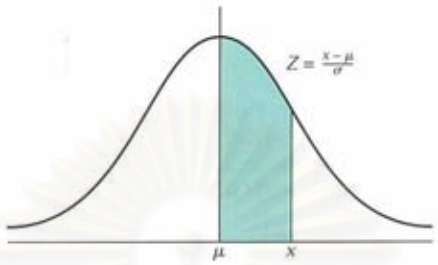

TABLE A.1 Normal Curve Areas

Z	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	0.0000	0.0040	0.0080	0.0120	0.0160	0.0199	0.0239	0.0279	0.0319	0.0359
0.1	0.0398	0.0438	0.0478	0.0517	0.0557	0.0596	0.0636	0.0675	0.0714	0.0753
0.2	0.0793	0.0832	0.0871	0.0910	0.0948	0.0987	0.1026	0.1064	0.1103	0.1141
0.3	0.1179	0.1217	0.1255	0.1293	0.1331	0.1368	0.1406	0.1443	0.1480	0.1517
0.4	0.1554	0.1591	0.1628	0.1664	0.1700	0.1736	0.1772	0.1808	0.1844	0.1879
0.5	0.1915	0.1950	0.1985	0.2019	0.2054	0.2088	0.2123	0.2157	0.2190	0.2224
0.6	0.2257	0.2291	0.2324	0.2357	0.2389	0.2422	0.2454	0.2486	0.2517	0.2549
0.7	0.2580	0.2611	0.2642	0.2673	0.2704	0.2734	0.2764	0.2794	0.2823	0.2852
0.8	0.2881	0.2910	0.2939	0.2967	0.2995	0.3023	0.3051	0.3078	0.3106	0.3133
0.9	0.3159	0.3186	0.3212	0.3238	0.3264	0.3289	0.3315	0.3340	0.3365	0.3389
1.0	0.3413	0.3438	0.3461	0.3485	0.3508	0.3531	0.3554	0.3577	0.3599	0.3621
1.1	0.3643	0.3665	0.3686	0.3708	0.3729	0.3749	0.3770	0.3790	0.3810	0.3830
1.2	0.3849	0.3869	0.3888	0.3907	0.3925	0.3944	0.3962	0.3980	0.3997	0.4015
1.3	0.4032	0.4049	0.4066	0.4082	0.4099	0.4115	0.4131	0.4147	0.4162	0.4177
1.4	0.4192	0.4207	0.4222	0.4236	0.4251	0.4265	0.4279	0.4292	0.4306	0.4319
1.5	0.4332	0.4345	0.4357	0.4370	0.4382	0.4394	0.4406	0.4418	0.4429	0.4441
1.6	0.4452	0.4463	0.4474	0.4484	0.4495	0.4505	0.4515	0.4525	0.4535	0.4545
1.7	0.4554	0.4564	0.4573	0.4582	0.4591	0.4599	0.4608	0.4616	0.4625	0.4633
1.8	0.4641	0.4649	0.4656	0.4664	0.4671	0.4678	0.4686	0.4693	0.4699	0.4706
1.9	0.4713	0.4719	0.4726	0.4732	0.4738	0.4744	0.4750	0.4756	0.4761	0.4767
2.0	0.4772	0.4778	0.4783	0.4788	0.4793	0.4798	0.4803	0.4808	0.4812	0.4817
2.1	0.4821	0.4826	0.4830	0.4834	0.4838	0.4842	0.4846	0.4850	0.4854	0.4857
2.2	0.4861	0.4864	0.4868	0.4871	0.4875	0.4878	0.4881	0.4884	0.4887	0.4890
2.3	0.4893	0.4896	0.4898	0.4901	0.4904	0.4906	0.4909	0.4911	0.4913	0.4916
2.4	0.4918	0.4920	0.4922	0.4925	0.4927	0.4929	0.4931	0.4932	0.4934	0.4936
2.5	0.4938	0.4940	0.4941	0.4943	0.4945	0.4946	0.4948	0.4949	0.4951	0.4952
2.6	0.4953	0.4955	0.4956	0.4957	0.4959	0.4960	0.4961	0.4962	0.4963	0.4964
2.7	0.4965	0.4966	0.4967	0.4968	0.4969	0.4970	0.4971	0.4972	0.4973	0.4974
2.8	0.4974	0.4975	0.4976	0.4977	0.4977	0.4978	0.4979	0.4979	0.4980	0.4981
2.9	0.4981	0.4982	0.4982	0.4983	0.4984	0.4984	0.4985	0.4985	0.4986	0.4986
3.0	0.4987	0.4987	0.4987	0.4988	0.4988	0.4989	0.4989	0.4989	0.4990	0.4990

BIOGRAPHY

Ms. Suwadee Samuthananon was born on 8th of March, 1980 in the city of Bangkok, Thailand. She obtailed a Bachelor of Engineering in Mechanical Engineering from Mahidol University, Thailand in 2001. She was working at Toyota Motor Thailand Co, Ltd. in the position of engineer from 2001 – 2004. Currently, she is working for Toyota Motor Asia Pacific Engineering and Manufacturing as material engineer. In 2005, she enrolled as a part-time student working toward a Master's degree in engineering management at the Regional Centre for Manufacturing Systems Engineering, Chulalongkorn University.