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IMPROVEMENT OF INVENTORY CONTROL SYSTEM

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วิทยานิพนธ์ฉบับนี้เกี่ยวข้องกับการจัดการคงคลังในเชิงปฏิบัติจริงของบริษัทซื้อมาขายไปแห่งหนึ่งที่เพิ่งก่อตั้งใหม่ โดยใช้ข้อมูลการขายในอดีตจำนวน 10 เดือน ในช่วงเดือนพฤษภาคม 2550 ถึงเดือนกุมภาพันธ์ 2551 เพื่อบรรเทาความแปรปรวนโดยในขั้นแรกได้แบ่งวิธีการศึกษาของสินค้าออกเป็น 3 กลุ่ม เพื่อเลือกสินค้า เพียง 1 กลุ่มที่มีความสำคัญที่สุดต่อการดำเนินกิจการมาทำการศึกษานี้

พบว่าสินค้านำเข้าจากต่างประเทศที่ทราบว่าจะมีการขึ้นราคาสินค้าล่วงหน้าได้ถูกจัดให้เป็นกลุ่มที่มีความสำคัญต่อการดำเนินการ และมีความสำคัญทางด้านการเงินต่อบริษัทแห่งนี้มากที่สุด โดยใช้โมเดลการสั่งสินค้าแบบทราบว่าราคาจะขึ้นล่วงหน้ามาประยุกต์ใช้ เพื่อเป็นเกณฑ์ในการตัดสินใจในการพิจารณาการกักกักตุนสินค้าก่อนราคาขึ้น และจำนวนสินค้าในการสั่งซื้อเพื่อการกักตุน เพื่อให้ได้ความคุ้มค่าที่สุดต่อการลงทุน ส่วนสินค้าชนิดอื่นที่ราคาสินค้าค่อนข้างไม่เปลี่ยนแปลงได้ใช้โมเดลปริมาณการสั่งซื้อตายตัวแบบดั้งเดิม เพื่อลดต้นทุนและเพิ่มประสิทธิภาพของคงคลัง

เมื่อทราบจำนวนสินค้าแต่ละประเภทที่ต้องการสั่งซื้อ และจัดเก็บในคงคลังแล้ว พบว่าบริษัทมีพื้นที่ไม่เพียงพอในการจัดเก็บ กล่าวคือสินค้ากลุ่มที่มีความสำคัญที่สุดข้างต้นต้องการพื้นที่จัดเก็บทั้งสิ้น 8,421.88 ลูกบาศก์เมตร แต่บริษัทมีพื้นที่จัดเก็บดังกล่าวเพียง 1,750 ลูกบาศก์เมตร ซึ่งเหตุการณ์ลักษณะนี้พบได้อยู่เสมอสำหรับบริษัททั่วๆไปที่มีข้อจำกัดของพื้นที่จัดเก็บสินค้า และการศึกษานี้ได้ปรับลดสัดส่วนการเก็บสินค้าลงเพื่อจัดเก็บได้อย่างเหมาะสมจากการคำนวณ โดยสมการลากรานจ์ มัลติพลายเออร์ ซึ่งเป็นผลทำให้เกิดการจัดการคงคลัง ที่มีประสิทธิภาพมากยิ่งขึ้น ในแง่ของต้นทุนด้านราคา และพื้นที่จัดเก็บ

จากการศึกษาข้างต้นพบว่าบริษัทสามารถลดค่าใช้จ่ายในการจัดเก็บสินค้าคงคลังในส่วนของสินค้ากลุ่มธรรมดาที่ใช้โมเดลพื้นฐานได้ 44,594.93 บาท หรือ 7.89 เปอร์เซ็นต์ของต้นทุนการจัดเก็บสินค้าเดิม ส่วนสินค้าในกลุ่มนำเข้าจากต่างประเทศและสินค้าที่จัดซื้อภายในประเทศที่ทราบว่าจะมีการขึ้นราคาสินค้าล่วงหน้า สามารถลดค่าใช้จ่ายลงได้ 594,512.30 บาท

Regional Center of Manufacturing Systems Engineering

Student's signature:....................................

Field of study: Engineering Management

Principal Advisor's signature:......................

Academic year: 2008

4771627021 : MAJOR ENGINEERING MANAGEMENT
KEY WORD: Inventory Control/ Known Price Increase/ Limited Area Inventory
CHANPEN MITRABKAKDI : IMPROVEMENT OF INVENTORY CONTROL SYSTEM. THESIS PRINCIPAL ADVISOR : ASST. PROF. REIN BOONDISKULCHOK, D. Eng , 82 pp.

This thesis attempts to look at the inventory management practices of a relatively new company that has shown progress in its operations. The business of the case company is trading. The main job involves analyzing relevant historical documents over the 10 months from May 2007 to February 2008 to cover the fluctuation of demand. The company's products are divided into 3 categories to facilitate analysis, and eventually to select only the most important category for detailed study.

The imported products with known price increases turned out to have the most value and were of the most importance to the company. The Known Price Increase Model was then modified and applied to these products to serve as the basis for considering the stocks that had to be ordered for storage in order to optimize return on investment. The conventional Fixed Order Quantity Model was used for the products the prices of which do not change frequently.

As the case company has 2 warehouses that are situated apart, and have limited storage capacity, it was studied the ratio of the products for storage at the 2 warehouses to increase efficiency and better management control. When an attempt to determine the quantities of all the products under study that have to be ordered and stocked in the inventory was carried out, it was discovered that the company did not have sufficient storage capacity for all of them, namely, the storage capacity needed was 8,421.88 cubic meters but the storage capacity available in warehouse A is only 1,750 cubic meters. This shortfall is not unusual, especially since this company is quite new and could reasonably be expected to be cautious in its operations.

The study shows that the total savings from using the Fixed Order Quantity Model for all the unclassified products is 44,594.93 baht, or equal to 7.89 per cent of the Total Stocking Cost *(TSC)*. The savings from applying the Known Price Increase Model to imported products and domestic products with known price increases products is 594,512.30 baht.

Regional Center of Manufacturing Systems Engineering

Field of study Engineering Management

Academic year 2008

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My acknowledgement of the assistance of all those mentioned above is, of course, exclusive of all the errors, for which I alone am responsible.

Contents

Page

List of Tables

Table **Page**

List of Figures

Figure **Page**

CHAPTER I
INTRODUCTION

1.1. Background

Managing inventories is critical to ensuring high customer service levels. However, inventories are a very costly asset to maintain. Having the right amount of inventory to meet customer requirements is vital. Efficient inventory control allows the company to have the right amount of stock in the right place at the right time. It ensures that capital is not tied up unnecessarily.

AAA Company is a small-sized company incorporated in 2006 and located in an industrial real estate near Bangkok. It is a distributor and procurer of all types of equipment, tools, instruments, consumable materials, computer peripherals and safety accessories for the manufacturing, construction and agriculture industries.

AAA became aware that production costs are crucial to the survival of manufacturers and that it could help them save on some types of production costs if they were to work with it. Moreover, they could increase their profitability by purchasing goods and services from AAA. In its view, this was the easiest and most convenient way for manufacturers amidst a critical economy to benefit quickly from a change in its sourcing policies as it would generate higher profits in a short period of time. It was also a more practical option for the manufacturers as they would not need to make major changes to their engineering management systems or procedures, which normally involve expensive consulting fees and long project lead times and also require a big number of stakeholders and staff in order to carry out such large risky projects, the results of which are obviously not guaranteed. Based on its analysis of its business operating environment, AAA set out to reach out to manufacturers in a particular area as its main target market.

AAA realized that the manufacturing industry in Thailand has been severely affected by strong international and domestic business competition. In addition, there are many uncontrollable factors that manufacturers are unable to avoid, such as political pressures and economic policies that affect the cost of living, fuel prices, minimum wages, material costs, etc. In the last ten years, the manufacturing industry has been bearing a continuous rise in the costs of production. As a result, manufacturers' costs of production have been increasing every year, but, on the other hand, they are forced to reduce their profit margins due to the global and radical business competition.

AAA realizes the importance of good inventory management, thus it needs an appropriate plan to control inventories to meet customers' requirements and to balance all relevant costs, such as holding costs, shortage costs, purchase costs, and ordering costs. This study supports ordering policies to control inventories more efficiently and effectively.

1.1.1. Products

AAA provides 420 product lines from 15 suppliers divided in 9 categories as follows.

1.1.1.1. Measuring tools
1.1.1.2. Finishing tools
1.1.1.3. Fastening tools
1.1.1.4. Cutting tools
1.1.1.5. Automotive tools
1.1.1.6. Agricultural tools
1.1.1.7. Welding tools
1.1.1.8. Safety accessories
1.1.1.9. Packaging products

AAA's products may be divided into the following 3 groups:

- Group A represents 20 per cent of the product items in inventory and 65 per cent of the inventory value.
- Group B represents 15 per cent of the items in inventory and 25 per cent of the inventory value.
- Group C represents 65 per cent of the items in inventory and 10 per cent of the inventory value.

In the above, group A is considered critically important to the company and requires close monitoring and tight control as the products in this group have high value for storage compared to the products in the other groups. Products in groups B and C require only simple monitoring and control periodically – there are 336 items in these 2 groups but their value is only 35 per cent of the total inventory value.

1.1.2. Characteristic of Products

Normally, the products that AAA deals in are imperishable and the models do not change often because most of them are basic tools and accessories not related to fashionable or technological trends. One important factor that AAA has to consider is that they need to be stored in a dry place because they are susceptible to humidity in the air as most of them are made of metal and, in some cases, natural materials such as pig bristles and cow leather. Most of them are durable and can last more than one year. Although AAA does not need to worry about the vulnerability of the products, it should not keep stocks for a long time because they tie up capital.

1.1.3. Storage Capacity

AAA has the following storage capacity.

1.1.3.1. A warehouse with 1,750 cubic meters of storage capacity. This warehouse is very close to AAA's administrative officers. It is considered to be valuable because of this proximity and convenient access, which facilitates stocking and checking. This capacity is called Warehouse A.

1.1.3.2. A warehouse with 9,200 cubic meters of storage capacity. This warehouse is quite far from AAA's administrative officers. It is used to store low-turnover and low-importance products. This capacity is called Warehouse B.

1.2. Statement of Problems

Although AAA is reasonably successful in its penetration of target customers in this sector, it suffers from underperformance in inventory control, which leads to lower competitiveness. AAA supplies many kinds of products as mentioned in the "Background" above, it does not have proper inventory control according to the types of product. Unfortunately, AAA tends to place large-volume orders to get the lowest prices per unit for the wrong types. As a result, there are surpluses of products stored in its warehouse and AAA has to bear high sink costs from low-turnover products that are in storage. There is another one category that deserves study, namely, imported products, because their turnover is very high compared to the other products handled by the company. The prices of these imported products have been on the increase, particularly in the recent few years. AAA has problems in competing with its competitors that have higher stock levels of such products at pre-increase and so can sell their products to customers at those pre-increase prices while AAA has to mark up its selling prices in view of its higher new cost. On top of that, AAA is selling its products on a catch-up basis with competitors, namely, its prices are always one step higher than its competitors' because of the lack of inventory at lower prices. By the time its competitors are forced to raise their prices to the same level as AAA's prices when they have to order new stocks, AAA is also forced to raise its prices even higher because it, too, has to order new stocks, which are priced higher than before. When the stocks have almost run out, AAA has to place new orders for products at the higher prices while its competitors still have stocks for sale to their customers at lower prices. AAA's customers always survey the market prices, so AAA is compelled to reduce the margins on its products frequently. For other products, sometimes AAA incurs expenses in having to collect the product from the supplier. Sometimes AAA's customers want the products instantly but the suppliers cannot deliver the products instantly since they have their own delivery lead times. In such cases AAA would need to pick up the products from the suppliers, but AAA cannot find free staff to do so.

This results in delivery delays or lower sales volumes and also adversely affects customer satisfaction. AAA has limited storage capacity for group A products. The capacity of storage available to store group A products properly is only 1,750 cubic meters. So, AAA cannot stock the essential products at the appropriate levels and does not know the appropriate types and sizes, and quantities and the correct timing for replenishment of stock levels. The problems involved in inventory control are as follows.

1. AAA has limited storage capacity for keeping the products, so AAA does not have optimal stocks levels.
2. There are delivery delays due to inventory shortages.
3. The quantity of Safety Stock held by AAA is not sufficient to prevent lost.
4. Reorder Points and Order Quantities are not appropriate.
5. It bears high sink costs from low-turnover products that are in storage.
6. When prices are about to go up, AAA cannot decide whether to order additional stocks and in what quantities.

1.3. Objective

The objective of this study is to improve AAA's inventory management. At present, the company uses intuitive judgments based on its own skills and own experiences to purchase and stock inventory. Therefore, the objective of the study is

- To design the most appropriate inventory control plan with optimum inventory levels and minimum costs within the constraints of limited storage capacities in the cases of known price increase in products and products the prices of which seldom increase.

1.4. Scope of study

To study and improve AAA's inventory control of products by considering the Fixed Order Quantity Model and Known Price Increase Model according to each product categorized in each group, by analyzing relevant historical documents over the past 10 months to cover the fluctuation of demand.

1.5. Research procedures

1.5.1. Search for relevant literature, such as books, articles in journals, articles in magazines, and electronic sources

1.5.2. Compile a list of literature

1.5.3. Study the literature

1.5.4. Gather primary data in accordance with the relevant information

1.5.5. Develop common components database

1.5.6. Assess results

1.5.7. Make recommendations for further revision

1.5.8. Compose the draft thesis

1.5.9. Prepare for the presentation

1.5.10. Revise the thesis

1.5.11. Wrap up the thesis

1.6. Expected Results

Determination of optimum inventory levels for products under consideration that could be used industry-wide by importers and distributors.

1.7. Expected Benefits

1.7.1. Improvements in inventory control

1.7.2. Reduction in the cost of inventory as much as possible

1.7.3. Reduction in lost sales

1.7.4. Reduction in slow-moving inventory

1.7.5. Application of this case study to other sections in AAA and to other industries

CHAPTER II
LITERATURE SURVEY
AND THEORETICAL CONSIDERATION

2.1. Literature Survey

2.1.1. Bhaba R. Sarker et al. (2004)

A supplier may offer price discounts to increase his own cash flow or reduce his stock levels of certain products. In such cases, the manufacturer may be able to benefit from such an offer and improve the effectiveness of his inventory system by placing orders for additional quantities during this offer period. In the study, Economic Order Quantity (*EOQ*) models with a discounted price are developed to obtain the optimal ordering policy during the sales period for five different cases: (a) coincidence of sales period with replenishment time, (b) non-coincidence of sales period with replenishment time, (c) sales period is longer than a cycle, (d) discounted price as a function of the special ordering quantity, and (e) incremental discount. The sales period and the discounted price vary from case to case. A special quantity is ordered during the offer period to derive maximum possible advantage from the discounted. The optimal ordering policy is obtained by maximizing the difference between the two costs: Regular *EOQ* cost and special quantity cost during the sales period. Moreover, a comparison of different discount scenarios is developed to obtain an idea of the effect of different parameters on the ordering policies.

