# DESIGNING ORDER POLICY AND MANAGING INVENTORY LEVEL AND RELEVANT PARAMETERS IN PAPER BUSINESS

By
KANYARAT TANARATNACHAI

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

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

ABAC School of Management
Assumption University
Bangkok, Thailand

January 2009

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|---|---|
| Project Title | Designing Order Policy and Managing Inventory Level And Relevant Parameters in Paper Business |
| Name | Ms. Kanyarat Tanaratanachai |
| Project Advisor | Dr. Peeratarat Ittarattanachoke |
| Academic Year | January 2009 |

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ABAC School of Management, Assumption University has approved this final report of the six-credit course, SCM 2202 Graduate Project, submitted in partial fulfillment of the requirements for the degree of Master of Science in Supply Chain Management.

Approval Committee:

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January 2009

**Assumption University**

**Martin de Tours School of Management**

**Master of Science in Supply Chain Management**

**Form signed by Proofreader of the Graduate Project**

Asst. Prof. Brian Lawrence, have proofread this Graduate Project entitled Designing Order Policy and Managing Inventory Level and Relevant Parameters in Paper Business

Ms. Kanyarat Tanaratnachai

and hereby certify that the verbiage, spelling and format is commensurate with the quality of internationally acceptable writing standards for a master degree in supply chain management.

Signed _____

( Asst. Prof. Brian Lawrence )

Contact Number / Email address blawrence@au.edu

Date: 1 ม.ค. 59

**Assumption University**
**Martin de Tours School of Management**
**Master of Science in Supply Chain Management**

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I, _Ms. Kanyarat Tanaratanachai [please print name]

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21/1/09

# ABSTRACT

In the business environment with high competition, every company tries to give good service to customers. The availability of products, in both the breadth of range of items and depth of stock in each item, is important. In addition, to increase customer service levels will enhance the company image and leadership. Shortage or stock- out have more effect than just lost sales. An accurate forecast method would be the important tool that helps a company to provide the right inventory level. However, if demand is uncertain or become more variable, the forecasting tools may not perfectly solve the problems. An unsuitable forecast method may result in initial over-buying. To provide high customer service level, the company has to make a trade-off between inventory cost and the need for profitability of the company.

Supply chain management provides the potential for organizations to reduce costs and improve customer service performance. The economic order quantity (EOQ) model is a classic independent demand inventory system that provides many useful ordering decisions with the purpose of finding the order quantity of an item which minimizes total inventory costs. However, the EOQ model still does not provide the best solution to every situation. Applying additional parameters would help to complete the EOQ model and optimize the solution.

This project will study the situation of a leading specialty paper company in Thailand, all of whose products are imported from worldwide mills. The company uses last year sales data to forecast demand and order quantity for all 200 SKUs. Over-buying and stock-out are usually found in many SKUs. Holding such high inventory, the company still faces shortage and lost sales. This project will study the decision making tool between a Continuous Review System and a Periodic Review System. In addition, this project will apply the EOQ model with opportunity cost as the additional parameter to find the right order quantity and inventory level that could maximize profit to the company.

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# CHAPTER 1: INTRODUCTION

This chapter provides the business overview of a paper merchant located in Bangkok. It includes the product, target market, as well as problem analysis, and scope and objective of this project.

## 1. Company Background

The paper company started the business as a merchant of specialty paper 20 years ago. The company is operating through modern management and advance computer systems linked together between a large automatic warehouse and sales office bases to ensure finest quality of products and services for customers.

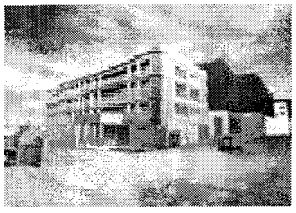
The company is one of the leading specialty paper merchants in Thailand, all of whose products are imported from worldwide mills. The company importa in containers from each supplier, and resells in retail and wholesales to the customers in Bangkok and nearby provinces. The company uses last year's sales data to forecast demand and order quantity for all 200 SKUs. Over-buying and stock-out are usually found in many SKUs. Holding such high inventory, it still faces shortage and lost sales. This project will develop a decision making tool that helps the company to place the proper order quantity and inventory level by balancing the related cost and profitability.

### 1.1 Location

Head Office (Sales office)

Location: Center of Bangkok

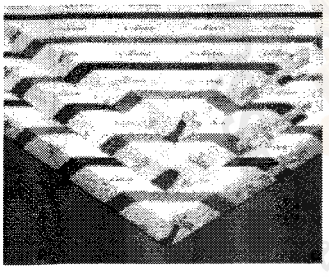
Warehouse

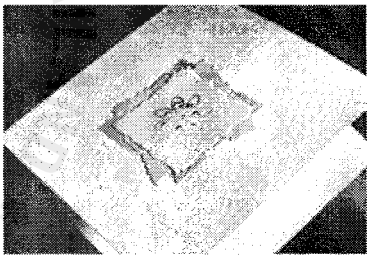


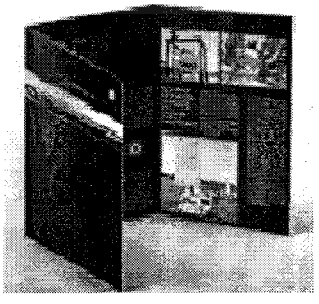
Location: Suburb area

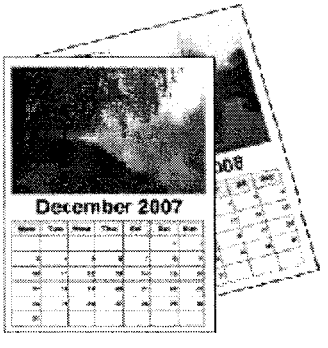
**1.2 Products**

Specialty Paper can be divided into 6 categories with a total of 200 SKUs. The papers are bought in big sheets which are ready packaged for reselling, the normal sizes being 70cm x 100cm, and 78cm x 109cm. The main purpose is for offset printing and any special printing techniques. Customers buy our specialty paper to convert into finished goods such as letterheads, name card, brochures, leaflets, magazines, calendars, cards and envelopes, annual reports, and packaging, etc.

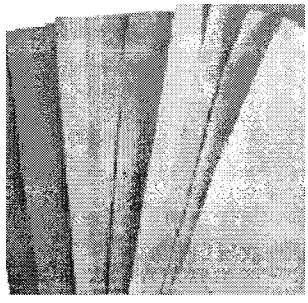




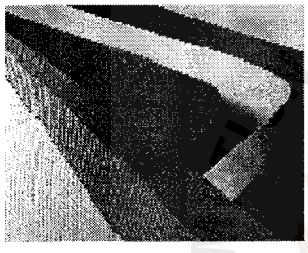


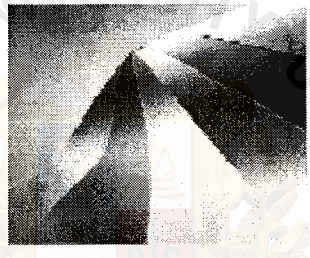
1. Carbonless paper (NCR)

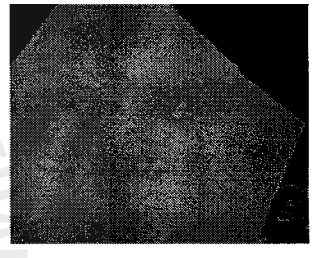


NCR. stands for No Carbon Required: it, is an alternative to "carbon paper" used to make a copy of an original, handwritten document without the use of any electronics. The paper is coated with tiny capsules that will break when they are pressed.

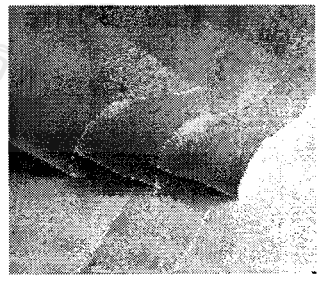
2. Specialty paper – (fast moving items) ACQ, TRT, Ambassador



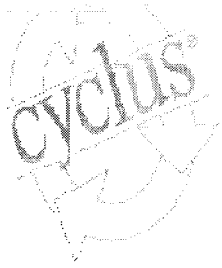


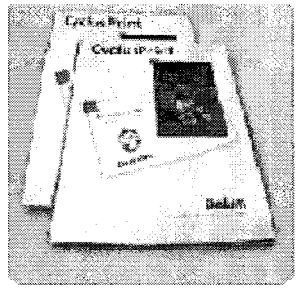


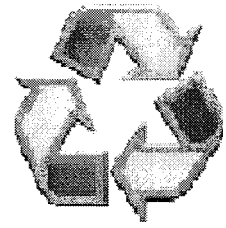
3. Specialty paper – (slow moving items, lumpy demand) CTAS, Cottage, Kilim, Linovac, C.Damasco, Prisma, D.Pinweave, D.Linen



4. Specialty paper – (recycled paper, lumpy demand) DCO, DCP, CCF, EX, Retreeve

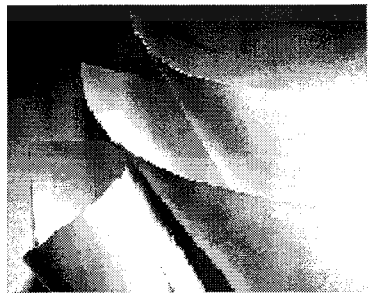




5. Specialty paper – (metallic paper, lumpy demand) Majestic, M.Chameleon, Comet, Stucco, S.Merida

6. Specialty paper – (smooth surface paper, lumpy demand) SPG, Dutch IB, Tatami, PGM



**1.3 Target Market**

Customers can buy paper in both retail and wholesale. The company offers a delivery service by using 3PL services from warehouse to customer's place. The retail buyer can also buy at the showroom at the sales office. The company divides customers into two segments. Two sales team are also divided according to customer segmentation: 1. Sales team for printing house 2. Sales team for end users.

Printing House

The company has 200 printing house customers in Bangkok. The Printing house will order the paper in big sheets and print as per the specification of customers. The demand and buying habit of the printing house can be divided into 2 types.

1. Constant demand: the product such as NCR, ACQ, TRT will have constant demand and the printing house will buy on a monthly basis.
2. Lumpy demand: demand for most paper can only be predicted roughly as customers do not use it on a regular basis. So the printing house will buy only when it get the order from customers.

Examples of Customers in the printing house category are

- Amarin Printing and Publishing PCL.
- Siriwatana Interprint PCL.
- TKS Siampress Management Co.,Ltd.
- Pimthong Printing and Packing Co.,Ltd.

End users

End users include the companies that buy paper for their own use which usually buy in small quantity. Advertising agencies and graphic houses are also in this group of customers: they are usually the people who design which paper to use in their projects, then they may buy by themselves or let a printing house buy and press to the finished product.

Examples of Customers in the end-user category are

- Dusit Hotel and Resort

- Starbucks Coffee
- Property Perfect
- SC MatchBox
- Green Peace

**1.4 Supply Chain Network**

The company has operated since 1988 in Bangkok. The office which includes sales & marketing department and all support departments is located in center of Bangkok. The warehouse is located in a suburb. The supply chain network is shown in Figure 1.

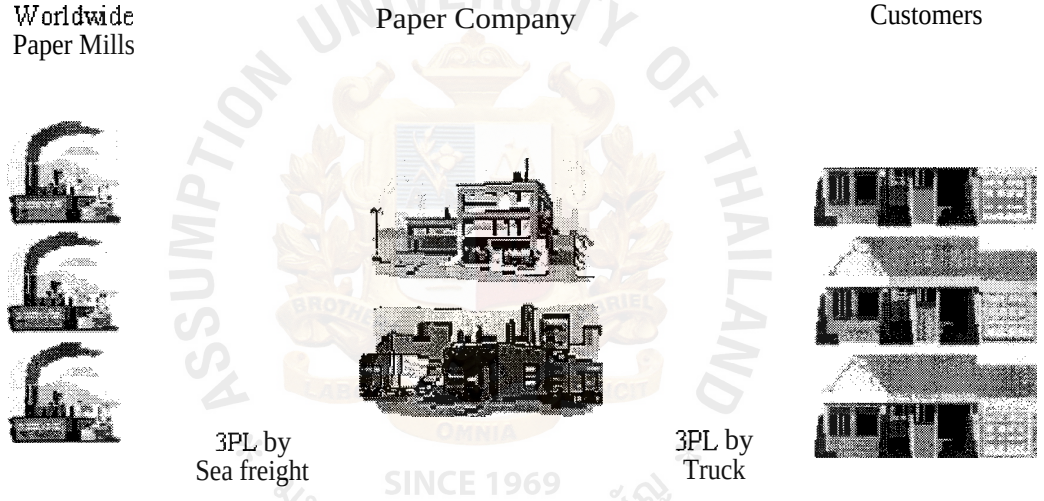



Figure 1.1: Supply Chain network of the Paper Company

**1.5 Suppliers:**

The company has more than 10 suppliers from worldwide mills. The major suppliers include Fedrigoni and Favini from Italy, James Cropper and Curtis from United Kingdom, M-Real from Germany, Dalum from Denmark, M&R from United State, and PT. Pindo from Indonesia. The company buys papers from those suppliers in C&F, CIF contracts by using sea transportation, and uses Third Party Logistics to deliver goods to the warehouse in the suburb.

1.6 Warehouse:

At the warehouse, all the products are stored in HighBay (ASRS), hi-tech conveyor machine for stock management. When Salespeople get the order from customers, they will key the order in SFA (Sale Force Automation) and this information will transfer to "BPCS" and be sent to the warehouse to pick up the goods for each order. The company uses a 3PL service to deliver papers to customers and this company only does logistic management such as pick up time, scheduling and routes, in order to take advantage of delivery performance and avoid high investment and labor management.

In the business environment with high competition, every company tries to give good service to customers. The availability of products in both the breadth of range of items and depth of stock in each item, is important, and can enhance the company image and leadership. Shortage or stock-out have more effect than just lost sales. To provide high product availability, the company has to balance between high inventory cost and the need for company profitability.

2. Problem Analysis

Sales Record by category

Table 1.1: Year 2005 and 2006 Sales Amount, Sales Quantity, Profit Margin and Stock value of paper in 6 categories.

| | 2005 Sale Amount | 2005 QTY | 2005 Margin Profit% | 2006 Sale Amount | 2006 QTY | 2006 Margin Profit% | Stock Value as of 31/12/06 |
|---|---|---|---|---|---|---|---|
| Total | 99,722,055 | 22,906,378 | 31.97% | 104,472,755 | 21,905,042 | 35.30% | 24,112,983 |
| 1. Carbonless Paper | 43,761,667 | 19,461,961 | 22.06% | 40,773,558 | 18,051,888 | 26.10% | 2,292,867 |
| 2. Specialty | | | 39.84% | | | 41.66% | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| paper – (fast moving items) | 22,957,114 | 1,308,551 | | 22,383,103 | 1,305,584 | | 5,235,646 |
| 3. Specialty paper – (slow moving items, lumpy demand) | 9,247,051 | 425,828 | 38.92% | 8,607,841 | 408,703 | 41.47% | 2,629,360 |
| 4. Specialty paper – (recycled paper, lumpy demand) | 7,548,596 | 533,674 | 49.43% | 9,385,688 | 715,926 | 43.38% | 3,216,741 |
| 5. Specialty paper – (metallic paper, lumpy demand) | 6,625,464 | 231,123 | 40.92% | 12,132,338 | 349,337 | 41.71% | 6,533,156 |
| 6. Specialty paper – (smooth surface paper, lumpy demand) | 9,582,162 | 945,241 | 35.68% | 11,190,227 | 1,073,604 | 36.91% | 4,205,213 |

The company had sales of 99.7 Million baht in 2005 and 104.4 Million baht in 2006. The stock value as of 31/12/2006 was 24.1 Million baht. The company had a profit margin of 31.97% in 2005 and 35.30% in 2006. Different product categories have different strategies, bargaining power with supplier, market opportunity, and market growth, so the profit margin in each category is different.

List of 10 items of paper selected by ABC analysis

Table 1.2: Year 2005 and 2006 Sales Amount, Sales Quantity, Profit Margin and Stock value of 10 items selected from ABC analysis.

| Item | Product Name | 2005 Sale Amount | 2005 QTY | 2005 Profit Margin % | 2006 Sale Amount | 2006 QTY | 2006 Profit Margin % | Stock Value as of 31/12/06 |
|---|---|---|---|---|---|---|---|---|
| A | IMPRESSION2000 CB WHITE 55G.24x36" | 14,732,882 | 6,805,267 | 21.04% | 13,014,330 | 6,028,803 | 24.30% | 755,333 |
| B | COMET 250g. 72x102cm. White | 1,272,813 | 29,255 | 46.35% | 2,644,507 | 62,479 | 47.39% | 734,561 |
| C | ACQ STUCCO 72x101cm. | 1,254,729 | 47,237 | 36.21% | 2,423,695 | 94,674 | 37.73% | 554,889 |
| D | AMB.LAID 220G 70x100cm.B/W | 1,991,523 | 71,174 | 53.19% | 2,116,313 | 75,230 | 53.95% | 161,913 |
| E | ACQ 200G 72x101cm. White | 1,537,365 | 83,249 | 34.30% | 1,263,095 | 67,736 | 34.94% | 551,609 |
| F | DUTCH B/W 300g 70x100cm | 452,366 | 17,731 | 41.36% | 1,142,290 | 46,339 | 44.97% | 207,371 |
| G | DCO 115g. 64x90cm. | 773,608 | 150,028 | 51.90% | 1,121,706 | 215,017 | 49.93% | 149 |
| H | MAJESTIC 290g 72x102cm. Anthracite | 135,296 | 1,655 | 50.56% | 131,583 | 1,936 | 44.01% | 111,758 |
| I | SYMBOL PEARL 170g.70x100cm. White | 611,558 | 27,485 | 30.83% | 96,058 | 3,378 | 41.50% | 83,926 |
| J | LINOVAC 175g. 78.7x109.2cm. Pink | 121,816 | 4,050 | 43.41% | 79,508 | 2,578 | 44.81% | 13,653 |

The above 10 items were selected from class A, B and C product by ABC analysis, and have characteristics of high sale items, high growth items, lumpy demand items and low growth items. These items will be used to study ordering policy, order quantity and level of inventory by Continuous review system (Q* by EOQ model in different scenarios) and Periodic review system.

### 2.1 Current Practice

The company forecast the demand and place orders to suppliers based on:

- Forecast: using last year's data as reference, and corporate required growth rate. Top Management will set the required growth rate of each year which turns into target sales volume. Then Marketing Department will allocate this budget into each category and each SKU based on the historical sales record. Each category will have a different growth rate depending on market situation and market trend. **All** items will be treating according to the same forecasting and replenishment rules.
- Minimum order: Each item has the minimum requirement of 1 ton. Suppliers usually require to place and dispatch the order in FCL (11 tons – 13 tons)

- Lead time: Paper is transported by sea freight and usually has a lead time of 3-4 months.
- Safety stock: no safety stock policy
- Demand Pattern: Customers may place the order from 1 sheet to 100,000 sheets per order in any item, as it depends on end user demand. If an item is not available, the customer will switch to other substitute products or to competitors as they cannot wait until the item arrives which usually takes 3-4 months.
- Obsolescence and Write-off: The items stocked in the inventory without any turnover or little turnover ratio will be sold at a discount rate or written off. The company will write off the obsolete items every year.

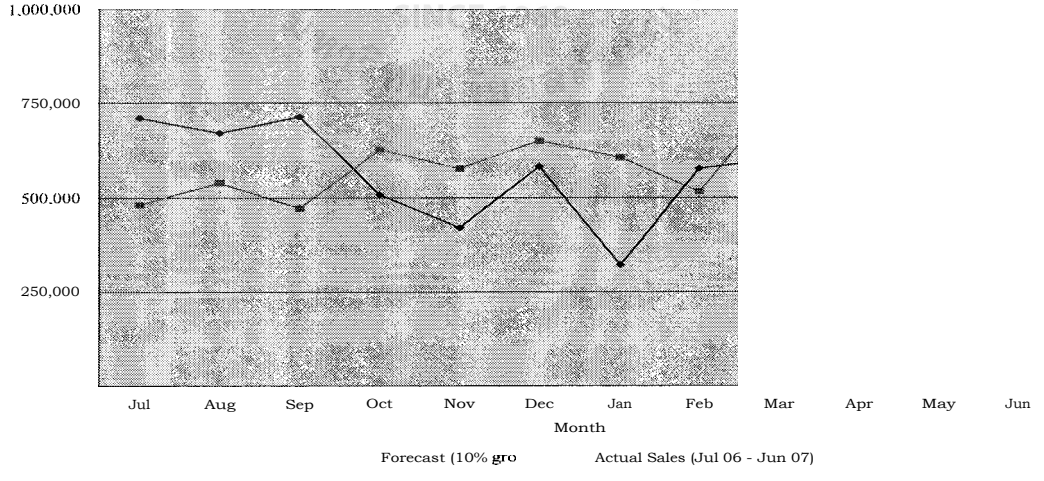
## 2.2 Problem Statement

The company places the order according to the forecast, but the company still faces:

- Order quantity and demand mismatch: order quantity obtained from forecast by using last year's data, and the actual demand in each period for many items are mismatches.

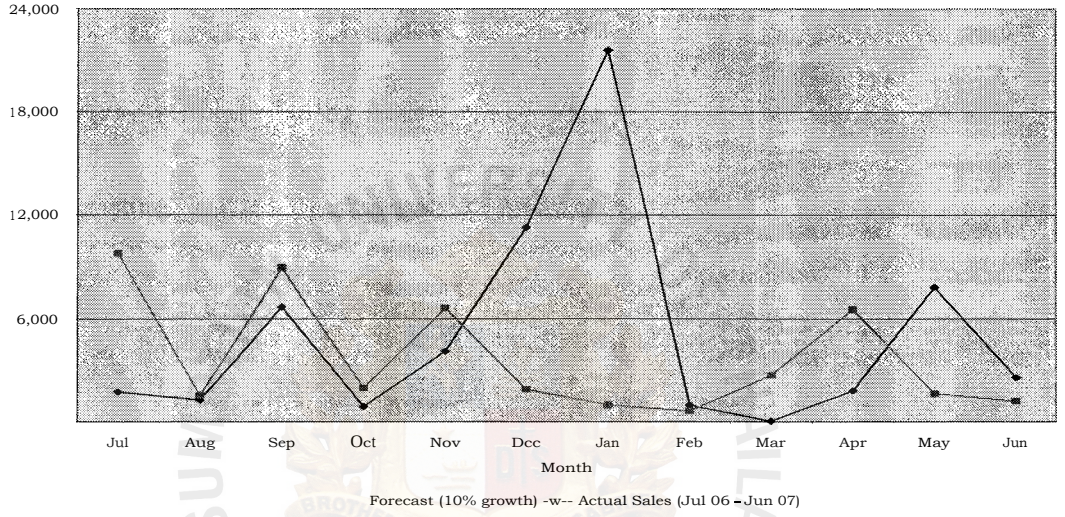
Table 1.3: Sales forecast and actual sales of selected 10 items from July 2006 – June 2007

Item A: IMPRESSION2000 CB WHITE 55G.24x36"



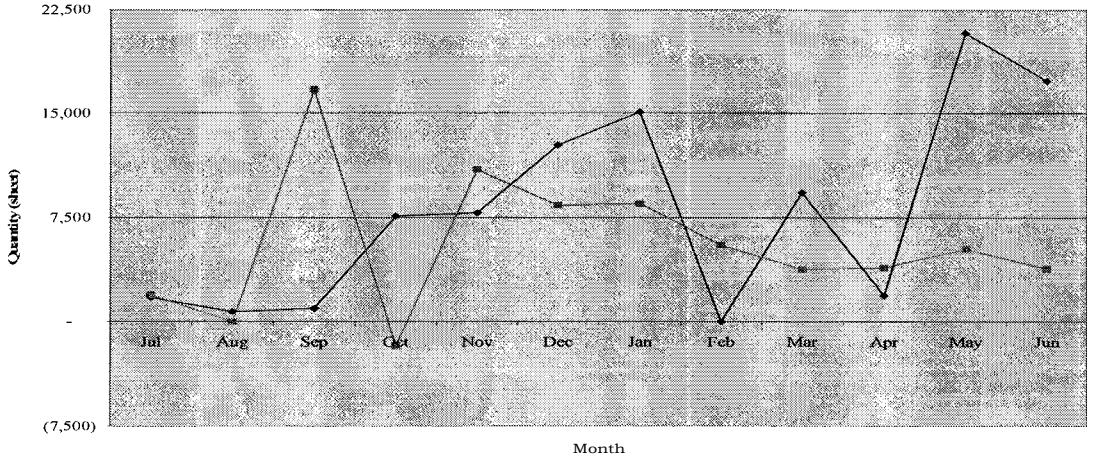
| IMPRESSION2000 CB WHITE 550.24x36" | Jul | Aug | Sep | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| History Sales (Jul 05 - Jun 06) | 645,801 | 609,383 | 649,026 | 462,364 | 383,210 | 529,461 | 293,810 | 524,670 | 547,363 | 371,324 | 370,983 | 570,981 |
| Forecast (10% growth) | 710,381 | 670,321 | 713,929 | 508,600 | 421,531 | 582,407 | 323,191 | 577,137 | 602,099 | 408,456 | 408,081 | 628,079 |
| Actual Sales (Jul 06 - Jun 07) | 482,505 | 539,387 | 473,409 | 626,951 | 577,387 | 650,033 | 606,200 | 516,110 | 765,676 | 706,239 | 970,840 | 890,545 |
| Diff (Absolute) | 227,876 | 130,934 | 240,520 | 118,351 | 155,856 | 67,626 | 283,009 | 61,027 | 163,577 | 297,783 | 562,759 | 262,466 |

## Item B: COMET 250g. 72x102cm. White



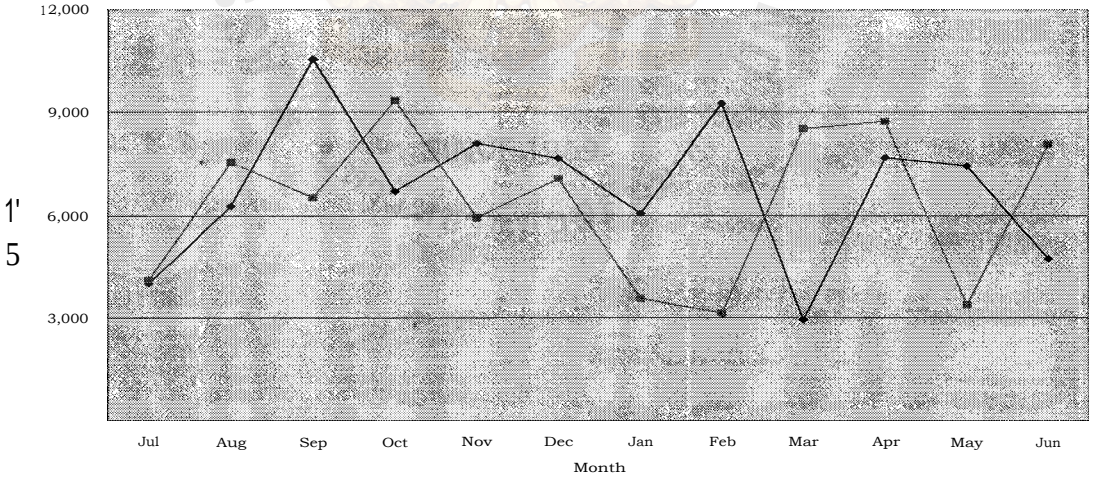

| COMET 250g. 72x102cm. White | Jul | Aug | Sep | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| History Sales (Jul 05 - Jun 06) | 1,580 | 1,146 | 6,111 | 794 | 3,750 | 10,268 | 19,643 | 862 | 24 | 1,642 | 7,145 | 2,341 |
| Forecast (10% growth) | 1,738 | 1,261 | 6,722 | 873 | 4,125 | 11,295 | 21,607 | 948 | 26 | 1,806 | 7,860 | 2,575 |
| Actual Sales (Jul 06 - Jun 07) | 9,798 | 1,542 | 8,976 | 1,975 | 6,645 | 1,886 | 966 | 608 | 2,711 | 6,566 | 1,638 | 1,195 |
| Diff (Absolute) | 8,060 | 281 | 2,254 | 1,102 | 2,520 | 9,409 | 20,641 | 340 | 2,685 | 4,760 | 6,222 | 1,380 |