2.1.2. Chase R. B. et al. (1998)

The study states that there are two types of inventory systems: Fixed Order Quantity Model (Q-Model) and Fixed Time Period Model (P-Model). Fixed Order Quantity Model is “event triggered” and Fixed

Time Period Model is “time triggered”. For Fixed Order Quantity Model, It starts an order when the event of reaching a specified reorder level occurs, whereas the Fixed Time Period Model places an order at the end of predetermined times. These two approaches differ in the following ways:

- Fixed Order Quantity Model favors high value items because average inventory is lower
- Fixed Order Quantity Model is more appropriate for crucial items because there is closer monitoring
- Fixed Time Period Model has a larger inventory to assure the items must be available at all times

2.1.3. Hojung Shin et al. (2006)

Inventory coordination in supply chains benefit from quantity discounts, which provide a practical foundation for inventory management and control. Sometimes, some supply chain partners may have difficulty in following the coordination policy because (1) the desired lot size adjustments may be different from the economic lot sizes and (2) the buyer may be exposed to risks if he orders excessive stock. The main objective of this study is to develop a quantity discount model that resolves the practical challenges associated with implementing quantity discount policies for supply chain coordination between a supplier and a buyer. The proposed Buyer’s Risk Adjustment (*B-RA*) model allows the supplier to offer discounts that make full use of the original economic lot sizes and share the buyer’s risks of overstocking when demand is uncertain. The analytical results suggest that the proposed B-RA discount approach is a feasible alternative for supply chain coordination under uncertain demand conditions.

2.1.4. Keisuke Matsuyama (2000)

The *EOQ* Model of inventory problem can help in determining the ordering cycle and quantity that should be ordered. When the purchase unit price is unchanged, the ordering cycle and ordering quantity, which minimize one day's average inventory cost, is not dependent on the purchase price. However, if the purchase price changes, the *EOQ* Model must be modified accordingly. The purchase unit price is discounted as the ordering increases. The discount of purchase price is related to a decreasing function of ordering quantity. This function is not always continuous and does not depend on the ordering quantity. In these circumstances, one day's average profit can be defined. So, the ordering cycle and ordering quantity, which maximize one day's average profit, can be set from this information. In addition, the situations under which the setup cost depends on the ordering quantity can be considered with the view to maximize benefits.

2.1.5. S. Hamid Mirmohammadi et al.(2008)

This paper presents an optimal algorithm based on branch-and-bound approach to determine lot sizes for a single item in material requirement planning environments with deterministic time-phased demand and constant ordering cost with zero lead time, where all-units discounts are available from vendors and backlog is not allowed. On the basis of the known characteristics of optimal order policy, a tree-search procedure is presented to construct the sequence of optimal orders. Some useful guidelines have been shown to be true, and they make the algorithm very efficient. To compare the usefulness of this algorithm with the other existing optimal algorithms, a pilot trial design with various environments has been developed. Experimental results show that the use of the optimal algorithm is much better than the performance of other existing optimal algorithms. If computational time is treated as a performance measure, this algorithm is probably the best among the existing optimal algorithms for real problems with large dimensions.

2.1.6. Prechachaisurat K. (1995)

Prechachaisurat developed a computer software aided instruction system on computer based production management for controlling inventory. The contents cover inventory management, characteristics of inventory, considerations in selecting inventory control techniques, inventory control techniques, inventory models, and inventory control software. His study specifies that inventory is a very important asset and so management must balance inventory levels properly to control and lower holding costs and yet have adequate items to deliver to the production line.

2.1.7. Stock J. et al. (1993)

They state that there are five reasons for holding inventory, namely: (1) to enable the company to benefit from economy of scale; (2) to balance supply and demand; (3) to enable manufacturing to concentrate on specific functions; (4) to provide a shelter against uncertainties in the demand and order cycle; and (5) to cushion the effects of the reactions between critical interfaces within the distribution channel. To improve inventory management, ABC analysis can be used to identify the important and the minor products. The products are divided into three groups by value: A items account for 5 per cent of items and contribute 70 per cent of sales, B items account for 10 per cent of items and contribute 20 per cent of sales, and C items account for 65 per cent of items and contribute only 10 per cent of sales. The first step in ABC analysis is to put the products in order by sales; the next step is to check whether the items are high-volume or low-volume

2.2. Theoretical Consideration

2.2.1. Hazard Risk Assessment Matrix

The Hazard Risk Assessment Matrix is a mean of measuring the severity of a failure. It does this by having different hazard levels which are designated by one number and one letter. The number represents the severity of the event. The numbers show: (1) Death, system loss, or irreversible environmental damage; (2) Severe injury, occupational illness, major system damage, or reversible severe environmental damage; (3) Injury requiring medical attention, illness, system damage, or mitigating environmental damage; (4) Possible minor injury, minor system damage, or minimal environmental damage.

The letter of the hazard level shows the Frequency of Occurrence, namely, (A) Expected to occur frequently; (B) Will occur several times in the life of an item; (C) Likely to occur sometime in the life of an item; (D) Unlikely, but possible to occur in the life of an item; (E) So unlikely, it can be assumed occurrence may not be experienced.

So, each hazard level is associated with a risk category. Risk categories assist risk-management team members in differentiating credible high-hazard threats that may result in loss of life and property from less probable risks, therefore aiding management in risk vs. cost decisions.

Figure 2.1: Hazard Risk Assessment Matrix

Frequency of Occurrence	Severity			
	1 Catastrophic	2 Critical	3 Marginal	4 Negligible
(A) Frequent	1A	2A	3A	4A
(B) Probable	1B	2B	3B	4B
(C) Occasional	1C	2C	3C	4C
(D) Remote	1D	2D	3D	4D
(E) Improbable	1E	2E	3E	4E

Risk Categories:

High **Serious** **Medium** **Low**

2.2.2. ABC Analysis

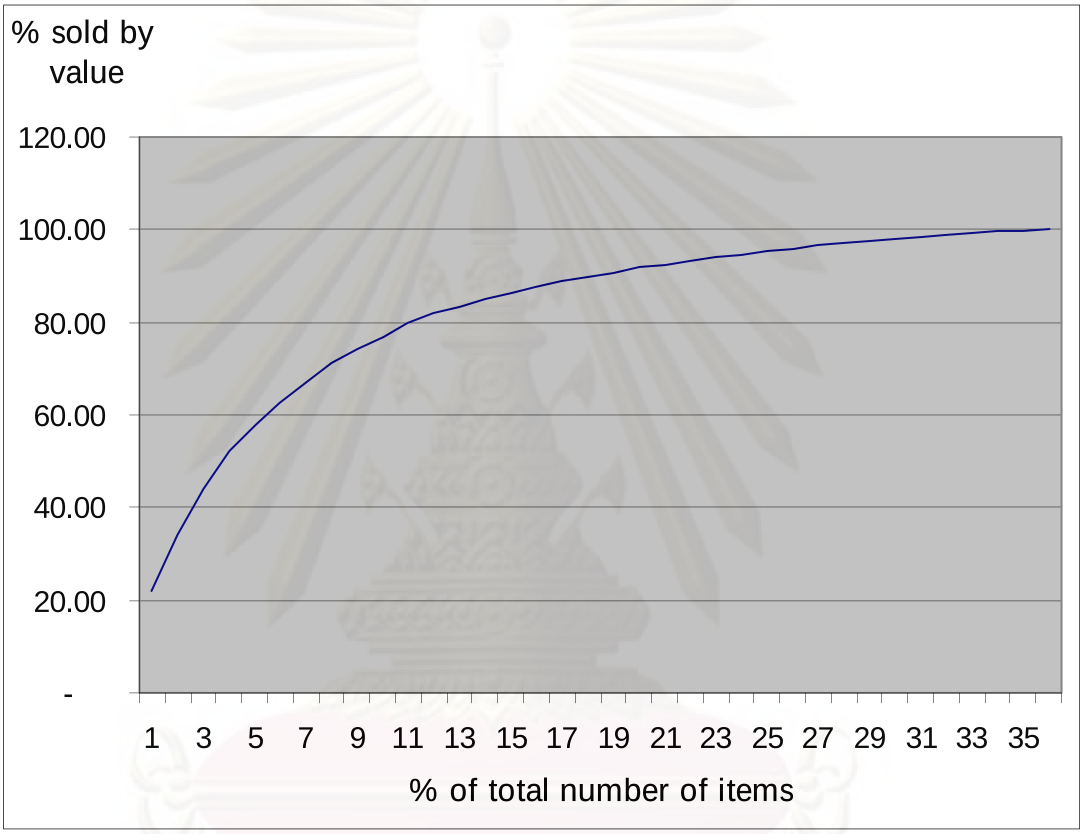
ABC analysis is a basic technique for identifying items which will have a significant impact on overall inventory cost and identifying different categories of stock that will require different management and controls because not all stock is equally valuable. The method usually categorizes inventory into three categories with each group having a different management control approach. When carrying out an ABC analysis, inventory items are with the results then ranked. The results of the ABC analysis provide information that helps evaluate how each inventory part should be monitored and controlled.

All the items of inventories are put in three categories, as below:

1. **A Class Items:** which are critically important and require close monitoring and tight control – while this may account for large value these will typically have a small percentage of the overall inventory count. "A Class" inventory will typically contain items that account for 80% of total value.
2. **B Class Items:** are of lower criticality requiring standard controls and periodic reviews of usage. "B Class" inventory will have around 15% of total value.

3. **C Class Items:** require the least controls, are sometimes issues as “unclassified stock”. The remaining 5% is in "C Class" inventory.

Figure 2.2: Pareto Curve



2.2.3. Forecasting

The application of business forecasting techniques provides an important tool in the decision making process. The generation of reliable estimates of future values will provide a clear competitive advantage for businesses. Such forecasts could be used in operational, strategic, and tactical decision making. The forecasting techniques involve consideration of historical data, and obtaining estimates based on past values and involve in analyzing a series of data given over a time period. Such techniques involve reducing the actual historical figures into a number of elements. Common elements in many time series include the following:

- **Trend**: This component can be considered as the overall pattern of changes in historical data viewed over a long period of time.
- **Seasonal variations**: These are the fluctuations around the trend which occur on a regular basis. Usually such regular variations occur over periods of one year or less.
- **Cyclical movements**: In addition to a trend in the series of values, it is often apparent that a cyclical component exists. These components indicate variations above or below the trend line for periods of longer than one year.
- **Irregular variations**: These include the unpredictable random fluctuations present in most practical time series. An analysis of these can be used to calculate. The likely errors and evaluate the reliability of the forecasting model used.

2.2.4. Inventory Control

Inventory is a quantity of items or resources that is held for some purpose or use. Inventory control is the activity of determining the range and quantities of resources which should be stocked, and it involves the ordering, storage and delivery. Inventory may be kept in-house or nearby for immediate use; or it may be held in a distant warehouse or distribution center for future use. The cost of holding too much stock can make the difference between profitability and loss. Alternatively, there are inherent risks involved in holding too little stock. The obvious problems are that stock will run out and consequently customers' orders will not be satisfied.

2.2.4.1. Purposes of Inventory

The primary reasons for holding stock are as follows:

To ensure stock is available: Holding inventory ensures that demand can be satisfied instantly. The stock acts as a buffer against unusually high usage and fluctuations in supply. Thus, if there is excessive demand or an extended delay in deliveries, the items in stock will help to satisfy most of the requirements.

To obtain economy of scale: In order to produce or order items in the most economic quantities it is usually needed to store items that are not immediately required. The production or ordering of single items as required may in practice not be an option because of the excessive costs involved. Often, discounts can be obtained when bulk orders are requested, and these will require stockholding facilities when received.

To reduce the risk of supplier failure or uncertainty: safety stocks are held to provide some protection against such contingencies and to hedge against anticipated shortage and price increases, especially in times of high inflation or as a deliberate policy of speculation

To protect against lead time uncertainties: such as where supplier's replenishment and lead times are not known with certainty – in such cases an investment in safety stocks is necessary if customer service is to be maintained at acceptable levels

2.2.4.2. The Relevant Terms for Inventory Control

Demand: The requirements of customers may, in practice, be difficult to estimate. Simple Models assume that the demand is constant, though in general, probabilistic estimated of demand may need to be used. The demand for some items may depend on orders for other goods.

When forecasting the future requirements for supplies, it can be distinguished between independent demand and dependent demand. The main points of difference are shown in Figure 2.3

Figure2.3: Main Differences between Independent and Dependent Demand

Independent demand	Dependent demand
Independent demand items are Finished goods or other end items	Dependent demand items are typically subassemblies or components used during The production of a finished or end product
Demand for independent items cannot be precisely forecast	Demand is derived from the number of units to be produced-for example, demand for 1000 cars will bive rise to a derived demand for 5000 car wheels

Lead Time: The time taken for the supplier to deliver the goods following placement an order is called the lead time.

Holding Costs: Costs involved in the storage of goods including overhead costs. Such costs can often be stated in terms of the cost per item of goods over a given time period.

Ordering Costs: These costs are the costs of placing an order for goods and are considered to be independent of the size of order. The ordering costs would be expressed as a fixed cost per order.

Purchase Costs: These are costs incurred relating to the individual items being ordered. These costs are stated per unit item.

Stockouts: A stockout occurs when demand exceeds the available stock. In this situation the demands of customers cannot be immediately satisfied.

Stockouts are treated in different ways, depending on the application. In some critical circumstances stockouts are simply not allowed. Other stockouts will result in immediate loss of sales. Alternatively, a stockout may simply result in a delay in the delivery of the item required.

Stockout Costs: If stockout occurs for a given item, additional costs may be incurred. Stockout costs can be expressed as the cost per item of unavailable stock. However, estimates of these costs can be subjective, particularly when estimating the cost of reduced customer good will and potential future loss of earnings.

Service levels: The actual service level attained in a given period, which can be determined from the formula:

$$\frac{\text{Number of times the items is provided on demand}}{\text{Number of times the item has been demanded}}$$

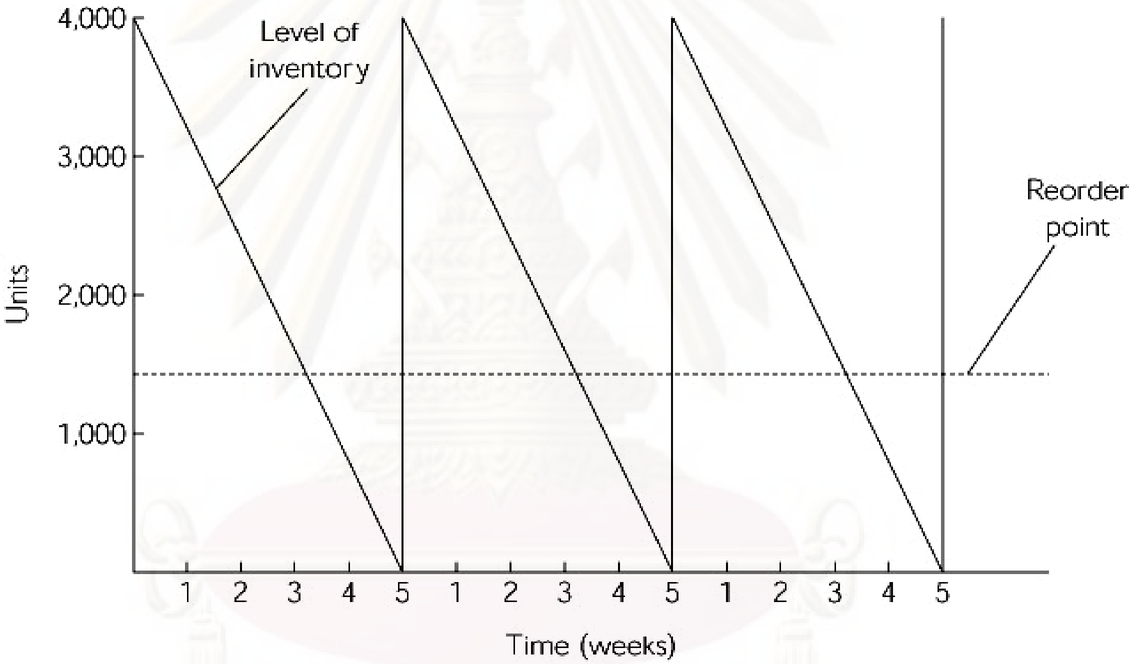
2.2.4.3. Fixed Order Quantity Model (R. H. Wilson 1934)

One of the simplest models in inventory control is the Fixed Order Quantity Model. This approach is used to estimate the size of order for a specified item that will minimize the overall inventory costs for that item. This model assumes the following:

- Continuous, constant, known and infinite rate of demand on one item of inventory
- A constant and known replenishment time
- No delay in the delivery of items. Thus, an order placed is immediately replenished.
- Items must never run ort of stock. Thus, all demands from customers can be satisfied immediately.