## Item C: ACQ STUCCO 72x101cm.



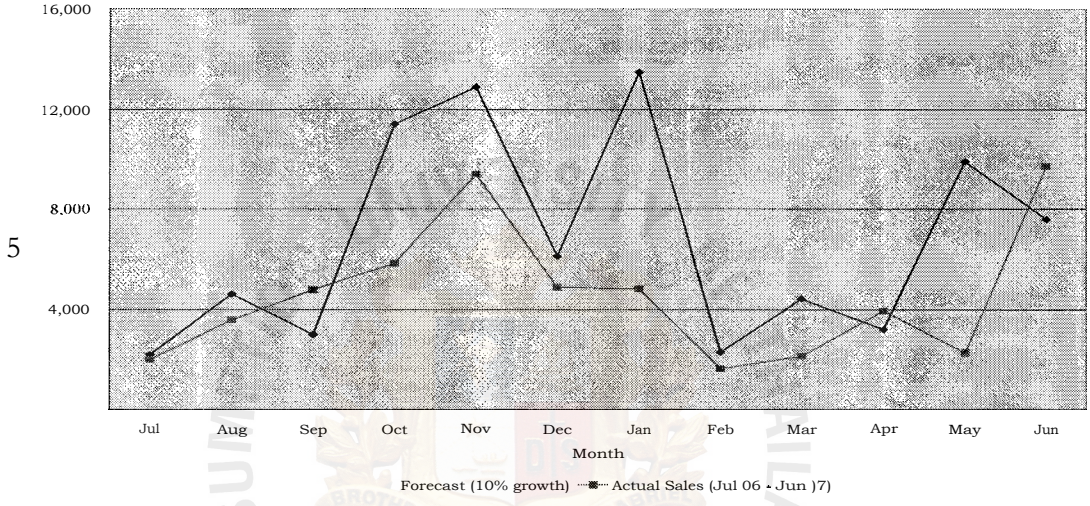

| ACQ STUCCO 72x101cm. | Jul | Aug | Sep | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| History Sales (Jul 05 - Jun 06) | 1,560 | 632 | 853 | 6,917 | 7,125 | 11,545 | 13,707 | (10) | 8,457 | 1,695 | 18,922 | 15,752 |
| Forecast (10% growth) | 1,716 | 695 | 938 | 7,609 | 7,838 | 12,700 | 15,078 | (11) | 9,303 | 1,865 | 20,814 | 17,327 |
| Actual Sales (Jul 06 - Jun 07) | 1,903 | (20) | 16,665 | (1,737) | 10,954 | 8,386 | 8,525 | 5,496 | 3,760 | 3,892 | 5,215 | 3,820 |
| Diff (Absolute) | 187 | 715 | 15,727 | 9,346 | 3,117 | 4,314 | 6,553 | 5,507 | 5,543 | 2,028 | 15,599 | 13,507 |

## Item D: AMB.LAID 220G 70x100cm.B/W



| AMB.LAID 220G 70x100cm.B/W | Jul | Aug | Sep | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| History Sales (Jul 05 - Jun 06) | 3,656 | 5,706 | 9,588 | 6,098 | 7,359 | 6,961 | 5,519 | 8,409 | 2,681 | 6,985 | 6,770 | 4,310 |
| Forecast (10% growth) | 4,022 | 6,277 | 10,547 | 6,708 | 8,095 | 7,657 | 6,071 | 9,250 | 2,949 | 7,684 | 7,447 | 4,741 |
| Actual Sales (Jul 06 - Jun 07) | 4,127 | 7,545 | 6,524 | 9,343 | 5,945 | 7,072 | 3,577 | 3,141 | 8,516 | 8,736 | 3,394 | 8,070 |
| Diff (Absolute) | 105 | 1,268 | 4,023 | 2,635 | 2,150 | 585 | 2,494 | 6,109 | 5,567 | 1,053 | 4,053 | 3,329 |

## Item E: ACQ 200G 72x101cm. White

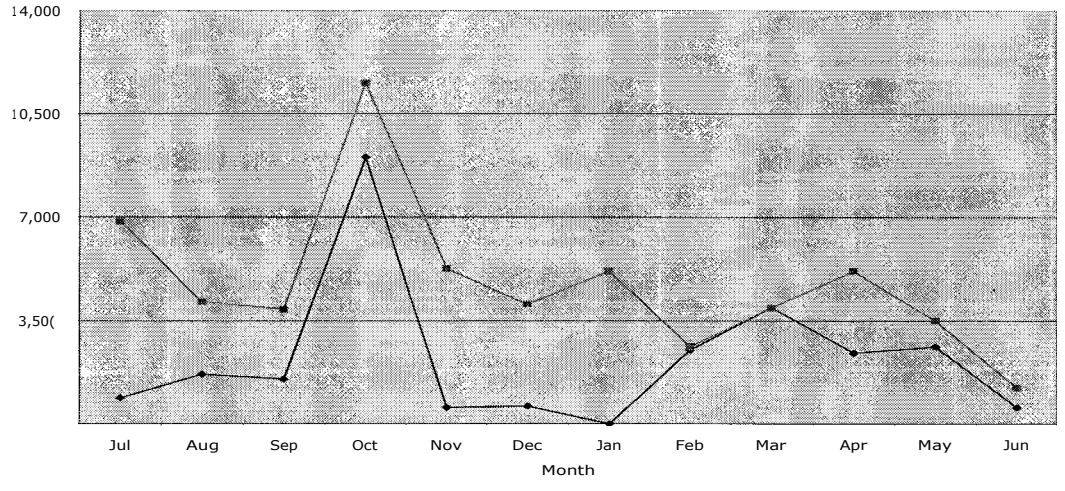



5

| ACQ 200G 72x101cm. White | Jul | Aug | Sep | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| History Sales (Jul 05 - Jun 06) | 2,007 | 4,198 | 2,730 | 10,383 | 11,726 | 5,568 | 12,261 | 2,092 | 4,026 | 2,916 | 9,004 | 6,901 |
| Forecast (10% growth) | 2,208 | 4,618 | 3,003 | 11,421 | 12,899 | 6,125 | 13,487 | 2,301 | 4,429 | 3,208 | 9,904 | 7,591 |
| Actual Sales (Jul 06 - Jun 07) | 2,015 | 3,583 | 4,795 | 5,846 | 9,407 | 4,890 | 4,818 | 1,635 | 2,135 | 3,958 | 2,272 | 9,728 |
| Diff (Absolute) | 193 | 1,035 | 1,792 | 5,575 | 3,492 | 1,235 | 8,669 | 666 | 2,294 | 750 | 7,632 | 2,137 |

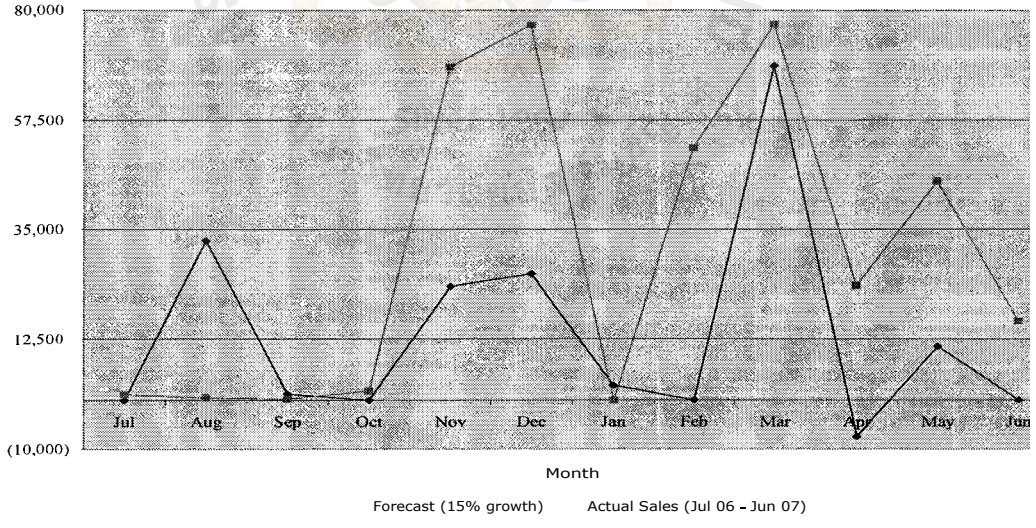
## Item F: DUTCH B/W 300g 70x100cm.

I



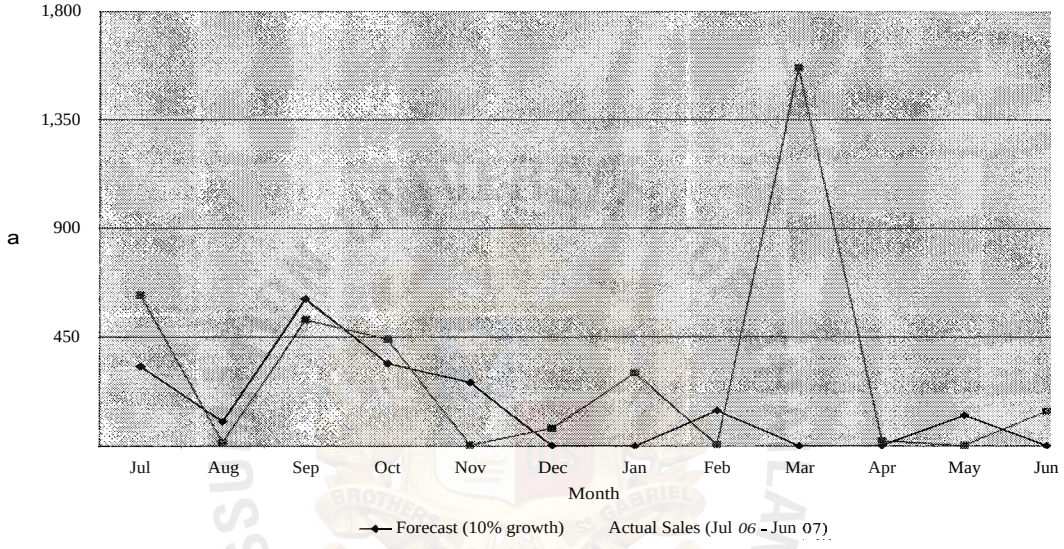

| DUTCH B/W 300g 70x100cm | Jul | Aug | Sep | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| History Sales (Jul 05 - Jun 06) | 764 | 1,469 | 1,324 | 7,848 | 481 | 520 | - | 2,179 | 3,450 | 2,095 | 2,284 | 480 |
| Forecast (15% growth) | 879 | 1,689 | 1,523 | 9,025 | 553 | 598 | | 2,506 | 3,968 | 2,409 | 2,627 | 552 |
| Actual Sales (Jul 06 - Jun 07) | 6,859 | 4,164 | 3,908 | 11,557 | 5,286 | 4,077 | 5,193 | 2,623 | 3,953 | 5,195 | 3,513 | 1,229 |
| Diff (Absolute) | 5,980 | 2,475 | 2,385 | 2,532 | 4,733 | 3,479 | 5,193 | 117 | 14 | 2,786 | 886 | 677 |

Item G: DCO 115g. 64x90cm.



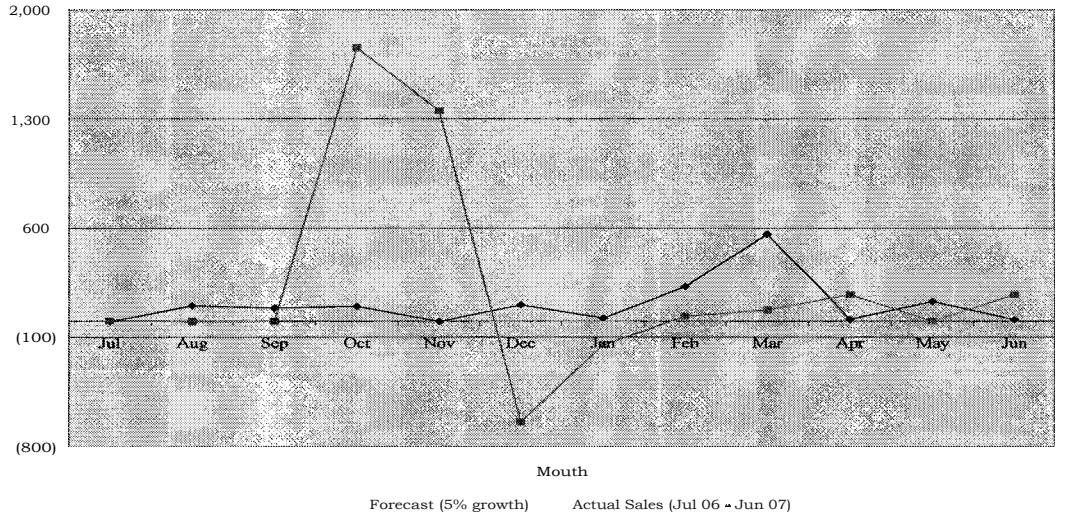
| DCO 115g. 64x90cm. | Jul | Aug | Sep | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| History Sales (Jul 05 - Jun 06) | | 28,404 | 1,130 | 5 | 20,315 | 22,560 | 2,650 | 20 | 59,782 | (6,490) | 9,599 | 3 |
| Forecast (15% growth) | | 32,665 | 1,300 | 6 | 23,362 | 25,944 | 3,048 | 23 | 68,749 | (7,464) | 11,039 | 3 |
| Actual Sales (Jul 06 - Jun 07) | 1,210 | 540 | 255 | 1,941 | 68,507 | 77,000 | | 51,760 | 77,150 | 23,540 | 44,846 | 16,250 |
| Diff (Absolute) | 1,210 | 32,125 | 1,045 | 1,935 | 45,145 | 51,056 | 3,048 | 51,737 | 8,401 | 31,004 | 33,807 | 16,247 |

## Item H: MAJESTIC 290g 72x102cm. Anthracite



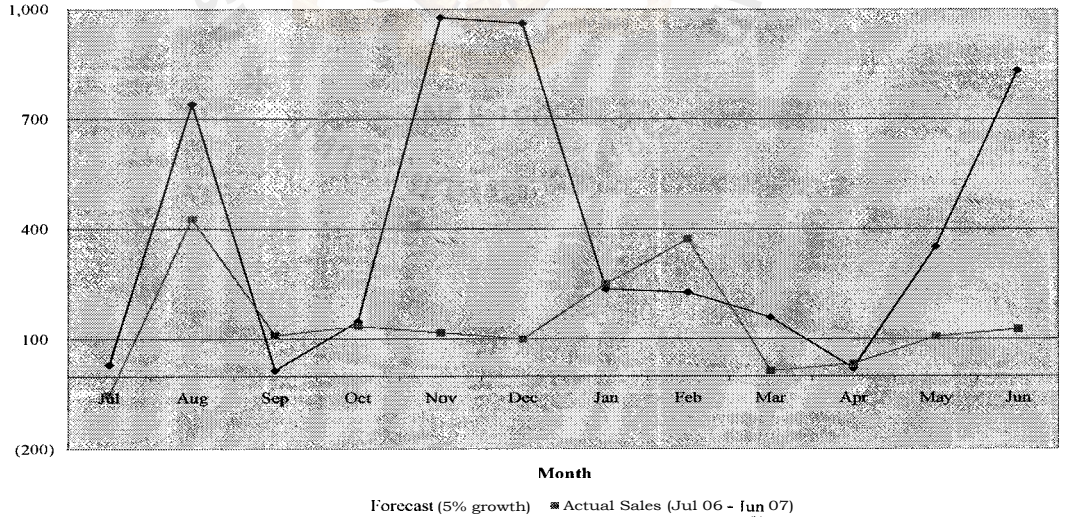

| MAJESTIC 290g 72x102cm. Anthracite | Jul | Aug | Sep | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| History Sales (Jul 05 - Jun 06) | 300 | 94 | 551 | 310 | 240 | 2 | - | 135 | 1 | 2 | 117 | 1 |
| Forecast (10% growth) | 330 | 103 | 606 | 341 | 264 | 2 | | 149 | I | 2 | 129 | 1 |
| Actual Sales (Jul 06 - Jun 07) | 621 | 18 | 520 | 441 | 5 | 75 | 302 | 6 | 1,565 | 22 | 3 | 146 |
| Diff (Absolute) | 291 | 85 | 86 | 100 | 259 | 73 | 302 | 143 | 1,564 | 20 | 126 | 145 |

## Item I: SYMBOL PEARL 170g.70x100cm. White




| SYMBOL PEARL 170g.70x100cm. White | Jul | Aug | Sep | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| History Sales (Jul 05 - Jun 06) | | 96 | 82 | 91 | | 100 | 20 | 211 | 534 | 12 | 120 | 10 |
| Forecast (5% growth) | | 101 | 86 | 96 | | 105 | 21 | 222 | 561 | 13 | 126 | 11 |
| Actual Sales (Jul 06 - Jun 07) | 5 | | 1 | 1,753 | 1,352 | (640) | (150) | 33 | 74 | 170 | 1 | 170 |
| Diff (Absolute) | 5 | 101 | 85 | 1,657 | 1,352 | 745 | 171 | 189 | 487 | 157 | 125 | 160 |

## Item J: LINOVAC 175g. 78.7x109.2cm. Pink



| LINOVAC 175g. 78.7x109.2cm. Pink | Jul | Aug | Sep | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| History Sales (Jul 05 - Jun 06) | 30 | 705 | 15 | 141 | 930 | 915 | 224 | 216 | 151 | 20 | 335 | 792 |
| Forecast (5% growth) | 32 | 740 | 16 | 148 | 977 | 961 | 235 | 227 | 159 | 21 | 352 | 832 |
| Actual Sales (Jul 06 - Jun 07) | (50) | 427 | 110 | 135 | 118 | 100 | 250 | 372 | 15 | 33 | 107 | 127 |
| Duff (Absolute) | 82 | 313 | 94 | 13 | 859 | 861 | 15 | 145 | 144 | 12 | 245 | 705 |

- High inventory level: most items have an inventory level of 5-6 months, and the management team have set targets for 3-4 months only. Even though, the company has a high inventory level, it still always gets comments from customers and its salespeople that product quantity is insufficient which limits the opportunity for sales in big projects.
- Product shortage: since the demand pattern is uncertain, the company always faces shortages in many items. When the customers have big projects or buy in large quantity, the item may run out of stock and take 1-3 months for a new order to arrive at the warehouse. To accelerate the shipment from suppliers is very difficult. If the product is not available according to customer's requirement, the sales may easily be lost to competitors as there are a lot of substitute products.
- Loss of sales and market possibility: In each year, the company has missed many big projects due to inventory level being less than customer demand. If the company increases inventory level, the sales volume may increase much more but the balance between sales and investment should be determined.
- Capital Investment constraint: the company has an inventory cost around 25 Million baht. while the sales volume is 100 Million per year. To increase or decrease the investment in the paper business, the company must ensure that the decision will maximize the best return on investment to the company.

To find a suitable ordering policy or appropriate inventory level would be an important tool that helps company to minimize inventory cost; however, demand has tended to become more variable and uncertain. Moreover, when a demand occurs, the request is sometimes for more than a single unit, which results in so-called lumpy demand. The unsuitable forecast method may result in initial over-buying. The fast-moving items can be quickly remedied by natural consumption but the slowing moving items can only

slowly be remedied, and some items will finally become obsolete and left with only their scrap value. So the company should work on the concept that can measure the trade-off between cost and service.

If current practices continue without finding a better solution to improve, the company may find it difficult to serve or match customer demand, and sales may drop as customers switch to competitors. Consequently, this company will face the problem of inventory level, capital investment, market share, and profitability.

**3. Objectives of the project**

- To create an inventory model or standard tool to support decision making.
- To study how to set the Continuous Review System to maximize profit (minimize cost) in paper business, how much inventory should be held in order to achieve it.
- To identify which factors should be accounted in a Continuous review system and impact on inventory level and profitability.
- To investigate and evaluate the effectiveness of the current model and the proposed model.

**4. Scope of the project**

- To study the Ordering policy and Continuous Review System of a Paper Company which is affected by additional factors such as opportunity cost and service level.
- To study the impact of opportunity cost and inventory holding level on the company's profit.
- To study inventory cost and profit at different inventory levels.
- To study the 10 items of paper selected from the ABC analysis

## CHAPTER 2 : LITERATURE REVIEW

The objective of inventory or stock is to smooth the production process from any uncertainty, but it can also apply to other industries which also have to keep inventory or stock. Examples are: the stock of money in a bank available to be distributed to customers; the stock of policemen in an area, etc.

In keeping inventory, most of the activities involve costs. So we have to deal with the inventory effectively in order to get the best profit when we sell the goods (Profit = revenue - cost). The question arises here is "how much stock should we have?". If the company keep too high an inventory level, it can ensures that the company will never run out of stock, and it is also an easy way of managing stock - but the cost of holding the inventory is expensive. In contrast, keeping too low an inventory level, the inventory holding cost will be low but it will easily face stock-out and lost sales if demand fluctuates or there is a delay in the supplier schedule.

One of the most widely used methods for determining re-order quantities is Economic Order Quantity

### 1. Definition of Economic Order Quantity (EOQ)

The Economic Order Quantity (EOQ) model is a classic independent demand inventory system that provides useful guidelines for ordering decisions. EOQ is the level of inventory that minimizes the total annual inventory cost. It shows the relationship between costs of placing orders, cost of carrying inventory, and the order quantity. EOQ indicates that some balance or trade-off or compromise is needed in deciding how much inventory to hold, and how much inventory to order. There are costs of holding inventory and costs of re-ordering inventory, and these two costs should be balanced in order to minimize the total annual inventory cost.

The framework used to determine this order quantity is also known as the Wilson EOQ Model. The model was developed by F. W. Harris in 1913. But still R. H. Wilson is

given credit for his early in-depth analysis of the model in 1934. EOQ model consists of two variables: ordering costs and holding costs in determine the order quantity.

Cost Components

Ordering cost, also known as purchase cost or set-up cost, is the direct variable cost associated with placing an order with the supplier. Order cost is not associated with the quantity ordered but primarily with physical activities required to process the order. Order cost includes managerial and clerical costs for preparing the purchase, as well as other incidental expenses that can be traced directly to purchase.

Holding cost or Carrying cost is the cost incurred for holding inventory in storage. It is primarily made up of the costs associated with the inventory investment and storage cost. Holding costs for the purpose of the EOQ calculation should only include costs that are variable based upon inventory levels such as warehousing expense, handling charges, insurance, pilferage, shrinkage, interest, taxes, shortage cost, obsolescence and the cost of capital. Some definitions of holding cost' component are:

- Insurance: insurance costs are directly related to the total value of the inventory, it should be accounted as a part of holding cost.
- Interest: borrowing money to pay for the inventory, the interest rate would be part of the holding cost.
- Taxes: tax should be include if taxes are required to be paid on the value of the inventory
- Obsolescence: technological advances or over-forecasting of requirements can result in obsolescence of product. It constitutes one of the largest elements of the holding cost.
- Storage cost: the cost incurred as a consequence of a stock-out, that is, when the demand cannot be fully and immediately satisfied due to a stock shortage. In other words, what is lost if the stock is insufficient to meet all demand. It is the most difficult to measure and is often handled by establishing a "service level" policy, i.e. certain percentage of demand will be met from stock without delay.

Assumptions of the Model

- The demand must be known and constant; the daily demand must be exactly the same throughout the entire year
- Delivery time is known and constant
- Replenishment is instantaneous; the entire order is delivered at one time, and partial shipments are not allowed
- Price is constant; quantity or price discounts are not allowed.
- The holding cost is known and constant.
- The ordering cost is known and constant
- Stock-outs are not allowed; inventory must be available at all times.

The Wilson EOQ approximation is lower bound than the true optimal EOQ, but the simplicity of calculation also gives a close result as of the optimum and has proved worthwhile. The combination of ordering costs and holding costs produces the total variable cost. A change in one of these costs will affect the other and finally changes in total variable cost. For example, ordering costs will vary with the number of orders placed. Ordering cost will reduce for any item if an order is placed fewer times but with larger quantity. This will result in an increase of average monthly inventory with related holding costs. In contrast, holding costs can be reduced by placing orders more frequently but in smaller quantity. The decreases in holding costs will increase ordering costs.

The chart below shows a level at which the combined variable costs of ordering and holding inventory are at a minimum.

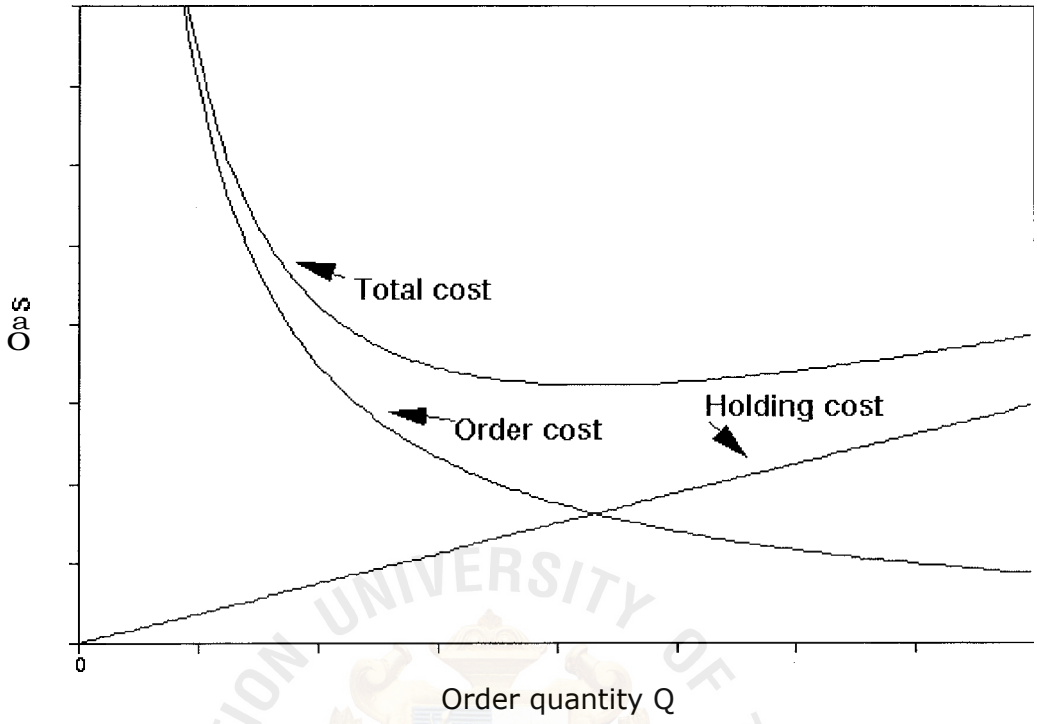



Figure 2.1: The Economic Order Quantity and Total Costs

Source: J E Beasley, Operations research notes, www.it.iitb.ac.in

This chart shows costs on the vertical axis or Y axis and the order quantity on the horizontal or X axis. The straight line which begins at the origin is the holding cost curve, the total cost of carrying units of inventory. When we order more quantity, the holding cost line increases proportionately. The downward sloping curve which starts from the upper part of Y axis and decreases as it approaches the X axis and moves to the right is the ordering cost curve. This curve represents the total ordering cost which depends on the size of the order quantity. The ordering cost will decrease as the order quantity is increased, consequently fewer orders need to be made in any particular period of time. The sum of the carrying cost curve and the ordering cost curve is represented in the total cost curve and the minimum point of the total cost curve corresponds to the same point where the carrying cost curve and the ordering cost curve intersect. The size of the order which produces this result is known as the EOQ.