- Purchase price is a fixed cost of each item
- Satisfaction of all demand
- Constant cost, independent of order quantity or time
- No inventory in transit costs
- No limits on capital availability
- Supplier monopoly

Figure 2.4: Fixed Order Quantity Model under the Condition of Certainty



Economic Order Quantity *(EOQ)*

$$EOQ = \sqrt{\frac{2C_o D}{C_h}}$$

where C_o = ordering cost (baht per order)

D = demand of usage (units per unit time)

C_h = holding cost (baht per unit per unit time)

Safety Stock with Service Level *(SS)*

Safety Stock is a quantity of stock that has been set aside to reduce the probability of stock-out, or to improve the Service Level. The purpose of the safety stock is to prevent product shortage from occurring. In order to determine the safety stock level, the risk of a product shortage and the desired service level must be identified. The equation below shows that the more accurate the forecast, the smaller your safety stock can be.

$$SS = Z\sigma_L$$

$$= Z\sqrt{LT * \sigma_d^2}$$

$$= Z\sigma_d\sqrt{LT}$$

where Z = deviation in a standardized normal distribution

σ_L = standard deviation of lead time demand

σ_d = standard deviation of demand per period

Reorder Point *(ROP)*

The reorder point for replenishment of stock occurs when the level of stock drops down to zero. There is always a time lag from the date of placing an order for products and the date on which products are received. As a result, the reorder point is always higher than zero, and if the company places the order when the inventory reaches the reorder point, the new products will arrive before the stock runs out. The decision on how much stock to hold is generally referred to as the order point problem, that is, how low should the inventory be depleted before it is reordered.

The two factors that determine the appropriate order point are the delivery time stock, which is the inventory needed during the lead time, and the safety stock, which is the minimum level of inventory that is held as a protection against shortages due to fluctuations in demand.

Therefore:

ROP = Normal consumption during lead time + Safety Stock

$$ROP = DDLT + SS$$

$$= \left(\bar{D} * LT \right) + SS$$

where $DDLT$ = demand during lead time

$\bar{D}$ = average monthly demand

SS = Safety Stock

Total Annual Cost *(TAC)*

TAC = ordering cost + holding cost + purchase cost

$$TAC = C_o\left[\frac{D}{Q}\right] + C_h\left[\frac{Q}{2}\right] + pD$$

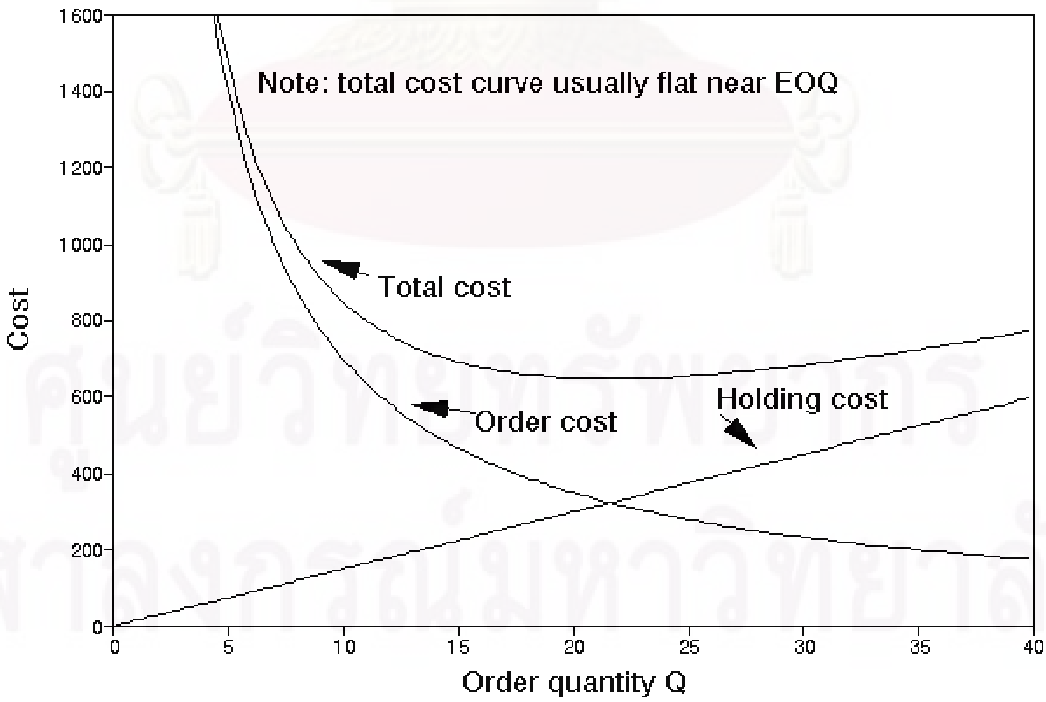
$$\Delta TAC = \left\{C_o\left[\frac{D}{Q}\right] + C_h\left[\frac{Q}{2}\right] + pD\right\}_{Actual} - \left\{C_o\left[\frac{D}{Q}\right] + C_h\left[\frac{Q}{2}\right] + pD\right\}_{New}$$

$$= \left\{C_o\left[\frac{D}{Q}\right] + C_h\left[\frac{Q}{2}\right]\right\}_{Actual} - \left\{C_o\left[\frac{D}{Q}\right] + C_h\left[\frac{Q}{2}\right]\right\}_{New}$$

Total Stocking Cost *(TSC)*

The right decisions regarding inventory levels are the result of a trade off between the costs of ordering and the costs of carrying the inventory over time. The right inventory level to carry will be the one that minimizes the total of these two costs. Figure 2.5 illustrates this concept.

Figure 2.5: Inventory Costs



The equation of *TSC* is:

$$TAC = C_o\left[\frac{D}{Q}\right] + C_h\left[\frac{Q}{2}\right]$$

Where C_o = ordering cost (baht/order)

C_h = holding cost (baht/10 months)

Q = order quantity (units)

D = forecast demand (months)

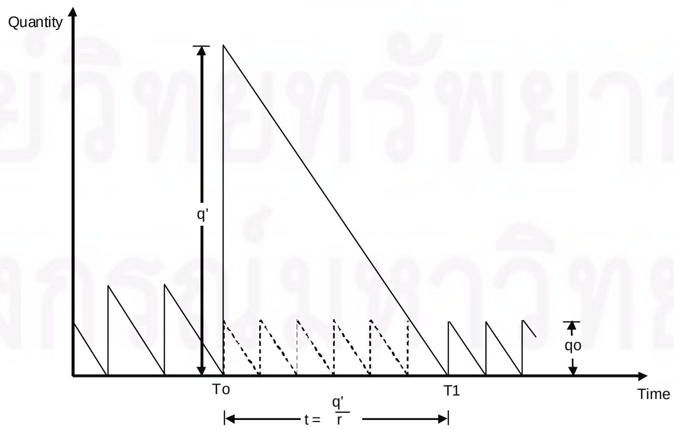
i = percentage of unit cost attributed to carrying inventory

p = purchase cost (baht/unit)

2.2.4.4. Known Price Increase Model

Consider the situation where a purchase cost increase announced to become effective at a certain definite date. However, any order placed now will be delivered at the current price, and can be scheduled for delivery when the present stock on hand goes to zero. It is assumed that the company has been using the *EOQ* as the lot size. Now it has the option of ordering a larger order, and, after that, of determining a new *EOQ*.

Figure 2.6: Inventory Level: Exception Order Policy and Default Policy



1. **Reorder Value** (q_2^*): This is the value of the order that has to be placed when the stocks that were ordered in the exception order have been sold out.
2. **Exception Order Value** ($q^{*'}$): This is the quantity that has to be ordered when issuing the exception order
3. **Optimum Gain Value** (G^*): This value is the optimum difference between the TAC of not issuing exception orders and the TAC of issuing exception orders.
4. **Exception Order Quantity Duration** ($t(q^{*'})$): This value is the time period (number of days) that the quantities in the exception orders can last.
5. **Interval between Reorders** ($t(q_2^*)$): This value is the time period (number of days) in between orders after the quantities in the exception orders have been sold out.

Where *r* = Demand (units/ time)

C_3 = Ordering Cost (baht/ order)

p = Annual Holding Cost Rate (per cent/ year)

d = Pre-Price Increase Purchase Cost (baht/ unit)

k = Price Increase (baht)

- **Reorder Value** (q_2^*)

$$q_2^* = \sqrt{\frac{2rc_3}{(d+k)p}}$$

- **Exception Order Value** ($q^{*'}$)

$$q^{*'} = q_2^* + \frac{k\left(q_2^* + \frac{r}{p}\right)}{d}$$

- **Optimum Gain Value (G^*)**

$$G^* = \frac{k}{d}\left(\frac{kr}{2p} + q_2^*\left(d+k\right) + c_3\right)$$

- **Exception Order Quantity Duration ($t(q^{*'})$)**

$$t(q^{*'}) = \frac{q^{*'}}{r}$$

- **Interval between Reorders ($t(q_2^*)$)**

$$t(q_2^{*'}) = \frac{q_2^{*}}{r}$$

CHAPTER III
METHODOLOGY

In order to achieve the objective of the study in this thesis, it is necessary to establish the steps clearly, starting from a study of the current inventory system in order to understand the context of the entire study. The steps are as follows.

1. Study the current inventory system
2. Identify the problems
3. Setup the inventory control plan
4. Implement the inventory control
5. Evaluate the implementation

3.1. Study the Current Inventory System

This is the first step to cope with the problems. The author will analyze the current inventory system and the historical relevant information for the past 10 months. The present context must first be understood, including the background of the establishment of the company, its target market, its product items, and the characteristic of the products.

3.2. Identify the Problems

When the current inventory system is analyzed, the next step is to identify the current problems in various perspectives namely, financial issue, warehouse capacity allocation, loss sale occurred from inefficient inventory control. It will be seen that, as the company under study has only been established recently, its systems and procedures are not yet fully in place, and there are several limitations as a result, whether they be infrastructures, human resources or operational processes, all of which need to be introduced and implemented quickly. Consequently, inefficiencies arise in the business operations. This study focuses only on inventory control system.

3.3. Set up the inventory system plan

The business of the case company is the trading of products. Therefore stocks are an important part of its assets and account for enormous financial investment. Its stocks therefore need to be managed carefully and efficiently to maximize their returns. This thesis is divided according to the suitability of each category of each product by means of Criticality Assessment Matrix.

The purposes of setting up the inventory plan are to find the appropriate quantities of the items to be replenished, the appropriate time to place the orders, and the critical level of each item. The author applies some theory below to find out the above answers.

3.3.1. Criticality Assessment Matrix

The case company has 420 product items, which is a large number and so it is best to initially study the most important product items in view of financial and other constraints. The rest of the items can be studied at a later stage.

The products are classified according to the importance of control and supervision and their actual sales value, because it is insufficient to just approach the study solely on the basis of sales value. As some of the product items are important to the company's business in terms of customer relations even though their value is not significant, they have to be classified in group A. In addition, the delivery of these particular product items cannot be delayed as they have a great impact on the salability of other product items. Some customers would not purchase other product items if these special product items are not available.

So, a modified model of the Hazard Risk Assessment Matrix is applied to achieve these aims.

3.3.2. Inventory Control

The consideration of the optimum points in the inventory control process is based on the different characteristic of each product group, as shown below.

3.3.2.1. Fixed Order Quantity Model

For products that will not have price increases, the conventional Fixed Order Quantity Model will be used. **The assumptions of this model are as follows.**

- Continuous, constant, known and infinite rate of demand on one item of inventory
- A constant and known replenishment time
- No delay in the delivery of items. Thus, an order placed is immediately replenished.
- Items must never run ort of stock. Thus, all demands from customers can be satisfied immediately
- Purchase price is a fixed cost of each item
- Satisfaction of all demand
- Constant cost, independent of order quantity or time
- No inventory in transit costs
- No limits on capital availability
- Supplier monopoly

3.3.2.2. Known Price Increase Model

For products the price increases of which are known in advance, the Known Price Increase Model will be used**. The assumptions of this model are as follows.**

- Continuous, constant, known and infinite rate of demand on one item of inventory
- A constant and known replenishment time

- No delay in the delivery of items. Thus, an order placed is immediately replenished.
- Items must never run ort of stock. Thus, all demands from customers can be satisfied immediately.
- The price increase of a product item is known in advance
- Constant cost, independent of order quantity or time
- No inventory in transit costs
- No limits on capital availability
- Supplier monopoly

3.3.2.3. Inventory Management with Limited Storage Capacity

The quantities of all the products that are purchased in group A, whether from overseas or locally, exceed the storage capacity available for them. As a result, it is necessary to calculate the appropriate ratio of each product item with respect to the storage capacity available, meaning that each product item will have to be reduced according to the ratio so determined for that particular item. It is necessary to do this because the stocking costs of the product items are different from one another, and so this method yields the ratio that will result in the lowest stocking costs and the inventory that is the most appropriate for management and the business. The storage capacity for products in groups B and C is sufficient and the ratio need not bee calculated.

3.4. Implement the Inventory Control

It is necessary to implement the inventory control plan to obtain the optimum solution. It starts with the Criticality Assessment Matrix to categorize items into group A, B, and C.

For the inventory management with limited storage capacity, each group of items is matched to the inventory model namely, Fixed Order Quantity Model and Known Price Increase Model to determine the holding costs, stockout costs, and ordering costs. Find out the economic order quantity (*EOQ*), safety stock (*SS*), and reorder point (*RP*).

3.5. Evaluating the Results of Implementing the New Inventory Control System

As the methods of calculating the cost savings of the product items in each category are different, different methods of evaluation need to be used.

The study evaluates the results of implementing by comparing the total cost before and after implementation, as well as the cost savings gained.

CHAPTER IV

IMPLEMENTATION

4.1. Forecasting Demand

Even though the demand of the products is not easy to control, AAA is a recently established company, so it tries to reduce the trend and seasonal variations because senior management believes that doing so would enable AAA to optimize its capital usage. AAA sells the products to industrial manufacturers directly, so it is easier to control sales. AAA does not want to expand sales, product lines, or customers because AAA wants to create efficient and effective operation processes within the company before expanding the business, otherwise it cannot support customers' requirements effectively, which would result in a bad reputation for AAA. For the above reasons, the demand of most products is quite predictable. But sometimes it faces unpredictable random fluctuations, which AAA tackles by adopting marketing push strategy to sell such products. So AAA only uses simple averages of historical data over a 10 month period starting from July 2007 to represent the movements of the products. The sales figures are shown in Table A.1 in Appendix A.

4.2. Method of Categorizing the Products

The method used is the Criticality Assessment Matrix which is a modified version of the Hazard Risk Assessment Matrix, and is adapted from the more conventional ABC Analysis method because AAA must consider the following factors:

1. Importance of the products to the business competitiveness: critical, marginal, or negligible, which are shown as 1, 2 , and 3 respectively in the matrix. Some products have to be kept in stock even though their value is not much because some customers insist on getting these products immediately even though they may not be of much value to

AAA. So if there is a shortage of these products, the good will with these customers will be adversely affected.