2. The benefit of **EOQ**

The EOQ model allows decision maker to find the particular quantity to order which minimizes those total inventory costs. The EOQ model which is applied to a given item or a group of items will result in the lowest cost from the sum of the two sets of costs than using any other system of replenishment. This is because of the balancing or equating of the two sets of costs, by reducing one set of costs without proportionally increasing the other set of costs.

In today's market, continuous constant demand seldom occurs. But the EOQ model is still widely used even though the original formula is simplistic and uses several unrealistic assumptions.

According to Dave Piasecki from www.inventoryops.com, EOQ may not apply to every inventory situation, however, most organizations will find it beneficial in at least some aspect of their operation. EOQ should be considered as a choice when you have repetitive purchasing or planning of an item. Though EOQ is recommended in demand steady situation, items with seasonal demand or demand variability can still use the EOQ model by going to shorter time periods for the EOQ calculation and making sure that the usage and carrying costs are based on the same time period. The research of Davis (1975) and Wemmerlov (1979) also stated that EOQ is simple to apply while other solution methods are often more complex to use. In addition, many companies claimed to have tried alternative methods like the Silver-Meal heuristic, the least unit-cost method and the fixed order quantity and have found them 'nervous'. The EOQ is less nervous to large forecast errors and also requires less investment in safety stock. Moreover, research findings showed that several companies aimed at reducing or completely eliminating safety stock.

In the study of Callerman and Hamrin (1984), the difference in total cost performance under conditions of stockouts between economic order quantity, part-period balancing and Wagner-Whitin, were little. And the Silver-Meal, the periodic order quantity and the lot-for-lot method did not perform well too. However, their research findings also

showed that the EOQ was more stable in the presence of fairly large forecast errors which resulted in lower safety stocks than other rules.

De Bodt and Wassenhove (1983) also performed a simulation study of a multi-stage M.R.P. system with large forecast errors. They assumed that the demand for the coming period was known with certainty and that emergency orders could be placed to avoid stockouts. The study showed that EOQ was the least nervous to forecast errors, yielded the lowest inventory costs and the lowest number of stockouts or emergency orders also found in EOQ.

3. Implementing **EOQ**

Dave Piasecki from www.inventoryops.com provided the steps that should be followed in implementing EOQ as :

1. Determine variables: The demand in quantity per unit time and associated costs such as ordering cost, holding cost and shortage cost must be determined.
2. Selecting method: If the items have steady demand and costs or less than one thousand SKUs, the calculation in a spreadsheet program can be the simplest method; item manager can manually calculate EOQ one item at a time and then enter the order quantity into the inventory system. If the items have higher variability in demand and costs, or have more than a few thousand SKUs, programming the EOQ formula into an existing inventory system should be implemented. This method allows a quick re-calculation of EOQ automatically as often as needed. The hybrid of the two systems can be used by downloading the data to a spreadsheet or database program, perform the calculations and then update either manually or through a batch program into the inventory system.
3. Test the formula: testing the program by running the EOQ program and manually checking the results using sample items that are representative of the variations of the inventory base, should be made prior to final implementation.
4. Project results: Run a simulation or use a representative sampling of items to determine what would be the overall short-term and long-term effects of EOQ calculation such as warehouse space, cash flow and operations. To increases

inventory levels, it needs additional storage requirements and compensates for the effects on cash flow. Dropping inventory level and increasing order frequency may need to evaluate staffing, equipment, and process changes to handle the increased activity, so temporary adjustments to the formula may have to apply if the immediate increase or decrease in inventory is not feasible.

5. Maintain and Evaluation: Since there might be changes in interest rates, storage costs, and operational costs, the values of ordering cost and holding cost should be evaluated at least once per year.

**4. The extension of the classical EOQ model**

The classical EOQ model which determines the order quantity by minimizing total inventory cost has been criticized in many aspect. Tersine (1992) states that classical EOQ models are difficult to obtain appropriate parameter estimates, involve the violation of the assumptions necessary for model validity and its inability to support the operation's improvement of organizations. So there are many studies that extend and include other necessary factors or formulate different assumptions into the classical EOQ model.

The study of "Including quality costs in the lot-sizing decision" by Hanna and Jobe (1996), as traditional EOQ model, has recently been criticized because it treats the lot-sizing decision as independent from other manufacturing considerations. They provide an approach that includes quality costs in lot-sizing considerations. They found that the traditional model overestimated the ideal lot size by over 100 percent. The extent of such overestimation is obviously related to the percentage of ordering costs that are actually quality costs. In this case, orders in smaller quantities would be more reasonable and the impact of bad lots would be more limited.

Deriving the optimal reorder and shortage points in order to minimize the total cost over the time horizon was studied by Goswami and Chaudhuri (1991) in "An EOQ model for deteriorating items with shortages and a linear trend in demand". The inventory replenishment policy over a fixed planning period for a deteriorating item having a deterministic demand pattern with a linear trend and shortages. They developed a

deterministic inventory model and found that the reorder number and the average system cost increases in shortage is not an allowed situation, while the system cost becomes much less by allowing shortages.

In reality, order cost and stock cost are usually affected by various uncontrollable factors and often show some fluctuation. Wang, Tang and Zhao (2007) studied the EOQ model in the fuzzy sense or fuzzy variables in "Fuzzy Economic Order Quantity inventory model without backordering". They construct a fuzzy expected value model (EVM) with which to find the optimal order quantity where cost in minimal, and a fuzzy dependent chance programming (DCP) model to find the optimal order quantity for maximizing the credibility of an event such that the total cost in the planning periods does not exceed a certain budget level. Fuzzy simulations and the PSO algorithm were developed and a numerical example showed good results.

Tersine and Barman (1994) and many others, have studied the unit discount from suppliers and/or freight discounts from shippers. San Jose and Laguna (2003) did an extended study of the EOQ model with backorders, constant shortage cost per unit and purchasing cost depending on the lot size. They used two stages of a quadratic function (first stage) and on the objective function of the Harris' EOQ model (second stage) to formulate the optimal policy. This was developed for the situation when a salesperson offers a fixed compensation to a client in a quantity discount for not losing the sale. The developed formulation is efficient.

**5. Opportunity Cost**

Opportunity cost is the value given up as a result of not taking certain action, or the value of a product forgone in order to produce or obtain another product. It could refer to the profit that the company could have earned from its assets such as capital, equipment or real estate if they had been used in a different way. Opportunity cost plays a crucial part in ensuring that scarce resources are used efficiently, and it is not restricted to monetary or financial costs. The real cost of output forgone, lost time, pleasure or any other benefit that provides utility, should also be considered. Economists often refer to the opportunity

cost of a resource as the value of the next-highest-valued alternative use of that resource or the benefits that you could have received by taking an alternative action. It should be noted that opportunity cost is not the sum of the available alternatives, but rather of the benefits of the best alternative of them.

Example of opportunity:

1. The difference in return between a chosen investment (invest in a stock which generates 3% return over the year) and another one that is necessarily passed up (gave up the opportunity of another investment i.e. a risk-free government bond yielding 7%). In this situation, the opportunity costs are 4% (7%-3%).
2. The opportunity cost of a person to keep his job: the opportunity cost is the benefit of going to school, including the additional intangible benefits such as pleasure, social interaction, and personal fulfillment as well as the tangible benefit of an increased future salary for his remaining working life. If the person had chosen to go to school, then the opportunity cost is the $24,000 per year that would have been earned at the full-time job.

Because resources are limited, a choice between two options must be made. If you could know the end outcome, it would be easy to make a decision, however, the risk that you could achieve greater benefits (both monetary or otherwise) with another option is the opportunity cost. (Investopedia, www.answers.com).

www.netmba.com has stated that scarcity of resources is one of the most basic concepts of economics. Scarcity has to trade off which will result in an opportunity cost. Opportunity cost is useful for comparing and evaluating the cost and benefit of choices. This concept can be applied to many situations:

- Consumer choice
- Production possibilities
- Cost of capital
- Time management
- Career choice

- Analysis of comparative advantage

Many companies do not include opportunity cost as an actual cost in their financial statement, but opportunity cost analysis is an important part of a company's decision-making processes.

6. Total Opportunity cost for Profit Maximization

Everyone attempts to do as well as they can for themselves: businesspeople also attempt to manage their businesses in order to improve their well being too. But in reality, business faces tough competition, and the only way that a business can survive is to pay attention to revenues and costs where profit maximization is the desired goal for many companies.

In economic terms, www.econ.ilstu.edu stated that profit is the difference between a company's total revenue and its total opportunity cost. Total revenue is the amount of income earned by selling products while total opportunity cost includes both the costs of all inputs into the production process plus the value of the highest-valued alternatives to which owned resources could be put. Since the goal of company is to maximize profit, we should either be increasing total revenue or reducing total opportunity cost so that the difference rises to a maximum. As businesspeople know what are their current revenues and costs, they can estimate total revenue and total cost for a higher (or lower) level of inventory. By simulating a change in inventory levels, they can estimate the new level of demand and profit and consider what should be the output level that maximizes profit. The company should produce or increase inventory level as long as the marginal revenue earned from additional units is greater than the marginal cost of those units. Marginal revenue is the additional revenue earned by selling one more unit of a product while marginal cost is the additional cost incurred in producing one more unit of output. The company should increase output or inventory only to the point at which marginal revenue is equal to marginal cost which is the level that can maximizes profit.

<u>Example of Profit Maximization</u>

A small company produces and sells furniture. Normally, they can produce three custom wardrobes per day and are able sell them for $500 a piece. This company employs six workers, each of whom earns $15 per hour ($120 per day). Material inputs cost $150 per wardrobe, and in addition, the company has overhead expenses of $130 per day. Thus, this company earns a profit of $200 per day. (($500 x 3) - ($720 + 450 + 130) = $1500-$l300= $200).

If the company increases production to four wardrobes per day, it has to hire two more workers (at another $240) and purchase another $150 worth of materials. Overhead expense do not change. The total cost will rise to $1690. And if the company is sure that it can sell all 4 wardrobes, its total revenue will be $2000 per day, so profit increases to $310 per day. Consequently, if everything remains unchanged, to produce and sell up to five wardrobes, the profit increases to $420 (total revenue = $2500 – total cost = $2080).

On the other hand, as skilled workers are in short supply, an additional two workers for producing the fifth wardrobe have to be hired at $20 per hour. This will increase the labor cost of the fifth wardrobe by $80 ($40 per worker per day x 2 workers). Thus, profit will be at $340 since total cost is $2160, which is still acceptable. However, when you hire the ninth and tenth workers, you are forced to raise the wages of your first eight workers too. So total revenue = $500 x 5 = $2500. Total cost = ($160 x 10) + ($150 x 5) + $130 = $2480, which leaves a profit of $20. In this case, the costs rise sharply when producing a fifth wardrobe: the good choice would be producing only four wardrobes a day.

**7. Customer service level**

Customer service level is the measurement in percentage of availability of demand by customers that can be supplied directly from the inventory. A common metric for measuring customer service level is Fill Rate, which measures the percentage of how often a particular product or item is available when customers want it.

The customer service level that a company provides to its customers is one of the most ¡mportant factors of an organization's success. If a product is not available, an immediate

sale may be lost. Consequently, long term sales may also be lost if the customer changes to another brand and then decides to stay with that brand.

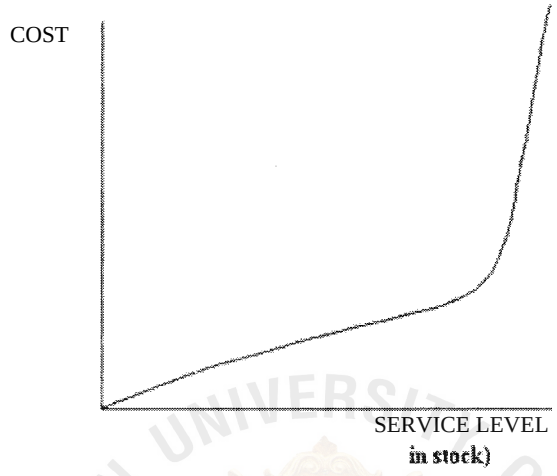



Figure 2.2 : Cost and customer service level trade-off.
Source : Mercer, D, Marketing for Managers, Orion, 1998

The percentage availability is described as the service level. The simplest answer for desired service level is achieved by 100% availability. But the cost of achieving this service level rises very steeply as it approaches 100%: to increase service level, a company will need to increase costs. The trade off between customer service level and cost is explicit. For indications in terms of demand generated, customers are not significantly affected by small variations if there are generally high levels of availability. However, there are other elements of customer service level such as lead time or order cycle time: the time it takes to meet an order and reliability of the lead-time is more important than the time itself as a customer may have to arrange a number of other activities in order to meet with the promised delivery of the product, which is also considered as a matter of trust as stated by Mercer (1998). According to Ettl et al. (2000, p. 216) , a common problem for asset managers is not knowing how to quantify the trade-off between service levels and the investment in inventory required to support those service levels.

Mariah, Renee and Linda (2008) stated that in most cases, a company often sets ideal customer service levels and inventory goals based on experience, without using a scientific approach. In addition, there are other factors such as forecast accuracy, demand variability, and order lead-time that are uncertain and effect the inventory and service level relationship. These factors are dynamic, with a non-stationary nature, so the ideal inventory and customer service levels will change with time. Therefore, it is important for a company to understand the impact of these factors in order to react to changes effectively as well as to understand where to focus efforts to improve delivery performance.

Gupta and Maranas (2003) capture the trade-off between customer service level and cost using stochastic programming. By employing a Monte Carlo sampling method with hundreds of scenarios of randomly generated demand, the minimum cost is found between the range of inventory and service levels. While Mariah, Renee and Linda (2008) use regression modeling of historical data, they explore the relationships between inventory, customer service level, and other factors via logistic regression. A cost is associated with inventory, and stock-outs leads to the determination of a minimum cost customer service level.

**8. Parameters affected by the EOQ model**

- Demand

Inventory management is influenced by the nature of demand (both independent and dependent demand). Specialty paper is independent demand which derives from end customers. This demand is uncertain. The company should find ways to manage this uncertainty which will help to reduce inventory levels while meeting customer expectations.

- Inventory cost

Minimized inventory costs is the primary objective of the EOQ model, by balancing holding costs of inventory and ordering or setup costs. Some other costs such as stock out costs, and opportunity cost, should also be accounted. Since there is a trade-off

between inventory costs and service level, the company should make the decision on inventory policy that corresponds to the capital available and can earn the best profit.

- Opportunity cost :

Opportunity cost is a key concept in economics as it implies the choice between two or more desirables and the value forgone from making the alternative decision. In this project, we include opportunity cost in the EOQ model in order to compute expected revenue or profit that the company could receive if the product is available. Opportunity cost will be consider in terms of the revenue forgone as a result of being unable to supply enough products to meet demand.

- Customer service level

The availability of inventory provides customer service while the EOQ model tries to minimize cost. To take opportunity cost as another factor, the company will be more concerned with costs and benefits to the company itself which may reduce the customer service level and their satisfaction.

- Profit

In implementing the EOQ model with opportunity cost, a company expects to increase its profit as it takes opportunity cost as another key decision factor into the formulation which will maximize the possibility in increased sales and making profit.

- Capital Investment

The result derived from EOQ might be much more different than current practice. Capital investment, cash flow and related factors in operation may not be immediately feasible and may not be optimal in the EOQ model in the short-term period.

The Economic Order Quantity (EOQ) model is a classic independent demand inventory system that provides many useful ordering decisions. Many researchers have developed different formulations with different parameters to be more suited to each business situation. We can obviously see that even though opportunity cost is an important factor

in making decisions, this factor still is not included in any formulation. This project will complete the EOQ model by linking opportunity cost to be another factor in the EOQ model, which should lead to better ordering decisions and improve the company's profitability.

**9. Continuous (Perpetual) Review System (Variable Order Interval System)**

Continuous inventory review system constantly reviews inventory level, and orders are placed when the stock reaches or falls below the predetermined reorder level. In this system, the reorders are usually in the same quantities but do not occur on a scheduled basis.

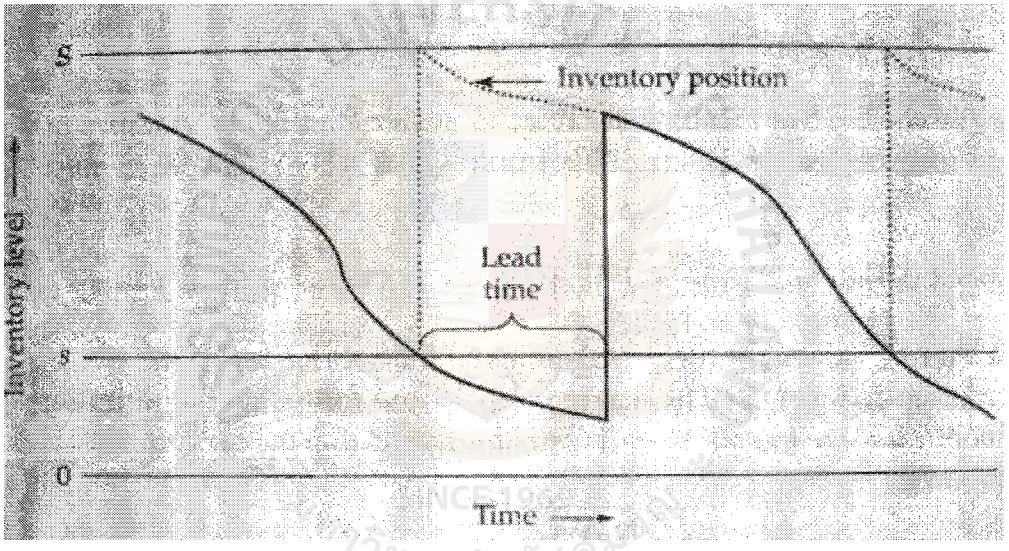



Figure 2.3: Inventory level in a continuous review system, (s,S) policy.

Source: Simchi-Levi, Kaminsky, Simchi-Levi, Designing & Managing the Supply Chain, Second Edition

Figure 2.3 shows the inventory level over time when a continuous review system is implemented. When the inventory level drops below level s, the company should order Q quantities in order to raise the inventory level to level S. The maximum inventory level is achieved immediately after receiving an order while the minimum level of inventory is achieved just before receiving an order.

Donald and Carl (1973), stated that Continuous-review (s, S) policy starts the cycle when on-hand plus on-order inventory falls to level s, then the order is placed to bring the inventory up to level S. The order is assumed to go into a single-server queue, where the order-filling time is dependent on the number of orders ahead of it. After the order has arrived and filled into inventory, the on-hand inventory increases by an amount Q.

Optimal policy for the single product problem can be characterized by two numbers s and S, with the condition of s < S. If the current inventory level is higher than the threshold s, there is no need to order. However, if current inventory level is lower than s then order in the quantity that make the inventory level reach the target level S. (Veinott 1965).

Two definitions in this system are s, S.

Reorder point (s) is the inventory position of an item less or equal to a certain number, and the new order should be made. (s) consists of two components:

1. Average demand during lead time: this quantity ensures that during lead time, the company will have enough inventories to cover demand $= L * AVG$
2. Safety stock: the amount of inventory that a company needs to keep to protect against deviation from average demand during a leadtime $= z * STD *$

Order-up-to level (S) is the inventory of an item raised up to a given target level. S is the maximum stock level.

s, S policy is affected by ordering cost and holding costs. S will have higher value when ordering cost is high and holding cost is low. It may be economical to carry units in inventory. The research of A.B.M. Zohrul Kabir and Ahmed S. Al-Olayan (1994), found that s, S policy is more cost-effective especially in a long lead time situation.

**10. Periodic Review System (Fixed Interval Re-order System)**

Periodic inventory review system reviews and reorders inventory in a specified time interval **but** order quantity may vary each time. This system will re-supply inventory at

predetermined time intervals (ie. review at the start of each week or the end of each month). An appropriate quantity is ordered based on current stock levels, safety stock level, and an established maximum inventory position.

A periodic inventory review system sets regular time intervals to review the inventory. Re-order quantity can vary and replenish up to a specified or target inventory level. The quantity re-ordered is calculated by subtracting existing inventory and on-order inventory from the target inventory level. (http://dictionary.bnet.com)

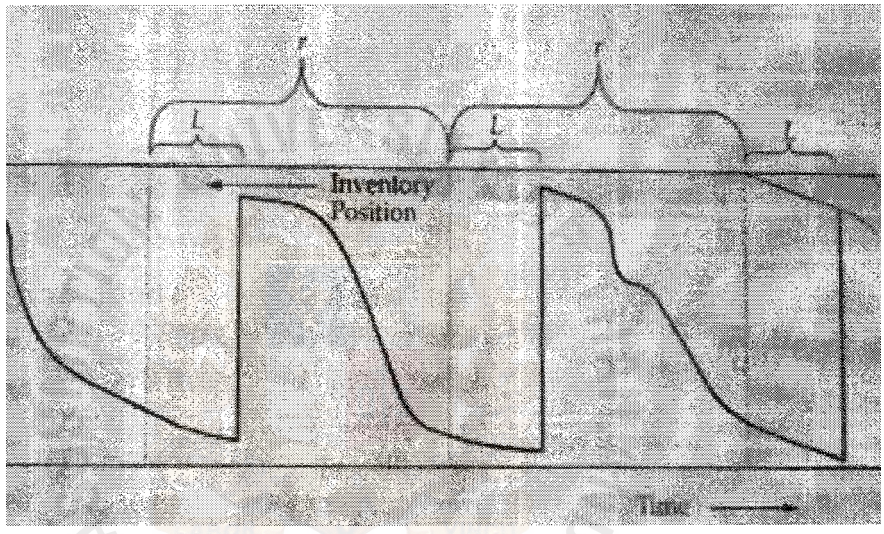



Figure 2.4: Inventory level in a periodic review system

Source: David Simchi-Levi, Philip Kaminsky, Edith Simchi-Levi, Designing & Managing the Supply Chain, Second Edition

Figure 2.4 shows the inventory level over time when a periodic review system is ¡mplemented. The company will determine a specified or target inventory level (base-stock level) which should be the level that is enough to protect the item against shortages until the next order arrives. In each review period, the company will place an order to raise the inventory position up to target inventory level (base-stock level) and the maximum inventory level is achieved immediately after receiving an order while the minimum level of inventory is achieved just before receiving an order.

Target inventory level (base-stock level) consists of two components:

1. Average demand during an interval $= (r + L) * AVG$
2. Safety stock: the amount of inventory that a company needs to keep to protect against deviation from average demand during a period of r + L months $= z * STD * \sqrt{r + L}$

In this system, the fixed cost of placing an order is a sunk cost and can be ignored because inventory levels are reviewed at a periodic interval and presume that the fixed cost was used to determine the review interval.

The research of Sani and Kingsman, (1997) stated that the Periodic inventory system is not a suitable choice in terms of cost. Even if the ordering cost is low and negligible which results in low annual costs for the very low demand items. But it is still not recommended because it gives quite lower customer service level when compared to the (s, S) systems.

11. Safety Stock

Safety stock is the minimum level of inventory that a company holds to prevent shortages that may occur due to fluctuations in demand. Safety stock level derives from the trade-off between the risk of stock-out, which may effect in customer dissatisfaction and lost sales, and the increased costs associated with carrying additional inventory.

Safety Factor

Safety factor (z) is associated with the service level: the number is constant.

Table 2.1: List of z values for different values of the service level

Service level and e safety factor, Z

| Service Level | 90% | 91% | 92% | 93% | 94% | 95% | 96% | 97% | 98% | 99% | 99.9% |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Z | 1.29 | 1.34 | 1.41 | 1.48 | 1.56 | 1,65 | 1.75 | 1.88 | 2.05 | 2.33 | 3.08 |

Source: David Simchi-Levi, Philip Kaminsky, Edith Simchi-Levi, Designing & Managing the Supply Chain, Second Edition

z is chosen from Table x.x. This will ensure that the probability of stock-outs during lead time is equal to 1 - service level

**12. Limitation of other tools**

Alternative tools to implement and manage inventory.

Vendor-Managed Inventory (VMI)

VMI is a set of processes to enable vendor-driven replenishment and can be implemented over the web. This is a contemporary concept by which a supplier can monitor a customer's inventory level and be responsible to replenish the inventory level of the customer within maximum and minimum levels as in the contract agreement. VMI may not be applicable in the paper business since the company's suppliers have more power than their distributors. This company is not in the position to request suppliers to implement this process. In addition, VMI is suitable if demand is certain or demand must be known, but this project cannot predict the demand for some items.

Collaborative Planning, Forecasting and Replenishment (CPFR)

CPFR aims to increase revenue, improve service and lower inventory levels by allowing manufacturers to collaborate with their retail customers. It is a useful tool for consumer product and retail industries. The paper business is a niche market, and customers hesitate to disclose information which is strategic information about their companies or make a commitment with a supplier. These issues, and the occurrence of unexpected demand due to the characteristics of specialty paper, mean that CPFR may not be implemented effectively in this business.

Just in Time

JIT is an inventory system that aims to improve profit and return on investment by reducing inventory and carrying costs and eliminating waste. The objective is to make

the right product available in the right place at the right time. This approach is not applicable to the paper business since customers need an immediate supply of the product while the company has a 3-4 months lead time to receive products from suppliers.

In addition, the prediction of demand by using different forecasting techniques may **not** be appropriate to this situation since the demand pattern is uncertain. So Economic Order Quantity that counts opportunity cost as an additional parameter would be a useful tool to decide the order quantity and inventory level that maximizes the company's profit.

# CHAPTER 3 : METHODOLOGY

Supply chain management provides the potential for organizations to reduce costs and improve customer service performance. In the current market situation, companies are pressured to achieve high customer service levels with fewer resources. To be more competitive, the companies also have to increase product variety and shorter delivery lead times to meet customer demand.

## 1. Research Strategy

This project uses case study methodology. A case study examines a specific situation or occurrence by extending the existing theory and empiric result of other similar cases. Case study is an ideal methodology when a holistic, in-depth investigation is needed (Feagin, Orum and Sjober, 1991). Yin (1984) stated that case study research method is an empirical inquiry that investigates a real life context of specific situation, when the boundaries between situation and context are not clearly evident and multiple sources are used as evidence.

## 2. Research Approach

Both Qualitative research and Quantitative research were used in this project. Qualitative research does not involve statistics or measurement: it uses judgment or subjective factors to obtain the result. Quantitative research focused on the collection and analysis of numerical data and statistics to manage decision making. All data collected in this project are based on the EOQ model, using literature and relevant factors that affect inventory, customer service level and profitability.

## 3. Data Collection

Both Primary data and secondary data were collected in order to support 3 scenarios of ordering decision. These two types of data can be categorized by the purpose of data that has been collected. Primary data are data gathered for specific purposes or for this project while secondary data are data that already exist or were collected for other purposes.

3.1 Primary Data

The primary data of this project were gathered through the company's database, documents, interviews and direct observation. The inventory level, forecast, sales volume, selling price and cost were downloaded from the company's ERP system ie. BPCS and powerplay. The company's policy, market situation and customer behavior were gathered from relevant persons such as Sales Director, Sales and Marketing manager, salespeople, accountant, purchaser, etc..

3.2 Secondary Data

The secondary data of this project were collected from AU library, online databases such as Emerald, JSTOR, suppliers' websites and Google in order to provide the broad knowledge base to cover the scope of this project.