2. Total sales value of each product per month: more than 10,000 baht, 5,001-10,000 baht, or 0-5,000baht. These 3 categories are shown as A, B, and C in the matrix.

The method of categorizing the products is shown in the table below.

Table 4.1: Criticality Assessment Levels

Item	Product code	Total sales value (Baht per month)	Importance to the business' competitiveness	Total sales value of each product per month	Criticality level
1	A12462	14,625	3	C	3C
2	A14114	14,300	3	C	3C
3	A16486	26,000	3	C	3C
4	A26546	13,780	3	C	3C
5	A30570	8,000	3	C	3C
6	A35578	22,500	3	C	3C
7	A44258	8,525	2	B	2B
8	A46282	5,400	2	B	2B
9	A48678	12,400	2	B	2B
10	A49318	8,450	2	B	2B
11	A53366	9,900	2	B	2B
12	A55906	10,125	2	B	2B
13	A56726	5,625	2	B	2B
14	A58738	4,160	2	B	2B
15	A71858	5,270	2	B	2B
16	A73882	6,600	2	B	2B
17	A76846	4,365	2	B	2B
18	B10450	52,875	2	B	2B
19	B17126	82,150	2	B	2B
20	B18498	22,500	2	B	2B
21	B22522	16,800	2	B	2B
22	B31330	38,025	2	B	2B
23	B32642	31,875	2	B	2B
24	B35198	36,000	2	B	2B
25	C71102	18,000	2	A	2A
26	D14474	28,000	2	A	2A
27	D20510	22,500	2	A	2A
28	D28558	12,240	2	A	2A
29	E20138	12,240	1	A	1A
30	F24534	14,300	2	A	2A
31	F29954	6,750	2	A	2A
32	F34594	7,500	2	A	2A
33	G33954	28,000	2	A	2A
34	H40630	5,600	2	A	2A
35	H51342	5,785	2	A	2A
36	H60750	9,600	1	A	1A
37	I55390	4,800	2	A	2A
38	J11986	11,550	2	A	2A
39	J24894	3,500	2	A	2A
40	K29174	7,500	2	A	2A
41	K44654	4,850	2	A	2A
42	K54966	7,370	3	A	3A

Table 4.1: Criticality Assessment Levels (Continued)

Item	Product code	Total sales value (Baht per month)	Importance to the business' competitiveness	Total sales value of each product per month	Criticality level
43	K66786	6,600	2	A	2A
44	L23150	8,000	2	A	2A
45	L32978	9,130	1	A	1A
46	M11102	16,800	1	A	1A
47	M32186	6,930	2	A	2A
48	M88438	64,350	2	A	2A
49	N25402	6,640	2	A	2A
50	N48306	19,350	2	A	2A
51	N64774	10,050	2	A	2A
52	P34266	26,000	2	A	2A
53	P54378	8,525	2	A	2A
54	Q52702	11,640	2	A	2A
55	R74834	7,178	2	A	2A
56	S26162	8,000	3	A	3A
57	S32418	18,216	1	A	1A
58	S32582	8,000	2	A	2A
59	S42642	13,000	2	A	2A
60	S54714	6,160	2	A	2A
61	S67426	4,675	2	A	2A
62	S98942	7,475	2	A	2A
63	T82870	12,600	2	A	2A
64	U42234	9,118	3	A	3A
65	U46414	5,724	2	A	2A
66	W46666	6,499	2	A	2A
67	W51990	14,640	2	A	2A
68	X72822	16,800	2	A	2A
69	Y47294	7,840	1	A	1A
70	Z36606	32,274	2	B	2B
71	Z36890	22,500	2	B	2B
72	Z38210	25,200	2	B	2B
73	Z38618	21,150	2	B	2B
74	Z41222	15,000	2	B	2B
75	Z43246	17,945	2	B	2B
76	Z45270	28,200	2	B	2B
77	Z50330	16,960	2	B	2B
78	Z50690	9,300	2	B	2B
79	Z52354	22,500	2	B	2B
80	Z62762	17,550	2	B	2B
81	Z66918	16,250	2	B	2B
82	Z68798	68,750	2	B	2B
83	Z70810	57,200	2	B	2B
84	Z87930	41,600	2	B	2B

As a result of the information obtained from the preceding table, the products are categorized in the table below

Figure 4.1: Criticality Assessment Matrix

Total sales value of each product per month	Importance to the business competitiveness		
	Critical(1)	Marginal(2)	Negligible(3)
More than B10,000 (A)	1A (group A 6 Items)	2A (group A 36 Items)	3A (group A 3 Items)
5,001-10,000 (B)	1B (group A 33 Items)	2B (group B 63 Items)	3B (group C 98 Items)
0-5,000(C)	1C (group A 6 Items)	2C (group C 127 Items)	3C (group C 48 Items)

The products in group A consist of categories 1A, 2A, 3A, 1B, 1C

The products in group B consist of categories 2B

The products in group C consist of categories 3B, 2C, 3C

After looking at the categorization as explained above, this case study will consider the products in group A only because they require close monitoring and control.

AAA's products in group A can be divided into 3 categories, namely

1. Ordinary domestic products, the prices of which seldom increase (there are 75 items in this category)
2. Imported products, the price increases of which are notified in advance by the oversea suppliers (the price increases are usually 8% each time; there are 7 items in this category)
3. Domestic products, the price increases of which are notified in advance by the domestic suppliers (the price increases are usually 10% each time; there are 2 items in this category)

4.3. Fixed Order Quantity Model (Q–Model)

The products which will be considered by using this model are shown in Table A.3 in appendix A

Start with calculating the holding cost which is the money spent to keep and maintain a stock of goods in storage. The holding cost is calculated as follows.

Monetary value			
Storage		452,000	baht
Handling		40,000	baht
Obsolescence		30,000	baht
Damage		40,000	baht
Administrative		120,000	baht
Loss (pilferage etc)		18,000	baht
Total		700,000	baht
Average Inventory Value		7,000,000	baht
Percent	=700,000/7,000,000*100=	10.00%	
Percentage value			
Estimated opportunity cost (% of inventory value)		5%	
Quit rent		5%	
Total percentage value		10%	
Total holding cost rate	= 10%+10% =	**20%**	

Then, calculate *EOQ* ,*SS,* and *ROP* by using the Fixed Order Quantity Model.

4.3.1. Economic Order Quantity *(EOQ)*

$$EOQ = \sqrt{\frac{2C_oD}{C_h}}$$

where C_o = Ordering cost (baht per order)

D = Demand of usage (units per unit time)

C_h = Holding cost (baht per unit per unit time)

For Product: A12462

$$EOQ = \sqrt{\frac{2CoD}{Ch}}$$

$$= \sqrt{\frac{2(1{,}180)(1{,}404)}{(125)(20\%)}}$$

$$= 364.0571 \text{ units}$$

But the supplier sells 12 units of A12462 each time, so AAA cannot buy 364.0571 units of A12462. AAA has to calculate the appropriate amount of the product to buy by using the Order Discrete Unit Equation, as follows.

$$Q' * (Q' - 1) \leq Q_0^2$$

$$31(30) \leq 30.3381^2$$

$$930 \leq 920.4$$

$$930 - 920.4 \leq 0$$

$$9.6 \leq 0$$

From the above, the value on the left hand side is greater than zero, thus the result of this equation is not true, and so AAA should place an order for 31 cases of A12462. Each case of A12462 contains 12 units, so AAA must purchase 30 cases x 12 units = 360 units.

4.3.2. Safety Stock with Service Level *(SS)*

The next step is to determine the Safety Stock (*SS*) by the following formula.

$$SS = Z\sigma_L$$
$$= Z\sqrt{LT * \sigma_d^2}$$
$$= Z\sigma_d\sqrt{LT}$$

where Z = deviation in a standardized normal distribution

σ_L = standard deviation of lead time demand

σ_d = standard deviation of demand per period

For AAA, the service level of Z is 90%, so the Service Factor (Z) is 1.28, and the Lead Time *(LT)* is 5days.

Thus SS $= (1.28)(9.4953)\sqrt{5}$

$= 27.1770$ units

As can be seen, *SS*= 27.1770 units, but 27.1770 is not an integer, and so this value is rounded up to 28 to suit AAA's service level policy.

4.3.3. Reorder Point *(ROP)*

Now that Safety Stock (*SS*) has been determined, the Reorder Point (*ROP*) can be calculated in the following way.

$$ROP = DDLT + SS$$

$$= \left(\bar{D} * LT\right) + SS$$

where $DDLT$ = Demand during lead time

$\bar{D}$ = Average monthly demand

SS = Safety stock

Thus $ROP = [(117/30)(5)] + 28$

$= 46.6770$ units

AAA deploys the same principle for rounding the figures as that used for rounding up the *SS* figures. So, the *ROP* is rounded up to 47 units. When the *ROP* is 47 units, a new order will be placed 360 units (which is the *EOQ*). Since the average sales per month is 117 units, the *EOQ* of 360 units can last 3 months and 3 days.

The same methodology shown above is used to obtain the *EOQ, SS,* and *ROP* values for the remaining 74 product items. The variables for the remaining 74 product items are different, as shown in table A.3 in Appendix A. However, the Holding Cost Rate for all of these 74 product items is kept at a constant of 20% of the Purchase Cost per Annum, the Ordering Cost is a constant of 1,180 baht, and the Service Factor (Z) is a constant of 1.28.

The table below shows the final *EOQ, SS, and ROP* values that have been calculated for all 75 product items by using the above methodology.

Table 4.2: Summary of the Final *EOQ, SS, and ROP* Values of 75 Products

Item	Product code	*EOQ* (Units)	*SS* (Units)	*ROP* (Units)	Item	Product code	*EOQ* (Units)	*SS* (Units)	*ROP* (Units)
1	A12462	360	28	47	39	M11102	1224	25	95
2	A14114	696	29	66	40	M32186	150	22	28
3	A16486	1212	46	219	41	N25402	760	16	43
4	A26546	828	28	71	42	N48306	228	16	30
5	A30570	200	13	17	43	N64774	252	14	21
6	A35578	312	29	49	44	P34266	1300	34	121
7	A44258	228	20	33	45	P54378	636	27	43
8	A46282	230	24	39	46	Q52702	336	19	35
9	A48678	276	19	32	47	R74834	324	18	31
10	A49318	264	15	21	48	S26162	216	18	30
11	A53366	684	22	64	49	S32418	264	19	34
12	A55906	200	14	18	50	S32582	216	15	23
13	A56726	120	17	21	51	S42642	216	17	28
14	A58738	180	14	17	52	S54714	210	24	39
15	A71858	180	17	23	53	S67426	468	12	21
16	A73882	264	25	43	54	S98942	504	33	52
17	A76846	250	17	25	55	T82870	800	34	69
18	C71102	1260	15	90	56	U42234	372	15	24
19	D14474	444	29	63	57	U46414	792	15	42
20	D20510	400	22	35	58	W46666	312	22	37
21	D28558	1152	16	73	59	W51990	1200	16	77
22	E20138	1224	21	78	60	X72822	240	18	32
23	F24534	696	29	66	61	Y47294	240	14	19
24	F29954	204	17	25	62	Z36606	336	22	76
25	F34594	210	15	23	63	Z36890	312	15	36
26	G33954	444	41	108	64	Z38210	432	14	32
27	H40630	200	16	23	65	Z38618	240	19	35
28	H51342	444	18	33	66	Z41222	240	23	40
29	H60750	228	18	32	67	Z43246	516	21	83
30	I55390	720	29	49	68	Z45270	1056	15	93
31	J11986	192	31	40	69	Z50330	300	16	27
32	J24894	156	22	27	70	Z50690	600	17	43
33	K29174	216	15	23	71	Z52354	192	19	31
34	K44654	276	12	17	72	Z62762	800	15	60
35	K54966	588	18	41	73	Z66918	372	34	75
36	K66786	552	29	49	74	Z70810	2244	224	462
37	L23150	168	19	28	75	Z87930	500	25	60
38	L32978	650	16	43					

4.4. Known Price Increase Model: Imported Products

For the products which AAA knows from the suppliers in advance that the Purchase Costs will be increased, AAA will use the Known Price Increase Model to determine whether to place exception orders or not. If AAA finally decides to place exception orders, AAA has to determine the quantities in the exception orders, and when to place subsequent orders.

4.4.1. Two Factors Consideration

First of all, the following two factors have to be taken into consideration.

- **Container capacity:** AAA chooses to use the smallest containers available, namely, 20-foot containers with a capacity of W2.5 x L6.0 x H2.5 meters (28 cubic meters). The usable volume is actually only 26.1 cubic meters, and the total payload weight is not more than 24 tons. The suppliers' condition is that the minimum order is one full container load, which means that AAA has to order at least 26.1 cubic meters of product weighing not more than 24 tons.
- **The number of units per case:** The number of units per case varies by product, by manufacturer, and according to suitability. So it is necessary to calculate the quantity in Order Discrete Units.

The table below shows the variables used in the calculation of the order discrete units of each product that can fit into a container in accordance with the condition above.

Table 4.3 Variables used in the Calculation of the Order Discrete Units of Known Price Increase Products

Item	Product code	Volume/unit (Cubic m)	Weight/unit (Kg)	Number of unit/case (Units)	Weight/case (Kg)	Quantity/case (Units)
1	B10450	0.01500	0.80	100	80.00	100
2	B17126	0.00355	0.60	100	60.00	100
3	B18498	0.00855	5.00	50	250.00	50
4	B22522	0.00246	1.70	72	122.40	72
5	B31330	0.01200	3.00	500	1500.00	500
6	B32642	0.00551	0.40	1000	400.00	1000
7	B35198	0.01000	1.40	100	140.00	100

Next, the maximum Order Discrete Units will be calculated, as shown below.

Let C_v be the maximum order discrete units and C_w be the maximum weight of the product per container

$$C_v = \frac{26.1\ m^3}{\text{volume of each product in cubic meters } (m^3/\text{unit})}$$

$$C_w = \frac{24{,}000\ kg}{\text{weight of each product in cubic meters } (kg/\text{unit})}$$

If $C_v < C_w$, the C_v value will be used

But if $C_v > C_w$, the C_w value will be used

The following is an example of the calculation for B10450

$$C_v = \frac{26.1\ m^3}{0.015\ (m^3/\text{unit})}$$

= 1,740 units

$$C_w = \frac{26.1\ m^3}{0.80\ (kg/\text{unit})}$$

= 30,000 units

$C_v < C_w$

So the number of units to be used is 1,740 units.

It is necessary to adjust the above figure to fit the packing configuration of 100 units per case

$$\therefore \quad \frac{1{,}740\ \text{units}}{100\ \text{units per case}} = 17.40 \text{ cases.}$$

The result must be rounded downward, because if it is rounded up, the number will exceed the permissible capacity. So AAA should order 17 cases of B10450 per container, or 17 x 100 = 1,700 units.

The following table shows the maximum order discrete units for all the products.

Table 4.4: Maximum Order Discrete Units that Fit into a Container

Item	Product code	Number of cases per container (Cases)	Number of units per container (Units)
1	B10450	17	1,700
2	B17126	73	7,300
3	B18498	61	3,050
4	B22522	147	10,584
5	B31330	4	2,000
6	B32642	4	4,000
7	B35198	26	2,600

In addition, the ordering cost of seven product items has to be determined first because they are items imported from overseas. The ordering cost is shown below.

Table 4.5 Breakdown of Costs of Ordering Imported Products

Description	Operator1	Operator2	Operator3	Cost (Baht)
	Salary@B20,000	Salary@B12,000	Salary@B7,000	
	Number of minutes spent in excution (Mins)			
Labour cost				
Deciding what products need to be replenished	120			166
Preparation of purchase requisition	30			42
Preparation of purchase order	30			42
Receiving and putting goods away		180	720	498
Inspecting goods		240		200
Updating inventory records	30	10		50
Processing the vendor's payment	30			42
Communication and equipment expenses				
Telephone				30
Fax				20
Paper				50
Printer cartridge				20
Copier cartridge				20
Clearing expenses				20,000
Total cost				21,180

4.4.2. Known Price Increase Model

Then, the following values have to be determined.

1. **Reorder Value** (q_2^*): This is the value of the order that has to be placed when the stocks that were ordered in the exception order have been sold out.
2. **Exception Order Value** ($q^{*'}$): This is the quantity that has to be ordered when issuing the exception order
3. **Optimum Gain Value** (G^*): This value is the optimum difference between the TAC of not issuing exception orders and the TAC of issuing exception orders.
4. **Exception Order Quantity Duration** ($t(q^{*'})$): This value is the time period (number of days) that the quantities in the exception orders can last.
5. **Interval between Reorders** ($t(q_2^*)$): This value is the time period (number of days) in between orders after the quantities in the exception orders have been sold out.

Where r = Demand (units/ time)

C_3 = Ordering cost (baht/ order)

p = Annual holding cost rate (per cent/ year)

d = Pre-price increase purchase cost (baht/ unit)

k = Price increase (baht)

Now the following values will have to be determined: q_2^*, $q^{*'}$, G^*, $t(q^{*'})$, $t(q_2^*)$

Product B10450 is used as an example of these calculations, as shown below.

4.4.2.1. Reorder Value (q_2^*)

$$q_2^* = \sqrt{\frac{2rc_3}{(d+k)p}}$$

$$= \sqrt{\frac{2(1{,}175x12)(21{,}280)}{(225+18)(20\%)}}$$

=3,506 units

The result above has to be adjusted according to the order discrete units principle before it can be used in further calculations. This applies to all products. The method of adjusting this result is shown below.

$$Q' * (Q' - 1) \quad \leq Q_0^2$$

$$3(2) \quad \leq 2.01^2$$

$$6 \quad \leq 4.06$$

$$6 - 4.06 \quad \leq 0$$

$$1.94 \quad \leq 0$$

From the above, the value on the left hand side is greater than zero, thus the result of this equation is not true, and so AAA should place an order for 2 x 20-foot container loads of B10450. Each container load of B10450 contains 1,740 units, so the final order discrete units is 2 x 20-foot container loads x 1,740 =3 ,400 units.

4.4.2.2. Exception Order Value ($q^{*'}$)

$$q^{*'} = q_2^* + \frac{k\left(q_2^* + \frac{r}{p}\right)}{d}$$

$$= 3{,}400 + \frac{18\left(3{,}400 + \frac{(1{,}175x12)}{20\%}\right)}{225}$$

=9,312 units

The adjusted q_2^* = 3,400 will be used for determining $q^{*'}$. The result above has to be adjusted according to the Order Discrete Units Principle before it can be used in further calculations. This applies to all products. The method of adjusting this result is shown below.

$$\begin{aligned} Q' * (Q' - 1) &\le Q_0^2 \\ 6(5) &\le 5.35^2 \\ 30 &\le 28.64 \\ 30 - 28.64 &\le 0 \\ 1.36 &\le 0 \end{aligned}$$

From the above, the value on the left hand side is greater than zero, thus the result of this equation is not true, and so AAA should place an order for 5 x 20-foot container loads of B10450. Each container load of B10450 contains 1,740 units. So the final Order Discrete Units is 8,500 units.

4.4.2.3. Optimum Gain Value (G^*)

$$G^* = \frac{k}{d}\left(\frac{kr}{2p} + q_2^*(d+k) + C_3\right)$$

$$= \frac{18}{225}\left(\frac{18x(1{,}175x12)}{2(20\%)} + 3{,}400(125+18) + 21{,}180\right)$$

= 118,550.40 baht

The adjusted q_2^* = 3,400 will be used for determining G^*. The value of 118,550.40 baht is the optimum difference between the *TAC* of not issuing exception orders and the *TAC* of issuing exception orders.

4.4.2.4. Exception Order Quantity Duration ($t(q^{*'})$)

$$t(q^{*'}) = \frac{q^{*'}}{r}$$

$$= \frac{8{,}500}{225}$$

= 7.23 months

The adjusted $q^{*'}$ = 8,500 will be used for determining $t(q^{*'})$. It can thus be seen that the quantity of 8,500 units in the exception order is enough to last 7.23 months, or 7 months and 7 days.

4.4.2.5. Interval between Reorders ($t(q_2^*)$)

$$t(q_2^{*'}) = \frac{q_2^*}{r}$$

$$= \frac{3{,}400}{225}$$

= 2.89 months

The adjusted q_2^* = 3,400 will be used for determining $t(q_2^*)$. It can thus be seen that the quantity of 3,400 units in the Interval Between Reorders is enough to last 2.89 months, or 2 months and 27 days.

The table below shows all these values for each of the 7 products in this group. It will be recalled that these 7 products are imported from overseas that are expected to have price increases of 8 per cent each year.

Table 4.6: Summary of $q^{*'}$, $t(q^{*'})$, q_2^*, and $t(q_2^*)$ Values for Products in Group: Imported Products

Item	Product code	Exception order quantities (Units)	Exception order quantity duration	Ordinary order quantities (Units)	Interval between reorders
1	B10450	8,500	7months7days	3,400	2months27days
2	B17126	14,600	9months13days	7,300	4months21days
3	B18498	6,100	9months23days	3,050	4months26days
4	B22522	21,168	10months2days	10,584	5months1days
5	B31330	6,000	7months3days	2,000	2months11days
6	B32642	8,000	6months8days	4,000	3months4days
7	B35198	7,800	9months23days	2,600	3months8days

The total savings from issuing exception orders for all 7 products is 533,945.70 baht, or equal to 6.11 per cent of the total cost of the purchase costs.

4.5. Known Price Increase Model: Domestic Products

For the domestic products which AAA knows from the suppliers in advance that the Purchase Costs will be increased, AAA will employ the Known Price Increase Model to determine whether to place exception orders or not. If AAA finally decides to place exception orders, AAA has to determine the quantities in the exception orders, and when to place subsequent orders.

The values of $q_2^*, q^{*'}, G^*$, $t(q^{*'})$, $t(q_2^*)$ for the products that are purchased locally will now have to be determined. There are only 2 product items in this group, namely, M88438 and Z68798. The difference between the purchase of imported products and domestic products is that in the case of domestic products, it is not necessary to consider container capacity.

4.5.1. Factor Consideration

The factor that has to be taken into consideration is the number of units per case. The number of units per case varies by product, by manufacturer, and according to suitability. So it is necessary to calculate the quantity in Order Discrete Units. The number of units per case for M88438 and Z68798 used in the calculation of Known Price Increase Model are 10 units and 12 units respectively.

The ordering cost of these two product items has to be determined first. The ordering cost is shown below.

Table 4.7 Breakdown of Costs of Ordering Domestic Products

Description	Operator1	Operator2	Operator3	Cost (Baht)
	Salary@B20,000	Salary@B12,000	Salary@B7,000	
	Number of minutes spent in excution (Mins)			
Labour cost				
Deciding what products need to be replenished	120			166
Preparation of purchase requisition	30			42
Preparation of purchase order	30			42
Receiving and putting goods away		180	720	498
Inspecting goods		240		200
Updating inventory records	30	10		50
Processing the vendor's payment	30			42
Communication and equipment expenses				
Telephone				30
Fax				20
Paper				50
Printer cartridge				20
Copier cartridge				20
Total cost				1,180

4.5.2. Known Price Increase Model

Then, the following values have to be determined.

1. **Reorder Value (q_2^*):** This is the value of the order that has to be placed when the stocks that were ordered in the exception order have been sold out.
2. **Exception Order Value ($q^{*'}$):** This is the quantity that has to be ordered when issuing the exception order
3. **Optimum Gain Value (G^*):** This value is the optimum difference between the TAC of not issuing exception orders and the TAC of issuing exception orders.
4. **Exception Order Quantity Duration ($t(q^{*'})$):** This value is the time period (number of days) that the quantities in the exception orders can last.

5. **Interval between Reorders ($t(q_2^*)$):** This value is the time period (number of days) in between orders after the quantities in the exception orders have been sold out.

Where r = Demand (units/ time)

C_3 = Ordering cost (baht/ order)

p = Annual holding cost rate (per cent/ year)

d = Pre-price Increase purchase cost (baht/ unit)

k = Price increase (baht)

Now the following values will have to be determined: q_2^*, $q^{*\prime}$, G^*, $t(q^{*\prime})$, $t(q_2^*)$

Product B10450 is used as an example of these calculations, as shown below.

4.5.2.1. Reorder Value (q_2^*)

$$q_2^* = \sqrt{\frac{2rc_3}{(d+k)p}}$$

$$= \sqrt{\frac{2(325x12)(1{,}180)}{(198+19.8)(20\%)}}$$

$$=460 \text{ units}$$

The result above has to be adjusted according to the Order Discrete Units Principle before it can be used in further calculations. The method of adjusting this result is shown below.

$$Q' * (Q' - 1) \quad \leq Q_0^2$$

$$46(45) \leq 45.97^2$$

$$2{,}070 \leq 2{,}112.95$$

$$2{,}070 - 2{,}112.95 \leq 0$$

$$-42.95 \leq 0$$

From the above, the value on the left hand side is less than zero, thus the result of this equation is true, and so AAA should place an order for 46 cases of M88438. Each case of M88438 contains 10 units, so the Order Discrete Units is 46x10 = 460 units.

4.5.2.2. Exception Order Value ($q^{*'}$)

$$q^{*'} = q_2^* + \frac{k\left(q_2^* + \frac{r}{p}\right)}{d}$$

$$= 460 + \frac{19.80\left(460 + \frac{(325x12)}{20\%}\right)}{198}$$

=2,456 units

The adjusted q_2^* = 460 will be used for determining $q^{*'}$. The result above has to be adjusted according to the Order Discrete Units Principle before it can be used in further calculations. This applies to all products. The method of adjusting this result is shown below.

$$Q' * (Q' - 1) \leq Q_0^2$$

$$246(245) \leq 245.6^2$$

$$60{,}270 \leq 60{,}319.36$$

$$60{,}270 - 60{,}319.36 \leq 0$$

$$-49.36 \leq 0$$

From the above, the value on the left hand side is less than zero, thus the result of this equation is true, and so AAA should place an order for 246 cases of M88438. Each case of M88438 contains 10 units, so the Order Discrete Units is 246x10 = 2,460 units.

4.5.2.3. Optimum Gain Value (G^*)

$$G^* = \frac{k}{d}\left(\frac{kr}{2p} + q_2^*(d+k) + c_3\right)$$

$$= \frac{19.80}{198}\left(\frac{19.8x(325x12)}{2(20\%)} + 460(198+19.8) + 1{,}180\right)$$

= 29,441.80 baht

The adjusted q_2^* = 460 will be used for determining G^*. The value of 29,441.80 baht is the optimum difference between the *TAC* of not issuing exception orders and the *TAC* of issuing exception orders.

4.5.2.4. Exception Order Quantity Duration ($t(q^{*'})$)

$$t(q^{*'}) = \frac{q^{*'}}{r}$$

$$= \frac{2{,}460}{325}$$

= 7.23 months

The adjusted $q^{*'}$ = 2,460 will be used for determining $t(q^{*'})$. It can thus be seen that the quantity of 2,460 units in the exception order is enough to last 7.6 months, or 7 months and 17 days.

4.5.2.5. Interval Between Reorders ($t(q_2^*)$)

$$t(q_2^{*'}) = \frac{q_2^*}{r}$$

$$= \frac{3{,}400}{225}$$

= 2.89 months

The adjusted q_2^* = 460 will be used for determining $t(q_2^*)$. It can thus be seen that the quantity of 3,400 units in the Interval between Reorders is enough to last 1.42 months, or 1 months and 12 days.

The table below shows all these values for each of the two products in this group. It will be recalled that these two domestic products are expected to have price increases of 10 per cent each year.

Table 4.8: Summary of $q^{*'}$, $t(q^{*'})$, q_2^*, and $t(q_2^*)$ Values for Products in Group: Domestic Products

Item	Product code	Exception order quantities (Units)	Exception order quantity duration	Ordinary order quantities (Units)	Interval between reorders
1	M88438	2,460	7months17days	460	1months12days
2	Z68798	9,384	7months15days	1,716	1months11days

The total savings from issuing exception orders for all two domestic products is 60,566.60 baht, or equal to 6.04 per cent of the total purchase costs.

4.5.3. Inventory Management with Limited Storage Capacity

After obtaining the *EOQ* values of all 84 product items, the products have to be stored. However, before the products can be stored, calculations have to be made to determine whether there is enough storage capacity or not.

The equation is:

$$s_1 Q_1 + s_2 Q_2 + \ldots + s_k Q_k + \ldots + s_n Q_n < S$$

Where S = Available storage capacity (m^3)

s_k = Product packaging size (m^3)

Q = Order quantity (units)

n = Product quantity

(0.150)(360) + (0.140)(696) + (0.120)(1,212) + (0.090)(828) + (0.002)(200) + (0.005)(312) + (0.035)(228) + (0.020)(230) + (0.012)(276) + (0.004)(264) + (0.030)(684) + (0.002)(200) + (0.170)(120) + (0.036)(180) + (0.107)(180) + (0.107)(264) + (0.012)(250) + (0.300)(3,600) + (0.036)(8,600) + (0.107)(5,900) + (0.012)(16,000) + (0.060)(600) + (0.028)(500) + (0.100)(3,000) + (0.012)(1,260) + (0.001)(444) + (0.030)(400) + (0.250)(1,152) + (0.250)(1,224) + (0.160)(696) + (0.006)(204) + (0.036)(210) + (0.107)(444) + (0.012)(200) + (0.450)(444) + (0.200)(228) + (0.120)(720) + (0.002)(192) + (0.050)(156) + (0.210)(216) + (0.300)(276) + (0.036)(588) + (0.170)(552) + (0.012)(168) + (0.300)(650) + (0.036)(1,224) + (0.107)(150) + (0.300)(480) + (0.036)(760) + (0.200)(228) + (0.220)(252) + (0.700)(1,300) + (0.170)(636) + (0.300)(336) + (0.036)(324) + (0.107)(216) + (0.012)(264) + (0.300)(216) + (0.036)(216) + (0.107)(210) + (0.012)(468) + (0.170)(504) + (0.030)(800) + (0.250)(372) + (0.036)(792) + (0.107)(312) + (0.310)(1,200) + (0.110)(240) + (0.036)(240) + (0.030)(336) + (0.660)(312) + (0.250)(432) + (0.035)(240) + (0.140)(240) + (0.220)(516) + (0.500)(1,056) + (0.240)(300) + (0.040)(600) + (0.035)(192) + (0.140)(800) + (0.220)(372) + (0.025)(1,788) + (0.100)(2,244) + (0.001)(500) < 1,750

8,421.88 m^3 < 1,750 m^3

From the calculation above, it can be seen that there is not enough storage capacity to store all the products that are ordered. So, it is necessary to determine the optimum ratio of the products that should be stored in the available storage capacity by using the Lagrange Multipliers Equation.

Lagrange Multipliers

The following describes how to find such values.