**4. The Structural Equation Modeling Approach**

This research was conducted using the Continuous Review System with 3 concepts of Economic Order Quantity (EOQ model) and the Periodic Review System

Model Parameters and Formulation

Model Parameters

The parameters used in the Continuous Review System which applies the EOQ model in 3 scenarios are:

AVG = average (monthly) demand

STD = standard deviation of (monthly) demand

L = replenishment lead time

z = safety factor, is constant

Q = order quantity

Q* = optimal order quantity

D = annual requirement or demand

C = purchase cost per unit

S = cost of placing one order

k = holding cost rate, where annual holding cost per unit (H) = k x C

The parameters used in the Periodic Review System scenario are:

r = the length of the review period

L = lead time AVG = average (monthly) demand

STD = standard deviation of (monthly) demand

z = safety factor, is constant

Model Formulation

Scenario # 1 Continuous (Perpetual) Review System (Variable Order Interval System)

Expected level of inventory after receiving an order is

$$Q + z * STD *$$

Expected level of inventory before an order arrives is

$$z * STD * \sqrt{L} \quad = \text{ safety stock}$$

Average inventory level is

$$\frac{}{2} + z * STD * \sqrt{L}$$

Order up to level

$$S = Q + s$$

Scenario # 1.1 (Classical EOQ model)

Order quantity

$$Q = \overline{\quad * AVG}$$

According to Wilson, the EOQ model states the total cost function for finding the minimum inventory cost as

Total inventory cost = purchase cost + ordering cost + holding cost

In this project, there is no price or quantity discount which does not affect the order decision, so we remove purchase cost from this formula and change to:

Total inventory cost = ordering cost + holding cost = $(S * \frac{D}{\quad}) + (k * C * \frac{Q}{2})$

$$EOQ = Q^* = \sqrt{\frac{2SD}{\quad}}$$

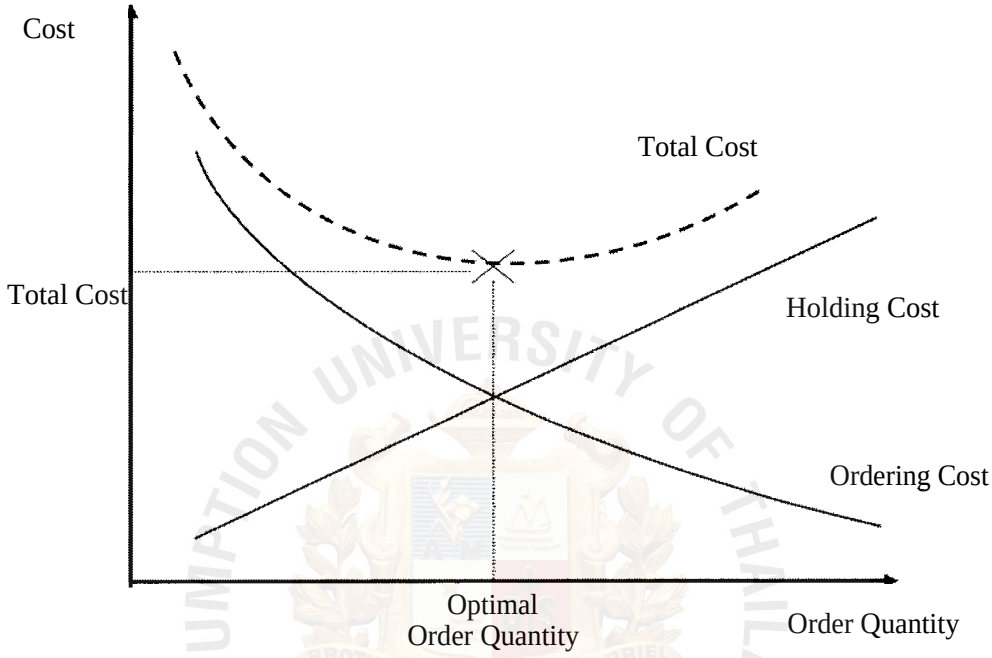



Figure 3.1: Economic Order Quantity and Total costs under classical the EOQ model

Scenario # 1.2 (EOQ model with opportunity cost as additional parameter)

EOQ Model is a part or factor in a Continuous Review System. In addition, most companies know that opportunity cost analysis is important but they usually do not use opportunity cost as a factor when making the decision.

Scenario # 1.2.1 (EOQ with opportunity cost "-"): $O_1$

This scenario will count the opportunity cost as risk that the company may not able to sell the product, which can happen when the market trend is down: the demand will decrease. If the company has high inventory level, this will result in high cost. Including opportunity cost as another factor of cost function can optimize the EOQ model and help

the company to make the right decision in placing order, and the inventory level, to improve its profitability.

Total inventory cost = ordering cost + holding cost + opportunity

$$= (S * \frac{D}{\quad}) + (k * C * \frac{Q}{2}) + CO_1 \frac{Q}{2}$$

$$EOQ\ Q^* = \sqrt{\frac{2SD}{H + CO,}}$$

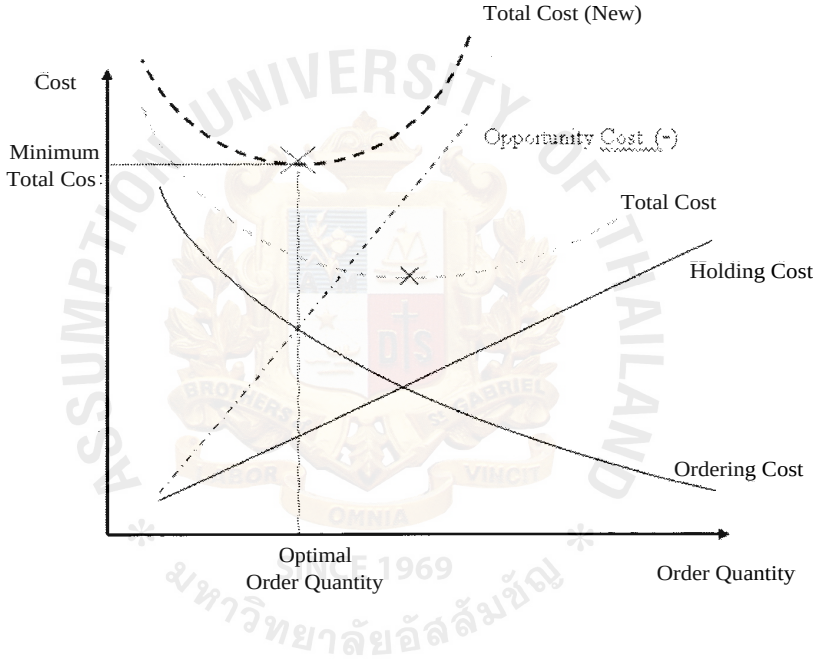



Figure 3.2: Expected result when including opportunity cost as risk to be another parameter in EOQ model

Scenario # 1.2.2 (EOQ with opportunity cost "+"): 02

This scenario will count opportunity as a chance for growth in which the company can sell more if they hold additional inventory. In an upside market trend, the demand will increase. If the company has higher inventory level, this will result in high revenue.

Total inventory cost = ordering cost + holding cost - opportunity cost

$$= (S * \frac{D}{Q}) + (k * C * \frac{Q}{2}) - CO_z \frac{Q}{2}$$

$$EOQ = Q^* = \sqrt{\frac{2SD}{H - CO,}}$$

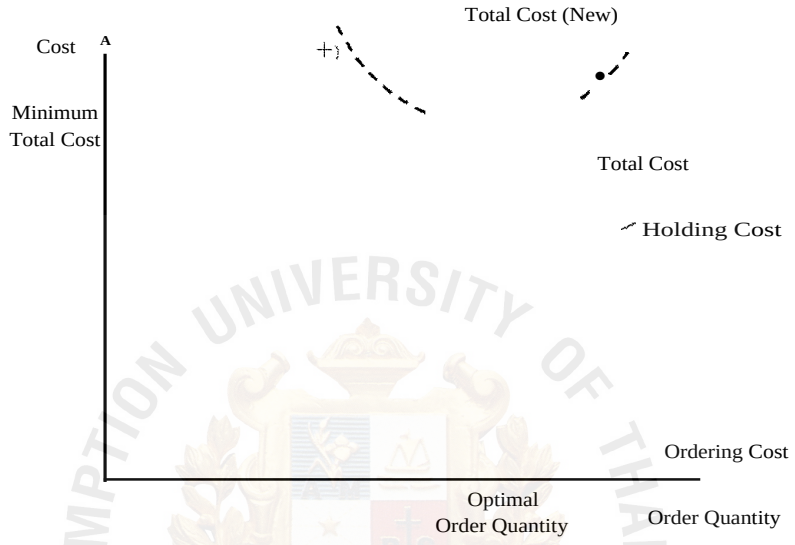



Figure 3.3: Expected result when including opportunity as profit to be another parameter in EOQ model

Scenario #2 **Periodic Review System (Fixed Interval Re-order System)**

The company will review the inventory at the end of each month.

Expected level of inventory after receiving an order is

$$r * AVG + z * STD * \sqrt{r + L}$$

Expected level of inventory before an order arrives is

$$z * STD * \sqrt{r + L}$$

Average inventory level is

$$\frac{r * AVG}{2} + z * STD * \sqrt{r + L}$$

Note:

- The cost of placing one order of specialty paper is Baht 6,000 per order, while the holding cost rate is 15% per annum
- From management policy, the company will use a 90% service level and allow 3 months of inventory.

**5. The result of EOQ model**

Table 3.1: The result of Classical EOQ model of each item

| | | EOQ Model | | | |
|---|---|---|---|---|---|
| Item | Product Name | Q* | Avg. Inv Level (sheet) | Months for Sales | Avg. Inv Cost (B) |
| A | IMPRESSION2000 CB WHITE 55G 24x36" | 649,283 | 324,641 | 0.50 | 480,856 |
| B | COMET 250g. 72x102cm. White | 12,957 | 6,478 | 1.75 | 137,400 |
| C | ACQ STUCCO 72x101cm. | 18,590 | 9,295 | 1.67 | 143,856 |
| D | AMB.LAID 220G 70x100cm.B/W | 22,668 | 11,334 | 1.79 | 134,090 |
| E | ACQ 200G 72x101cm. White | 19,058 | 9,529 | 2.08 | 115,610 |
| F | DUTCH B/W 300g 70x100cm | 19,202 | 9,601 | 2.00 | 119,896 |
| G | DCO 115g. 64x90cm. | 107,159 | 53,580 | 1.77 | 135,499 |
| H | MAJESTIC 290g 72x102cm. Anthracite | 2,800 | 1,400 | 4.51 | 53,191 |
| I | SYMBOL PEARL 170g.70x100cm. White | 3,649 | 1,825 | 7.91 | 30,352 |
| J | LINOVAC 175g. 78.7x109.2cm. Pink | 3,126 | 1,563 | 10.75 | 22,319 |
| Total | | | | | 1,373,070 |

The average inventory level and inventory cost for 10 items are much lower than current ordering policy. However, the nature of this company does not match with the basic assumption of EOQ such as demand of paper is not known or constant, replenishment is instantaneous and stock-outs are not allowed, and inventory must be available at all times. With these assumptions, EOQ is not able to apply directly to this project: its result may

not be accurate, so we consider applying the continuous review system and periodic review system.

# CHAPTER 4: RESULTS AND ANALYSIS

From the previous chapter's calculation by different ordering systems, each scenario shows different levels of inventory which result from related factors such as opportunity risk, opportunity growth, ordering and holding cost, in each scenario. By analysing those results, the company can select the right and appropriate decision to maximize profit.

## 1. Average Inventory Cost

Table 4.1: Average inventory cost of each scenario

| | | | Continuous Review System (The Order Quantity) | Continuous Review . System (with Opportunity " - ") | Continuous Review System i with Opportunity " " ) | Periodic Review System |
|---|---|---|---|---|---|---|
| Item | Product Name | Sales Amount (฿) | Avg. Inv Cost (฿) | Avg. Inv Cost (3) | Avg. Inv Cost (฿) | Avg. Inv Cost (฿) |
| A | IMPRESSION2000 CB WHITE 55G | 19,513,205 | 661,578 | 630,289 | 677,962 | 1,085,352 |
| B | COMET 250g. 72x102cm. White | 2,225,300 | 197,076 | 176,466 | 215,474 | 221,094 |
| C | ACQ STUCCO 72x101cm. | 1,872,052 | 214,777 | 194,937 | 234,040 | 243,165 |
| D | AMB.LAID 220G 70x100cm.B/W | 2,431,680 | 98,408 | 82,048 | 107,108 | 106,394 |
| E | ACQ 200G 72x101cm. White | 1,129,181 | 106,270 | 94,744 | 113,770 | 112,018 |
| F | DUTCH B/W 300g 70x100cm | 1,554,039 | 106,011 | 91,383 | 148,793 | 112,394 |
| G | DCO 115g. 64x90cm. | 2,903,992 | 218,672 | 195,100 | 247,307 | 245,585 |
| H | MAJESTIC 290g 72x102cm. | 335,160 | 53,853 | 44,949 | 72,833 | 50,348 |
| I | SYMBOL PEARL 170g.70x100cm. | 80,301 | 33,209 | 27,759 | 34,243 | 30,148 |
| J | LINOVAC 175g. 78.7x109.2cm. Pink | 54,936 | 10,908 | 7,346 | 11,668 | 6,194 |
| | Total | 32,099,846 | 1,700,762 | 1,545,020 | 1,863,198 | 2,212,692 |

In analyzing the total of 10 items, the continuous review system (with opportunity cost "-") shows the lowest inventory cost, while the periodic review system shows the highest inventory cost. However, in analyzing each item separately, the lowest inventory cost is varied in all scenarios based on characteristics of that particular item.