Firstly, find the lowest Total Stocking Cost (*TSC*) and so the function is given by

$$f(Q) = \sum_{i=1}^{n} C_{o_i} \frac{D_i}{Q_i} + C_h \frac{Q_i}{2} \qquad (1)$$

$$\text{Min } \sum_{i=1}^{n} C_{o_i} \frac{D_i}{Q_i} + C_h \frac{Q_i}{2}$$

Next the limited storage capacity must be a constant (*K*) 1,750 m^3

$$g(Q) = \sum_{i=1}^{n} S_i Q_i \qquad (2)$$

s.t. $\sum_{i=1}^{n} S_i Q_i = K$

where s_k = Product packaging size (m^3)

λ = Lagrange multiplier

S = Available storage capacity (m^3)

C_o = Ordering cost (baht per order)

D = Demand (units per unit time)

C_h = Holding cost (baht per unit per unit time)

Now applying Lagrange Multipliers.

Let the Lagrange Multiplier for this model be λ

$$L(Q,\lambda) = f(Q) + \lambda\left(g(Q) - K\right) \qquad (3)$$

Plugging equations (1) and (2) into equation (3)

$$L(Q,\lambda) = \sum_{i=1}^{n} C_{o_i}\frac{D_i}{Q_i} + C_h\frac{Q_i}{2} + \lambda\left[\sum_{i=1}^{n} S_i Q_i - K\right]$$

Look at First-Order Conditions:

$$\frac{\partial L}{\partial Q} = 0 \qquad \text{for } i = 1,2,\ldots,n$$

$$\frac{\partial L}{\partial Q} = -C_{o_i}\frac{D_i}{Q_i^2} + \frac{1}{2}C_h + \lambda S_i = 0$$

$$\frac{1}{2}C_h + \lambda S_i = C_{o_i}\frac{D_i}{Q_i^2}$$

$$Q_i^2 = \frac{C_{o_i} D_i}{\frac{1}{2}C_h + \lambda S_i}$$

$$Q_i = \sqrt{\frac{C_{o_i} D_i}{\frac{1}{2}C_h + \lambda S_i}}$$

$$Q_i = \sqrt{\frac{2C_{o_i}D_i}{2\left(\frac{1}{2}C_h + \lambda S_i\right)}}$$

$$\therefore \quad Q_i = \sqrt{\frac{2C_{o_i}D_i}{C_h + 2\lambda S_i}} \qquad (4)$$

Look at First-Order Equations:

$$\frac{\partial L}{\partial \lambda} = 0 \qquad \text{for } i = 1,2,\ldots,n$$

Now determine λ such that

$$\frac{\partial L}{\partial \lambda} = \sum_{i=1}^{n} S_i Q_i - K = O \qquad (5)$$

Plugging equation (4) into equation (5)

$$\sum_{i=1}^{n} S_i \sqrt{\frac{2C_{o_i}D_i}{C_h + 2\lambda S_i}} - K = O$$

This gives,

$$s_1\sqrt{\frac{2C_{o_1}D_1}{C_h + 2\lambda S_1}} + s_2\sqrt{\frac{2C_{o_2}D_2}{C_h + 2\lambda S_2}} + \ldots + s_{84}\sqrt{\frac{2C_{o_{84}}D_{84}}{C_h + 2\lambda S_{84}}} = S$$

where s_k = Product packaging size (m^3)

λ = Lagrange multiplier

S = Available storage capacity (m^3)

C_o = Ordering cost (baht per order)

D = Demand (units per unit time)

C_h = Holding cost (baht per unit per unit time)

Therefore, substituting the actual values obtained earlier, namely, s_k, S, C_o, D, and C_h to determine λ such that Q_i meets the original constraints, the result is:

$$(0.150)\sqrt{\frac{2(1{,}800)(117)}{25+2\lambda(0.150)}}+(0.140)\sqrt{\frac{2(1{,}800)(220)}{13+2\lambda(0.140)}}$$

$$+\ldots+(0.001)\sqrt{\frac{2(1{,}800)(260)}{32+2\lambda(0.001)}}=1{,}750m^2$$

Trial and Error is used to solve the above equation to obtaining λ value

$\therefore$ λ = 25.05

After obtaining the value of λ (25.05),

The values of all the variables (s_k, C_o, D, C_h ,and λ) are substituted to determine the adjusted Q value.

$$Q_k=\sqrt{\frac{2C_{ok}D_k}{C_h+(2)(25.05)s_k}}$$

Therefore $$Q_1=\sqrt{\frac{(2)(1{,}800)(117)}{25+(2)(25.05)(0.150)}}=113.82 \text{ units}$$

This procedure is then applied to the other 83 products.

The table below shows the quantities of the products after using the Lagrange Multipliers Equation

Table 4.9: Comparison of the Order Quantities and Stored Quantities in a Limited Storage Capacity

Item	Prpduct code	*EOQ*	After adjusted Lagrange	Item	Product code	*EOQ*	After adjusted Lagrange
1	A12462	360	113.82	43	K66786	552	162.53
2	A14114	696	198.93	44	L23150	168	59.54
3	A16486	1,212	341.92	45	L32978	650	151.52
4	A26546	828	248.90	46	M11102	1,224	393.22
5	A30570	200	59.92	47	M32186	150	52.94
6	A35578	312	111.42	48	M88438	480	74.40
7	A44258	228	77.75	49	N25402	760	247.21
8	A46282	230	80.50	50	N48306	228	75.01
9	A48678	276	95.44	51	N64774	252	76.68
10	A49318	264	94.50	52	P34266	1,300	203.80
11	A53366	684	227.66	53	P54378	636	169.09
12	A55906	200	59.93	54	Q52702	336	94.59
13	A56726	120	41.01	55	R74834	324	112.16
14	A58738	180	64.40	56	S26162	216	69.42
15	A71858	180	58.02	57	S32418	264	90.75
16	A73882	264	82.13	58	S32582	216	61.87
17	A76846	250	89.96	59	S42642	216	74.84
18	B10450	3,600	407.22	60	S54714	210	68.91
19	B17126	8,600	2,303.08	61	S67426	468	162.30
20	B18498	5,900	357.83	62	S98942	504	138.71
21	B22522	16,000	1,436.96	63	T82870	800	236.62
22	B31330	600	386.17	64	U42234	372	102.96
23	B32642	500	639.89	65	U46414	792	252.49
24	B35198	3,000	368.14	66	W46666	312	98.71
25	C71102	1,260	433.61	67	W51990	1,200	236.63
26	D14474	444	160.16	68	X72822	240	81.51
27	D20510	400	109.54	69	Y47294	240	82.28
28	D28558	1,152	249.10	70	Z36606	336	119.48
29	E20138	1,224	249.10	71	Z36890	312	80.72
30	F24534	696	194.13	72	Z38210	432	126.45
31	F29954	204	73.12	73	Z38618	240	85.08
32	F34594	210	75.26	74	Z41222	240	75.78
33	G33954	444	146.92	75	Z43246	516	147.96
34	H40630	200	70.94	76	Z45270	1,056	213.70
35	H51342	444	94.94	77	Z50330	300	93.10
36	H60750	228	71.70	78	Z50690	600	199.61
37	I55390	720	175.59	79	Z52354	192	66.12
38	J11986	192	68.58	80	Z62762	800	220.38
39	J24894	156	54.32	81	Z66918	372	110.25
40	K29174	216	66.65	82	Z68798	1,788	606.03
41	K44654	276	72.30	83	Z70810	2,244	629.04
42	K54966	588	194.30	84	Z87930	500	170.89

CHAPTER V
EVALUATION

5.1. Savings Evaluation

The main objectives of the study are to determine the savings that can be obtained by using the Total Annual Cost *(TAC)* and G^* values. In the case where the Fixed Order Quantity Model is used, the *TAC* will be used, but in the case where the Known Price Increase Model is used, the G* value is used instead.

5.1.1. For Unclassified 75 Product Items, Using the Fixed Order Quantity Model

The *TAC* that is used later is the value obtained from calculation, but the *TAC* used previously was made up of the actual costs that were collected unsystematically.

Total Annual Cost *(TAC)*

$$TAC = \text{ordering cost} + \text{holding cost} + \text{purchase cost}$$

$$TAC = C_o\left[\frac{D}{Q}\right] + C_h\left[\frac{Q}{2}\right] + pD$$

$$\Delta TAC = \left\{C_o\left[\frac{D}{Q}\right] + C_h\left[\frac{Q}{2}\right] + pD\right\}_{Actual} - \left\{C_o\left[\frac{D}{Q}\right] + C_h\left[\frac{Q}{2}\right] + pD\right\}_{New}$$

$$= \left\{C_o\left[\frac{D}{Q}\right] + C_h\left[\frac{Q}{2}\right]\right\}_{Actual} - \left\{C_o\left[\frac{D}{Q}\right] + C_h\left[\frac{Q}{2}\right]\right\}_{New}$$

Total Stocking Cost *(TSC)*

Total Stocking Cost is the sum of Holding Cost and Ordering Cost not including the Purchase Cost. The equation of *TSC* is:

$$TAC = C_o\left[\frac{D}{Q}\right] + C_h\left[\frac{Q}{2}\right]$$

Where C_o = ordering cost (baht/order)

C_h = holding cost (baht/10 months)

Q = order quantity (units)

D = forecast demand (months)

i = percentage of unit cost attributed to carrying inventory

p = purchase cost (baht/unit)

For example, the calculation of the *TAC* of A12462 is shown below

$$\Delta TAC = \left\{C_o\left[\frac{D}{Q}\right] + C_h\left[\frac{Q}{2}\right]\right\}_{Actual} - \left\{C_o\left[\frac{D}{Q}\right] + C_h\left[\frac{Q}{2}\right]\right\}_{New}$$

$$= \left\{1{,}180\left[\frac{1{,}170}{432}\right] + 20.83\left[\frac{432}{2}\right]\right\}_{Actual} - \left\{1{,}180\left[\frac{1{,}170}{360}\right] + 20.83\left[\frac{360}{2}\right]\right\}_{New}$$

$= 110.83$ baht

As shown in Table A.4 in Appendix A, the total savings from using the Fixed Order Quantity Model for all 75 domestic products is 44,594.93 baht, or equal to 7.89 per cent of the Total Stocking Cost *(TSC)*.

5.1.2. For 9 Product Items, Using the Known Price Increase Model

G^***:** The optimum difference between the *TAC* of not issuing exception orders and the *TAC* of issuing exception orders.

$$G^* = \frac{k}{d}\left(\frac{kr}{2p} + q_2^*(d+k) + C_3\right)$$

Where r = Demand (units/ time)

C_3 = Ordering Cost (baht/ order)

p = Annual Holding Cost Rate (per cent/ year)

d = Pre-Price Increase Purchase Cost (baht/ unit)

k = Price Increase (baht)

For 7 imported product items:

$$G^* = \frac{18}{225}\left(\frac{18x(1{,}175x12)}{2(20\%)} + 3{,}400(125+18) + 21{,}180\right)$$

= 118,550.40 baht

The adjusted q_2^* = 3,400 obtained from Chapter4 will be used for determining G^*. The value of 118,550.40 baht is the optimum difference between the *TAC* of not issuing exception orders and the *TAC* of issuing exception orders for B10450.

As shown below, the total savings from issuing exception orders for all 7 products is 533,945.66 baht

Table 5.1: Savings from Issuing Exception Orders: Imported Products

Item	Product code	G* (Baht)
1	B10450	118,550.40
2	B17126	50,895.36
3	B18498	70,728.00
4	B22522	54,400.70
5	B31330	77,078.40
6	B32642	75,494.40
7	B35198	86,798.40
Total		533,945.66

For 2 domestic product items:

$$G^* = \frac{19.80}{198}\left(\frac{19.8x(325x12)}{2(20\%)} + 460(198+19.8)+1{,}180\right)$$

= 29,441.80 baht

The adjusted q_2^* = 460 obtained from Chapter4 will be used for determining G^*. The value of 29,441.80 baht is the optimum difference between the *TAC* of not issuing exception orders and the *TAC* of issuing exception orders of M88438.

As shown below, the total savings from issuing exception orders for all 2 products is 60,566.60 Baht

Table 5.2: Savings from Issuing Exception Orders: Domestic Products

Item	Product code	G* (Baht)
1	M88438	29,441.80
2	Z68798	31,124.80
Total		60,566.60

G^* value from imported and domestic product items are the sum of 533,945.7 baht and 60,566.6 baht equal to 594,512.3 baht.

5.2. Inventory Management with Limited Storage Capacity

With regard to calculation of the ratio of the most important products in Table 4.9 of chapter 4, it is found that the quantity of each type of product for storage in warehouse A is greatly in reduced. This result is beneficial to the management of the case company because it is in line with their original objective of dividing the usage of the 2 warehouses, whereby warehouse A is used for storage of working stock whereas warehouse B is intended for storage of the bulk stocks and the slow-moving products in groups B and C. To maximize and optimize the benefits of the new inventory control system, it is recommended that the layouts and aisles of the storage shelves in warehouse A and warehouse B be redesigned.

5.3. Improved Policy

In the past inventory control was done virtually and based on the experience of the owner and the employees, and so inventory management costs were not optimum. From the results obtained from the recent study, the inventory management of group A products will be improved significantly. For group A products that will not have price increases, the Fixed Order Quantity Model will be used, but for group A products the price increases of which are known in advance the Known Price Increase Model will be used to determined whether there are actual savings or not. On top of that, the ratio of the products will be reduced in order to optimize savings. In the case of groups B and C products, they are not considered important to the company business and so a different model called the Fixed Time Period Model will be used.

5.4. Advantages and Disadvantages of Implementing the New Policy

- **Advantages:**

  The new policy will result in cost savings and a systematic inventory management practice. So the workers can work more efficiently and the same time, they cannot cheat or pilfer stocks. It becomes more difficult for them to engage in undesirable behavior.
- **Disadvantages:**

  At present the workers in AAA are not used to working in a highly efficient environment where there are strict control and strict management systems. The introduction of the new policy may result in some or all of the workers resisting change, and this may result to a drop in performance. To remedy this possible problem it may be necessary to increase wages or hire additional personnel and workers at a higher cost. If this happens, AAA's expenses may increase. Additional personnel and/ or workers will probably have to be employed to handle the tasks of managing the new systems, calculate *EOQ* and other significant values, keep track of stock levels, etc. These additional expenses may make the introduction of the new policy not financially viable.

CHAPTER VI
CONCLUSION AND FURTHER STUDY

6.1. Conclusion

This thesis looked at the inventory management practices of a relatively new company that has shown progress in its operations. The case company trades in hand tools, which it procures from overseas and locally. Relevant historical documents over the 10 months from May 2007 to February 2008 were analyzed. The company's products were then divided into 3 categories to facilitate analysis, and eventually to select only the most important category for detailed study.

It was found that the imported products with known price increases have the most value and are of the most importance to the company. The Known Price Increase Model proves to be a viable basis for considering the stocks that had to be ordered for storage in order to optimize return on investment. The conventional Fixed Order Quantity Model also contributed to the determination of the usefulness of the study in respect of the products the prices of which do not change frequently.

The next step – studying the ratio of the products for storage at the 2 warehouses to increase efficiency and better management control – proved to be the correct step to achieve the objective of the study.

The total savings from using the Fixed Order Quantity Model for all the unclassified products is 44,594.93 baht, or equal to 7.89 per cent of the Total Stocking Cost *(TSC)*. The savings from applying the Known Price Increase Model to imported products and domestic products with known price increases products is 594,512.30 baht.

When an attempt to determine the quantities of all the products under study that have to be ordered and stocked in the inventory was carried out, it was discovered that the company did not have sufficient storage capacity for all of them, namely, the storage capacity needed was 8,421.88 cubic meters but the storage capacity available in warehouse A is only 1,750 cubic meters. This shortfall is not unusual, especially since this company is quite new and could reasonably be expected to be cautious in its operations. The study yields the most suitable ratio for storage in terms of financial savings.

The conduct of this study has revealed the areas of improvements in AAA with regard to efficient and effective inventory management that can be beneficial to the company's operations. At the same time, a detailed review of the company's documentation flow can help to reduce bottlenecks. All these efforts will raise the levels of customer satisfactions if the findings are used positively.

6.2. Limitations

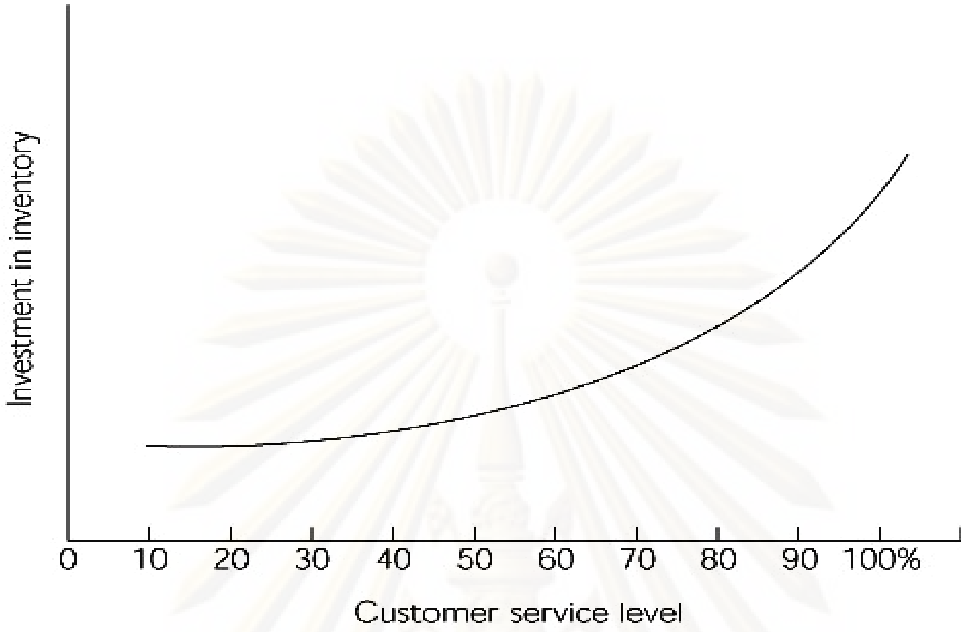
The data collected for this study are the data of a company that has not been in an operation very long. So the primary historical data collected may not be entirely reliable, especially since they have been changed the company's personnel and worker, which may cause errors to occur.

6.3. Recommendations for Further Study

- The personnel and workers may need training to familiarize themselves with the new systems, procedures and documentation. More computers may need to be purchased in order to support the new system. Additional studies and research into these areas will improve the overall efficiency and effectiveness or the models that are postulated above.

- It is recommended that a study be conducted into the desirability of improving the job descriptions of the various positions in the company to accommodate the introduction of the new policy.
- It may be necessary to find out whether the layouts of the storage areas inside the warehouses should be revised to increase efficiency.
- Conduct in-depth analysis of the existing workflow to determine ways of having more responsive order processing. This would of course involve a close examination of the existing documentation connected with the way orders are processed with a view to reduce response time and generate higher productivity.
- Look into the present logistics, covering warehousing, distribution, supply chain management, movement data, as these areas could yield additional savings.
- If sufficient time and financial resources are available, it might be beneficial to study the transportation component of the company's operations for the number of vehicles and transportation staff could very well be optimized.
- The present 2 warehouses are quite near to each other. It may be financially advantages to carry out a feasibility of study on whether savings and efficiencies could be achieved by relocating the warehouses (such as near customers, near the port or near suppliers), increasing the number of warehouses or storage places, or having a centralized storage facility, and so on.

Figure 6.1: Relationship between Inventory and Customer Service Level



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APPENDICES

APPENDIX A

Values Used for Calculating

Table A.1: Historical Sales Data

Item	Product	Unit cost	Sales	Sales (Units)									
	code	(Baht)	(Units)	May-07	Jun-07	Jul-07	Aug-07	Sep-07	Oct-07	Nov-07	Dec-07	Jan-08	Feb-08
1	A12462	125	117	120	110	115	125	110	135	100	122	122	109
2	A14114	65	220	225	230	210	210	210	236	210	216	235	220
3	A16486	50	520	535	520	525	508	515	525	500	530	535	510
4	A26546	53	260	250	260	279	265	270	265	260	250	255	247
5	A30570	200	40	35	47	30	41	48	39	34	40	45	40
6	A35578	180	125	135	135	110	140	130	120	125	119	125	110
7	A44258	155	55	50	49	55	60	65	58	45	55	50	60
8	A46282	120	45	40	45	50	39	48	55	45	35	40	50
9	A48678	155	80	75	85	89	70	80	89	82	80	71	80
10	A49318	130	65	60	59	65	59	75	62	60	78	64	70
11	A53366	55	180	175	185	171	170	180	189	182	180	189	180
12	A55906	225	45	50	39	45	40	55	48	35	45	50	40
13	A56726	225	25	25	30	30	25	35	20	25	15	20	20
14	A58738	130	32	25	30	32	25	34	45	40	32	29	30
15	A71858	155	34	27	30	34	29	36	47	42	34	31	32
16	A73882	120	55	50	65	55	60	48	58	45	60	50	55
17	A76846	97	45	50	40	39	45	55	45	48	50	35	40
18	C71102	40	450	455	441	450	459	451	448	445	446	455	449
19	D14474	140	200	205	210	190	215	190	216	190	196	190	200
20	D20510	180	125	135	135	110	140	130	120	125	119	125	110
21	D28558	36	340	335	347	330	341	348	339	334	340	345	340
22	E20138	36	340	330	341	334	345	347	335	349	349	338	329
23	F24534	65	220	225	230	210	235	210	236	210	216	210	220
24	F29954	150	45	40	45	50	39	48	55	45	35	40	50
25	F34594	150	50	55	41	50	59	51	48	45	46	55	49
26	G33954	140	200	205	210	190	215	190	200	190	196	190	216
27	H40630	140	40	35	47	30	41	48	39	34	40	45	40
28	H51342	65	89	95	80	88	80	84	89	98	85	95	94
29	H60750	160	60	65	51	60	69	61	58	55	56	65	59
30	I55390	40	120	125	130	110	135	110	136	110	116	110	120
31	J11986	210	55	60	80	50	40	55	65	50	45	50	55
32	J24894	140	25	35	35	10	30	32	20	25	19	25	20
33	K29174	150	50	55	41	50	59	51	48	45	46	55	49
34	K44654	97	50	48	55	41	49	59	46	55	45	50	55
35	K54966	55	134	124	130	134	129	136	147	142	134	131	132
36	K66786	55	120	125	130	110	135	110	136	110	116	110	120
37	L23150	200	40	35	47	30	41	48	39	34	40	45	40
38	L32978	55	166	156	171	161	163	168	170	163	168	175	168
39	M11102	40	420	419	435	415	420	428	420	419	422	400	420
40	M32186	198	35	45	20	45	40	42	30	35	29	35	30
41	M88438	198	84	90	75	83	75	79	84	93	80	90	89
42	N25402	40	166	156	171	161	175	168	170	163	168	163	168
43	N48306	225	86	92	80	85	77	85	86	95	82	82	91
44	N64774	150	67	72	58	67	76	68	55	62	70	72	65
45	P34266	50	520	535	508	525	520	535	525	500	530	520	505
46	P54378	55	155	150	125	148	165	160	158	155	167	151	168
47	Q52702	120	97	88	98	88	100	103	93	102	90	98	108
48	R74834	97	74	80	65	73	65	69	74	83	70	80	79
49	S26162	160	50	48	55	41	49	59	46	55	45	50	55
50	S32418	198	92	83	93	83	95	98	88	97	85	93	103
51	S32582	160	50	55	41	50	59	51	48	45	46	55	49
52	S42642	200	65	60	59	65	70	75	68	55	65	60	70
53	S54714	140	44	39	44	49	38	47	54	44	34	39	49
54	S67426	55	85	91	79	84	76	84	85	94	81	81	90
55	S98942	65	115	100	123	120	103	122	125	104	116	134	100
56	T82870	60	210	195	218	215	198	218	220	199	211	229	195
57	U42234	97	94	85	95	85	97	100	90	99	87	95	105
58	U46414	36	159	162	148	162	169	158	160	155	160	160	158
59	W46666	97	67	72	58	67	76	68	55	62	70	72	65
60	W51990	40	366	356	371	361	363	368	370	363	368	375	368
61	X72822	200	84	90	75	83	75	79	84	93	80	90	89
62	Y47294	140	56	51	50	56	61	66	59	46	56	51	61
63	Z36606	198	163	153	168	158	160	165	167	160	165	172	165
64	Z36890	180	125	130	122	120	125	133	131	118	130	120	125
65	Z38210	140	180	175	185	189	170	180	189	182	180	171	180
66	Z38618	225	94	85	95	85	97	100	90	99	87	95	105
67	Z41222	200	75	70	69	75	69	85	72	70	88	74	80
68	Z43246	97	185	190	182	195	185	179	187	179	189	180	181
69	Z45270	60	470	475	461	470	479	471	468	465	466	475	469
70	Z50330	160	106	110	97	105	111	100	106	95	120	110	105
71	Z50690	60	155	159	149	160	165	148	160	155	159	150	149
72	Z52354	300	75	69	70	85	75	69	88	74	70	72	75
73	Z62762	65	270	275	261	270	279	271	268	265	275	266	269
74	Z66918	130	125	135	130	110	140	120	125	120	119	129	125
75	Z68798	55	1250	1,300	1200	1300	1350	1200	1200	1300	1200	1200	1250
76	Z70810	40	1430	1,400	1500	1500	1400	1300	1400	1300	1500	1500	1500
77	Z87930	160	260	279	250	260	270	265	260	255	265	250	247
78	B10450	225	235	235	225	235	240	230	225	240	235	240	240
79	B17126	53	1550	1,500	1550	1650	1500	1500	1550	1600	1500	1550	1600
80	B18498	180	125	135	135	130	140	110	120	125	119	125	110
81	B22522	40	420	419	435	415	420	428	420	419	422	400	420
82	B31330	225	169	172	158	172	179	168	170	165	170	170	168
83	B32642	125	255	250	225	248	265	260	258	255	267	251	268
84	B35198	225	160	155	165	158	160	165	150	159	167	165	160

Table A.2: Model Used for Calculation

Item	Product code	Source of products	Model
1	A12462	Domestic	Fixed Order Quantity Model
2	A14114	Domestic	Fixed Order Quantity Model
3	A16486	Domestic	Fixed Order Quantity Model
4	A26546	Domestic	Fixed Order Quantity Model
5	A30570	Domestic	Fixed Order Quantity Model
6	A35578	Domestic	Fixed Order Quantity Model
7	A44258	Domestic	Fixed Order Quantity Model
8	A46282	Domestic	Fixed Order Quantity Model
9	A48678	Domestic	Fixed Order Quantity Model
10	A49318	Domestic	Fixed Order Quantity Model
11	A53366	Domestic	Fixed Order Quantity Model
12	A55906	Domestic	Fixed Order Quantity Model
13	A56726	Domestic	Fixed Order Quantity Model
14	A58738	Domestic	Fixed Order Quantity Model
15	A71858	Domestic	Fixed Order Quantity Model
16	A73882	Domestic	Fixed Order Quantity Model
17	A76846	Domestic	Fixed Order Quantity Model
18	B10450	Oversea	Known Price Increase Model
19	B17126	Oversea	Known Price Increase Model
20	B18498	Oversea	Known Price Increase Model
21	B22522	Oversea	Known Price Increase Model
22	B31330	Oversea	Known Price Increase Model
23	B32642	Oversea	Known Price Increase Model
24	B35198	Oversea	Known Price Increase Model
25	C71102	Domestic	Fixed Order Quantity Model
26	D14474	Domestic	Fixed Order Quantity Model
27	D20510	Domestic	Fixed Order Quantity Model
28	D28558	Domestic	Fixed Order Quantity Model
29	E20138	Domestic	Fixed Order Quantity Model
30	F24534	Domestic	Fixed Order Quantity Model
31	F29954	Domestic	Fixed Order Quantity Model
32	F34594	Domestic	Fixed Order Quantity Model
33	G33954	Domestic	Fixed Order Quantity Model
34	H40630	Domestic	Fixed Order Quantity Model
35	H51342	Domestic	Fixed Order Quantity Model
36	H60750	Domestic	Fixed Order Quantity Model
37	I55390	Domestic	Fixed Order Quantity Model
38	J11986	Domestic	Fixed Order Quantity Model
39	J24894	Domestic	Fixed Order Quantity Model
40	K29174	Domestic	Fixed Order Quantity Model
41	K44654	Domestic	Fixed Order Quantity Model
42	K54966	Domestic	Fixed Order Quantity Model
43	K66786	Domestic	Fixed Order Quantity Model
44	L23150	Domestic	Fixed Order Quantity Model
45	L32978	Domestic	Fixed Order Quantity Model
46	M11102	Domestic	Fixed Order Quantity Model
47	M32186	Domestic	Fixed Order Quantity Model
48	M88438	Domestic	Known Price Increase Model
49	N25402	Domestic	Fixed Order Quantity Model
50	N48306	Domestic	Fixed Order Quantity Model
51	N64774	Domestic	Fixed Order Quantity Model
52	P34266	Domestic	Fixed Order Quantity Model
53	P54378	Domestic	Fixed Order Quantity Model
54	Q52702	Domestic	Fixed Order Quantity Model
55	R74834	Domestic	Fixed Order Quantity Model
56	S26162	Domestic	Fixed Order Quantity Model
57	S32418	Domestic	Fixed Order Quantity Model
58	S32582	Domestic	Fixed Order Quantity Model
59	S42642	Domestic	Fixed Order Quantity Model
60	S54714	Domestic	Fixed Order Quantity Model
61	S67426	Domestic	Fixed Order Quantity Model
62	S98942	Domestic	Fixed Order Quantity Model
63	T82870	Domestic	Fixed Order Quantity Model
64	U42234	Domestic	Fixed Order Quantity Model
65	U46414	Domestic	Fixed Order Quantity Model
66	W46666	Domestic	Fixed Order Quantity Model
67	W51990	Domestic	Fixed Order Quantity Model
68	X72822	Domestic	Fixed Order Quantity Model
69	Y47294	Domestic	Fixed Order Quantity Model
70	Z36606	Domestic	Fixed Order Quantity Model
71	Z36890	Domestic	Fixed Order Quantity Model
72	Z38210	Domestic	Fixed Order Quantity Model
73	Z38618	Domestic	Fixed Order Quantity Model
74	Z41222	Domestic	Fixed Order Quantity Model
75	Z43246	Domestic	Fixed Order Quantity Model
76	Z45270	Domestic	Fixed Order Quantity Model
77	Z50330	Domestic	Fixed Order Quantity Model
78	Z50690	Domestic	Fixed Order Quantity Model
79	Z52354	Domestic	Fixed Order Quantity Model
80	Z62762	Domestic	Fixed Order Quantity Model
81	Z66918	Domestic	Fixed Order Quantity Model
82	Z68798	Domestic	Known Price Increase Model
83	Z70810	Domestic	Fixed Order Quantity Model
84	Z87930	Domestic	Fixed Order Quantity Model

Table A.3: Variables for Calculation 75 Product Items

Item	Product code	Demand/mo (Units)	Purchase cost (Baht/unit)	Quantity per case (Units)	Lead time (Days)
1	A12462	117	125	12	5
2	A14114	220	65	12	5
3	A16486	520	50	12	10
4	A26546	260	53	12	5
5	A30570	40	200	100	3
6	A35578	125	180	12	5
7	A44258	55	155	12	7
8	A46282	45	120	10	10
9	A48678	80	155	12	5
10	A49318	65	130	12	3
11	A53366	180	55	12	7
12	A55906	45	225	100	3
13	A56726	25	225	12	5
14	A58738	32	130	10	3
15	A71858	34	155	12	5
16	A73882	55	120	24	10
17	A76846	45	97	10	5
18	C71102	450	40	12	5
19	D14474	200	140	12	5
20	D20510	125	180	100	3
21	D28558	340	36	12	5
22	E20138	340	36	72	5
23	F24534	220	65	12	5
24	F29954	45	150	12	5
25	F34594	50	150	10	5
26	G33954	200	140	12	10
27	H40630	40	140	10	5
28	H51342	89	65	12	5
29	H60750	60	160	12	7
30	I55390	120	40	72	5
31	J11986	55	210	12	5
32	J24894	25	140	12	5
33	K29174	50	150	12	5
34	K44654	50	97	12	3
35	K54966	134	55	12	5
36	K66786	120	55	12	5
37	L23150	40	200	12	7
38	L32978	166	55	10	5
39	M11102	420	40	12	5
40	M32186	35	198	10	5
41	N25402	166	40	10	5
42	N48306	86	225	12	5
43	N64774	67	150	12	3
44	P34266	520	50	100	5
45	P54378	155	55	12	3
46	Q52702	97	120	12	5
47	R74834	74	97	12	5
48	S26162	50	160	12	7
49	S32418	92	198	24	5
50	S32582	50	160	12	5
51	S42642	65	200	12	5
52	S54714	44	140	10	10
53	S67426	85	55	12	3
54	S98942	115	65	12	5
55	T82870	210	60	100	5
56	U42234	94	97	12	3
57	U46414	159	36	12	5
58	W46666	67	97	12	7
59	W51990	366	40	100	5
60	X72822	84	200	12	5
61	Y47294	56	140	12	3
62	Z36606	163	198	12	10
63	Z36890	125	180	12	5
64	Z38210	180	140	12	3
65	Z38618	94	225	12	5
66	Z41222	75	200	24	7
67	Z43246	185	97	12	10
68	Z45270	470	60	12	5
69	Z50330	106	160	10	3
70	Z50690	155	60	12	5
71	Z52354	75	300	12	5
72	Z62762	270	65	100	5
73	Z66918	125	130	12	10
74	Z70810	1430	40	12	5
75	Z87930	260	160	100	4

Table A.4: Actual *TSC* and Improved *TSC* of 75 Product Items

Item	Product code	Demand/mo (Units)	Demand 10months	Purchase price (Baht/unit)	*Ch* (Baht)	*Q* (units)	Improved *TSC* (Baht)	Actual *Q* (Units)	Actual *TSC* (Baht)
1	A12462	117	1170	125	20.83	360	7,585.00	432.00	7,695.83
2	A14114	220	2200	65	10.83	696	7,499.89	1,044.00	8,141.59
3	A16486	520	5200	50	8.33	1212	10,112.71	1,584.00	10,473.74
4	A26546	260	2600	53	8.83	828	7,362.31	1,164.00	7,776.74
5	A30570	40	400	200	33.33	200	5,693.33	300.00	6,573.33
6	A35578	125	1250	180	30.00	312	9,407.56	408.00	9,735.20
7	A44258	55	550	155	25.83	228	5,791.49	300.00	6,038.33
8	A46282	45	450	120	20.00	230	4,608.70	280.00	4,696.43
9	A48678	80	800	155	25.83	276	6,985.29	360.00	7,272.22
10	A49318	65	650	130	21.67	264	5,765.30	348.00	5,974.02
11	A53366	180	1800	55	9.17	684	6,240.26	1,164.00	7,159.74
12	A55906	45	450	225	37.50	200	6,405.00	400.00	8,827.50
13	A56726	25	250	225	37.50	120	4,708.33	216.00	5,415.74
14	A58738	32	320	130	21.67	180	4,047.78	240.00	4,173.33
15	A71858	34	340	155	25.83	180	4,553.89	240.00	4,771.67
16	A73882	55	550	120	20.00	264	5,098.33	432.00	5,822.31
17	A76846	45	450	97	16.17	250	4,144.83	450.00	4,817.50
18	C71102	450	4500	40	6.67	1260	8,414.29	1,512.00	8,551.90
19	D14474	200	2000	140	23.33	444	10,495.32	492.00	10,536.75
20	D20510	125	1250	180	30.00	400	9,687.50	600.00	11,458.33
21	D28558	340	3400	36	6.00	1152	6,938.64	1,620.00	7,336.54
22	E20138	340	3400	36	6.00	1224	6,949.78	1,656.00	7,390.71
23	F24534	220	2200	65	10.83	696	7,499.89	840.00	7,640.48
24	F29954	45	450	150	25.00	204	5,152.94	312.00	5,601.92
25	F34594	50	500	150	25.00	210	5,434.52	360.00	6,138.89
26	G33954	200	2000	140	23.33	444	10,495.32	624.00	11,062.05
27	H40630	40	400	140	23.33	200	4,693.33	240.00	4,766.67
28	H51342	89	890	65	10.83	444	4,770.32	588.00	4,971.05
29	H60750	60	600	160	26.67	228	6,145.26	324.00	6,505.19
30	I55390	120	1200	40	6.67	720	4,366.67	1,296.00	5,412.59
31	J11986	55	550	210	35.00	192	6,740.21	252.00	6,985.40
32	J24894	25	250	140	23.33	156	3,711.03	252.00	4,110.63
33	K29174	50	500	150	25.00	216	5,431.48	372.00	6,236.02
34	K44654	50	500	97	16.17	276	4,368.68	480.00	5,109.17
35	K54966	134	1340	55	9.17	588	5,384.12	828.00	5,704.66
36	K66786	120	1200	55	9.17	552	5,095.22	672.00	5,187.14
37	L23150	40	400	200	33.33	168	5,609.52	252.00	6,073.02
38	L32978	166	1660	55	9.17	650	5,992.71	1,170.00	7,036.69
39	M11102	420	4200	40	6.67	1224	8,129.02	1,596.00	8,425.26
40	M32186	35	350	198	33.00	150	5,228.33	230.00	5,590.65
41	N25402	166	1660	40	6.67	760	5,110.70	1,140.00	5,518.25
42	N48306	86	860	225	37.50	228	8,725.88	300.00	9,007.67
43	N64774	67	670	150	25.00	252	6,287.30	312.00	6,433.97
44	P34266	520	5200	50	8.33	1300	10,136.67	2,000.00	11,401.33
45	P54378	155	1550	55	9.17	636	5,790.79	1,092.00	6,679.91
46	Q52702	97	970	120	20.00	336	6,766.55	480.00	7,184.58
47	R74834	74	740	97	16.17	324	5,314.06	396.00	5,406.05
48	S26162	50	500	160	26.67	216	5,611.48	288.00	5,888.61
49	S32418	92	920	198	33.00	264	8,468.12	408.00	9,392.78
50	S32582	50	500	160	26.67	216	5,611.48	348.00	6,335.40
51	S42642	65	650	200	33.33	216	7,150.93	288.00	7,463.19
52	S54714	44	440	140	23.33	210	4,922.38	260.00	5,030.26
53	S67426	85	850	55	9.17	468	4,288.16	612.00	4,443.89
54	S98942	115	1150	65	10.83	504	5,422.46	756.00	5,889.97
55	T82870	210	2100	60	10.00	800	7,097.50	1,400.00	8,770.00
56	U42234	94	940	97	16.17	372	5,988.72	528.00	6,368.76
57	U46414	159	1590	36	6.00	792	4,744.94	1,272.00	5,291.00
58	W46666	67	670	97	16.17	312	5,055.97	408.00	5,235.75
59	W51990	366	3660	40	6.67	1200	7,599.00	2,100.00	9,056.57
60	X72822	84	840	200	33.33	240	8,130.00	432.00	9,494.44
61	Y47294	56	560	140	23.33	240	5,553.33	312.00	5,757.95
62	Z36606	163	1630	198	33.00	336	11,268.40	540.00	12,471.85
63	Z36890	125	1250	180	30.00	312	9,407.56	540.00	10,831.48
64	Z38210	180	1800	140	23.33	432	9,956.67	744.00	11,534.84
65	Z38618	94	940	225	37.50	240	9,121.67	288.00	9,251.39
66	Z41222	75	750	200	33.33	240	7,687.50	360.00	8,458.33
67	Z43246	185	1850	97	16.17	516	8,401.62	732.00	8,899.24
68	Z45270	470	4700	60	10.00	1056	10,531.89	1,488.00	11,167.15
69	Z50330	106	1060	160	26.67	300	8,169.33	360.00	8,274.44
70	Z50690	155	1550	60	10.00	600	6,048.33	780.00	6,244.87
71	Z52354	75	750	300	50.00	192	9,409.38	336.00	11,033.93
72	Z62762	270	2700	65	10.83	800	8,315.83	1,500.00	10,249.00
73	Z66918	125	1250	130	21.67	372	7,995.05	492.00	8,327.97
74	Z70810	1430	14300	40	6.67	2244	14,999.61	2,928.00	15,522.98
75	Z87930	260	2600	160	26.67	500	12,802.67	700.00	13,716.19

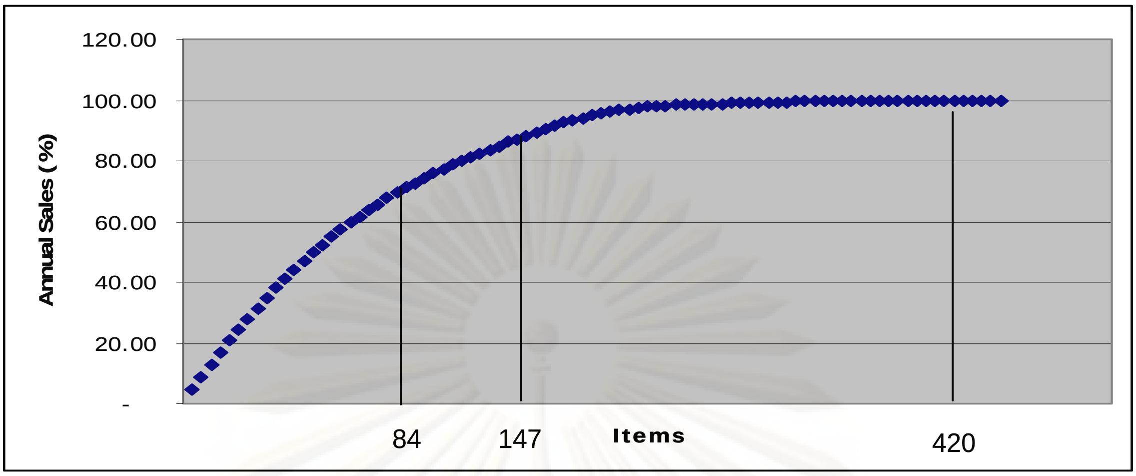
Table A.5: Standard Normal Table (Z-Table)

z	0	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0	0.5000	0.5040	0.5080	0.5120	0.5160	0.5199	0.5239	0.5279	0.5319	0.5359
0.1	0.5398	0.5438	0.5478	0.5517	0.5557	0.5596	0.5636	0.5675	0.5714	0.5753
0.2	0.5793	0.5832	0.5871	0.5910	0.5948	0.5987	0.6026	0.6064	0.6103	0.6141
0.3	0.6179	0.6217	0.6255	0.6293	0.6331	0.6368	0.6406	0.6443	0.6480	0.6517
0.4	0.6554	0.6591	0.6628	0.6664	0.6700	0.6736	0.6772	0.6808	0.6844	0.6879
0.5	0.6915	0.6950	0.6985	0.7019	0.7054	0.7088	0.7123	0.7157	0.7190	0.7224
0.6	0.7257	0.7291	0.7324	0.7357	0.7389	0.7422	0.7454	0.7486	0.7517	0.7549
0.7	0.7580	0.7611	0.7642	0.7673	0.7704	0.7734	0.7764	0.7794	0.7823	0.7852
0.8	0.7881	0.7910	0.7939	0.7967	0.7995	0.8023	0.8051	0.8078	0.8106	0.8133
0.9	0.8159	0.8186	0.8212	0.8238	0.8264	0.8289	0.8315	0.8340	0.8365	0.8389
1	0.8413	0.8438	0.8461	0.8485	0.8508	0.8531	0.8554	0.8577	0.8599	0.8621
1.1	0.8643	0.8665	0.8686	0.8708	0.8729	0.8749	0.8770	0.8790	0.8810	0.8830
1.2	0.8849	0.8869	0.8888	0.8907	0.8925	0.8944	0.8962	0.8980	0.8997	0.9015
1.3	0.9032	0.9049	0.9066	0.9082	0.9099	0.9115	0.9131	0.9147	0.9162	0.9177
1.4	0.9192	0.9207	0.9222	0.9236	0.9251	0.9265	0.9279	0.9292	0.9306	0.9319
1.5	0.9332	0.9345	0.9357	0.9370	0.9382	0.9394	0.9406	0.9418	0.9429	0.9441
1.6	0.9452	0.9463	0.9474	0.9484	0.9495	0.9505	0.9515	0.9525	0.9535	0.9545
1.7	0.9554	0.9564	0.9573	0.9582	0.9591	0.9599	0.9608	0.9616	0.9625	0.9633
1.8	0.9641	0.9649	0.9656	0.9664	0.9671	0.9678	0.9686	0.9693	0.9699	0.9706
1.9	0.9713	0.9719	0.9726	0.9732	0.9738	0.9744	0.9750	0.9756	0.9761	0.9767
2	0.9772	0.9778	0.9783	0.9788	0.9793	0.9798	0.9803	0.9808	0.9812	0.9817
2.1	0.9821	0.9826	0.9830	0.9834	0.9838	0.9842	0.9846	0.9850	0.9854	0.9857
2.2	0.9861	0.9864	0.9868	0.9871	0.9875	0.9878	0.9881	0.9884	0.9887	0.9890
2.3	0.9893	0.9896	0.9898	0.9901	0.9904	0.9906	0.9909	0.9911	0.9913	0.9916
2.4	0.9918	0.9920	0.9922	0.9925	0.9927	0.9929	0.9931	0.9932	0.9934	0.9936
2.5	0.9938	0.9940	0.9941	0.9943	0.9945	0.9946	0.9948	0.9949	0.9951	0.9952
2.6	0.9953	0.9955	0.9956	0.9957	0.9959	0.9960	0.9961	0.9962	0.9963	0.9964
2.7	0.9965	0.9966	0.9967	0.9968	0.9969	0.9970	0.9971	0.9972	0.9973	0.9974
2.8	0.9974	0.9975	0.9976	0.9977	0.9977	0.9978	0.9979	0.9979	0.9980	0.9981
2.9	0.9981	0.9982	0.9982	0.9983	0.9984	0.9984	0.9985	0.9985	0.9986	0.9986
3	0.9987	0.9987	0.9987	0.9988	0.9988	0.9989	0.9989	0.9989	0.9990	0.9990

APPENDIX B

Cumulative Sales for Considering Criticality Assessment Matrix

Figure B.1: Cumulative Sales for Considering Criticality Matrix



BIOGRAPHY

Mrs. Chanpen Mitrabhakdi was born in 1975. She graduated in Industrial Engineering from Kasetsart University. Several years later, in 2004, she graduated in General Management from Mahidol University's College of Management. That same year, she enrolled for a master's degree in Engineering Management at the Faculty of Engineering of Chulalongkorn University and a master's degree in Engineering Business Management from University of Warwick at The Regional Centre for Manufacturing Systems Engineering.