## 2. Average Inventory Level

Table 4.2: Average inventory level and Months for Sales of each scenario

| | | Risk | Growth | Continuous Review System (The Order Quantity) | | Continuous Review System (with Opportunity "-") | | Continuous Review System (with Opportunity "+") | | Periodic Review System | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Item | Product Name | 01 | 02 | Avg. Inv Level | Months for Sales | Avg. Inv Level | Months for Sales | Avg. Inv Level | Months for Sales | Avg. Inv Level | Months for Sales |
| A | IMPRESSION2000 CB WHITE 55G | 0.10 | 0.03 | 446,653 | 0.69 | 425,529 | 0.65 | 457,715 | 0.70 | 732,757 | 1.13 |
| B | COMET 250g. 72x102cm. White | 0.50 | 0.08 | 9,292 | 2.51 | 8,320 | 2.24 | 10,159 | 2.74 | 10,424 | 2.81 |
| C | ACQ STUCCO 72x101cm. | 0.40 | 0.08 | 13,878 | 2.49 | 12,596 | 2.26 | 15,122 | 2.71 | 15,712 | 2.82 |
| D | AMB.LAID 220G 70x100cm.B/W | 0.30 | 0.05 | 8,318 | 1.31 | 6,935 | 1.10 | 9,053 | 1.43 | 8,993 | 1.42 |
| E | ACQ 200G 72x101cm. White | 0.20 | 0.05 | 8,759 | 1.91 | 7,809 | 1.70 | 9,377 | 2.04 | 9,233 | 2.01 |
| F | DUTCH B/W 300g 70x100cm | 0.30 | 0.12 | 8,489 | 1.77 | 7,318 | 1.53 | 11,915 | 2.48 | 9,000 | 1.88 |
| G | DCO 115g. 64x90cm. | 0.80 | 0.10 | 86,468 | 2.86 | 77,147 | 2.55 | 97,791 | 3.23 | 97,110 | 3.21 |
| H | MAJESTIC 290g 72x102cm. | 0.70 | 0.12 | 1,418 | 4.57 | 1,183 | 3.81 | 1,917 | 6.18 | 1,325 | 4.27 |
| I | SYMBOL PEARL 170g.70x100cm. | 0.90 | 0.03 | 1,996 | 8.65 | 1,669 | 7.23 | 2,058 | 8.92 | 1,812 | 7.85 |
| J | LINOVAC 175g. 78.7x109.2cm. Pink | 0.60 | 0.03 | 764 | 5.26 | 514 | 3.54 | 817 | 5.62 | 434 | 2.98 |

Referring to management policy which allocates capital investment for carrying inventory by allowing 3 months of sales inventory level, all scenarios of items "A", "B", "C", "D", "E", "F" which consist of high sales items, high growth items, moderate to stable demand items and less than 50% risk items, have average inventory level and months of sales within the limit 3 months of sales. Furthermore, a continuous review system (with opportunity cost "-") shows the lowest average inventory level and months of sales in these 6 items. However, the company should not apply a continuous review system (with opportunity cost "-") to items "A", "B", "C", "D", "E", "F" because these items have risk less than 50%. Applying a continuous review system (with opportunity cost "-") will limit the opportunity to sell more and generate more profit.

Items "A", "D", "E", "F" which have a risk of being unsold between 10% - 30%, and 3% - 12% chance to sell more, should apply a continuous review system (with opportunity cost "+") to increase the chance to sell more and increase profitability.

Items "B", "C" which have a risk of being unsold between 40% - 50%, and 8% chance to sell more, should apply a continuous review system (the order quantity) in order to balance between risk and the chance to sell the product.

For items "G", "H", "I", "J" which consist lumpy demand items, low growth items and more than 50% risk items, have average inventory level and months of sales of more than 3 months. Applying a continuous review system (with opportunity cost "-") will lower inventory cost and increase profitability.

3. Comparing the result of each scenario by item

Item A: IMPRESSION2000 CB WHITE 55G.24x36"

Step 1: Collecting data, demand of item from Jul 2006 to Jun 2007, total 12 months

| IMPRESSION2000 | Jul | Aug | Sep | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Avg Demand | Std Deviation |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sales | 482,505 | 539,387 | 473,409 | 626,951 | 577,387 | 650,033 | 606,200 | 516,110 | 765,676 | 706,239 | 970,840 | 890,545 | 650,440 | 157,960 |

Step 2: Calculation and result of each scenario

Scenario # 1 Continuous (Perpetual) Review System

Scenario #1.1 Q by the order quantity

| Continuous Review System (The Order Quantity) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Lead time (3Mths) | Safety Stock | Avg DD during LT | Reorder Level s | Q | Order-up-to level | Avg. Inv Level | Months for Sales | Avg. Inv Cost |
| sqrt 3 | Z 90% = 1.29 | L x AVG | Z 90% = 1.29 | | S = Q+s | Z 90% = 1.29 | Z 90% = 1.29 | Z 90% = 1.29 |
| 1.73 | 352,937 | 1,951,321 | 2,304,258 | 187,432 | 2,491,689 | 446,653 | 0.69 | 661,578 |

Scenario #1.2.1 Q with opportunity cost (-) : $O_1$

| | | Continuous Review System (with Opportunity " ") | | | | | | |
|---|---|---|---|---|---|---|---|---|
| CO1 | Q | Safety Stock | Avg DD during LT | Reorder Level s | Order-up-to level | Avg. Inv Level | Months for Sales | Avg. Inv Cost |
| | Z 90% = 1.29 | | L x AVG | Z 90% = 1.29 | S = Q+s | Z 90% = 1.29 | | |
| 0.15 | 145,184 | 352,937 | 1,951,321 | 2,304,258 | 2,449,442 | 425,529 | 0.65 | 630,289 |

Scenario #1.2.2 Q with opportunity cost (+) : 02

| Continuous Review System (will Opportunity " + "j': | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| CO2 | Q | Safety Stock | Avg DD during LT | Reorder Level s | Order-up-to level | Avg. Inv Level | Months for Sales | Avg. Inv Cost |
| | | Z 90% = 1.29 | L x AVG | Z 90% = 1.29 | S = Q+s | Z 90% = 1.29 | | |
| 0.04 | 209,555 | 352,937 | 1,951,321 | 2,304,258 | 2,513,813 | 457,715 | 0.70 | 677.962 |

Scenario # 2 Periodic Review System

| Periodic Review System | | | | | |
|---|---|---|---|---|---|
| Next Order Arrive | base-stock level | Safety Stock | Avg. Inv Level | Months for Sales | Avg. Inv Cost |
| r + L | | Z 90% = 1.29 | Z 90% = 1.29 | Z 90% = 1.29 | Z 90% = 1.29 |
| 4.00 | 2,601,761 | 407,537 | 732,757 | 1.13 | 1,085,352 |

Scenario #1.1: Q = 187, 432 sheets, average inventory level is 446,653 sheets

Scenario #1.2.1: Q = 145, 184 sheets, average inventory level is 425,529 sheets

Scenario #1.2.2: Q = 209, 555 sheets, average inventory level is 457,715 sheets

Scenario #2: average inventory level is 723,757 sheets

Item A: IMPRESSION2000 CB White is the highest sales volume item of the company. All scenarios show the average inventory level between 0.65 – 1.13 months for sales. Since item "A" has high sales volume, a 10% risk of being unsold, with a 3% chance to sell more if holding more inventory, then the company should use a continuous review system (with opportunity cost "+") as its ordering policy.

Item B: COMET 250g. 72x102cm. White

Step 1: Collecting data demand of item from Jul 2006 to Jun 2007, total 12 months

| COMET 250g. 72x1 | Jul | Aug | Sep | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Avg Demand | Std Deviation |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sales | 9,798 | 1,542 | 8,976 | 1,975 | 6,645 | 1,886 | 966 | 608 | 2,711 | 6,566 | 1,638 | 1,195 | 3,709 | 3,322 |

Step 2: Calculation and result of each scenario

Scenario # 1 Continuous (Perpetual) Review System

Scenario #1.1 Q by the order quantity

| Continuous Review System (The Order Quantity) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Lead time (3Mths) | Safety Stock | Avg DD during LT | Reorder Level s | Q | Order-up-to level | Avg. Inv Level | Months for Sales | Avg. Inv Cost |
| sqrt 3 | Z 90%= 1.29 | L x AVG | Z 90%= 1.29 | | S = Q+s | Z 90%= 1.29 | Z 90%= 1.29 | Z 90%= 1.29 |
| 1.73 | 7,422 | 11,127 | 18,548 | 3,740 | 22,289 | 9,292 | 2.51 | 197,076 |

Scenario #1.2.1 Q with opportunity cost (-) : 01

| | | Continuous Review System (with Opportunity " ) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| CO1 | Q | Safety Stock | Avg DD during LT | Reorder Level s | Order-up-to level | Avg. Inv Level | Months for Sales | Avg. Inv Cost |
| | | Z 90% = 1.29 | L x AVG | Z 90% = 1.29 | S = Q+s | Z 90% = 1.29 | | |
| 10.60 | 1,797 | 7,422 | 11,127 | 18,548 | 20,345 | 8,320 | 2.24 | 176,466 |

Scenario #1.2.2 Q with opportunity cost (+) : 02

| | | Continuous Review System (with Opportunity " · " | | | | | | |
|---|---|---|---|---|---|---|---|---|
| CO2 | Q | Safety Stock | Avg DD during LT | Reorder Level s | Order-up-to level | Avg. Inv Level | Months for Sales | Avg. Inv Cost |
| | | Z 90% = 1.29 | Lx AVG | Z 90% = 1.29 | S = Q+s | Z 90% = 1.29 | | |
| 1.70 | 5,475 | 7,422 | 11,127 | 18,548 | 24,024 | 10,159 | 2.74 | 215,474 |

Scenario # 2 Periodic Review System

| Periodic Review System | | | | | |
|---|---|---|---|---|---|
| Next Order Arrive | base-stock level | Safety Stock | Avg. Inv Level | Months for Sales | Avg. Inv Cost |
| r + L | | Z 90% = 1.29 | Z 90% = 1.29 | Z 90% = 1.29 | Z 90% = 1.29 |
| 4.00 | 14,835 | 8,570 | 10,424 | 2.81 | 221,094 |

Scenario #1.1: Q = 3, 740 sheets, average inventory level is 9,292 sheets

Scenario #1.2.1: Q = 1, 797 sheets, average inventory level is 8,320 sheets

Scenario #1.2.2: Q = 5, 475 sheets, average inventory level is 10,159 sheets

Scenario #2: average inventory level is 10,424 sheets

Item B: COMET 250g. 72x102cm. White is metallic paper which has lumpy demand. All scenarios show the average inventory level between 2.24 – 2.81 months for sales. Since item "B" has high potential while the demand is low in some months, a 50% risk of neing

unsold, with a 8% chance to sell more if holding more inventory, the company should use a continuous review system (the order quantity) as its ordering policy.

Item C: ACQ STUCCO 72x101cm.

Step 1: Collecting data, demand of item from Jul 2006 to Jun 2007, total 12 months

| ACQ STUCCO 72x | Jul | Aug | Sep | Oct | Nov | Dec | n | Feb | Mar | Apr | May | Jun | Avg Demand | Std Deviation |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sales | 1,903 | (20) | 16,665 | (1,737) | 10,954 | 8,386 | 8,525 | 5,496 | 3,760 | 3,892 | 5,215 | 3,820 | 5,572 | 5,010 |

Step 2: Calculation and result of each scenario

Scenario # 1 Continuous (Perpetual) Review System

Scenario #1.1 Q by the order quantity

| Continuous Review System (The Order Quantity) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Lead time (3Mths) | Safety Stock | Avg DD during LT | Reorder Level s | Q | Order-up-to level | Avg. Inv Level | Months for Sales | Avg. Inv Cost |
| sqrt 3 | Z 90% = 1.29 | L x AVG | Z 90% = 1.29 | | S = Q+s | Z 90% = 1.29 | Z 90% = 1.29 | Z 90% = 1.29 |
| 1.73 | 11,194 | 16,715 | 27,909 | 5,367 | 33,276 | 13,878 | 2.49 | 214,777 |

Scenario #1.2.1 Q with opportunity cost (-) : $O_1$

| | | Continuous Review System (with Opportunity "-") | | | | | | |
|---|---|---|---|---|---|---|---|---|
| CO1 | Q | Safety Stock | Avg DD during LT | Reorder Level s | Order-up-to level | Avg. Inv Level | Months for Sales | Avg. Inv Cost |
| | | Z 90% = 1.29 | L x AVG | Z 90% = 1.29 | S = Q+s | Z 90% = 1.29 | | |
| 6.19 | 2,803 | 11,194 | 16,715 | 27,909 | 30,712 | 12,596 | 2.26 | 194,937 |

Scenario #1.2.2 Q with opportunity cost (+) : 02

| | | 'Continuous Review system (with Opportunity "+") | | | | | | |
|---|---|---|---|---|---|---|---|---|
| CO2 | Q | Safety Stock | Avg DD during LT | Reorder Level s | Order-up-to level | Avg. Inv Level | Months for Sales | Avg. Inv Cost |
| | | Z 90% = 1.29 | L x AVG | Z 90% = 1.29 | S = Q+s | Z 90% = 1.29 | | |
| 1.24 | 7,856 | 11,194 | 16,715 | 27,909 | 35,765 | 15,122 | 2.71 | 234.040 |

Scenario # 2 Periodic Review System

| Periodic Review System | | | | | |
|---|---|---|---|---|---|
| Next Order Arrive | base-stock level | Safety Stock | Avg. Inv Level | Months for Sales | Avg. Inv Cost |
| r + L | | Z 90% = 1.29 | Z 90% = 1.29 | Z 90% = 1.29 | Z 90% = 1.29 |
| 4.00 | 22,286 | 12,926 | 15,712 | 2.82 | 243,165 |

Scenario #1.1: Q = 5, 367 sheets, average inventory level is 13,878 sheets

Scenario #1.2.1: Q = 2,803 sheets, average inventory level is 12,596 sheets

Scenario #1.2.2: Q = 7,856 sheets, average inventory level is 15,122 sheets

Scenario #2: average inventory level is 15,712 sheets

Item C: ACQ STUCCO 72x101cm. is metallic paper which has lumpy demand. All scenarios show the average inventory level between 2.26 – 2.82 months for sales. Since item "C" has high potential while the demand is low in some months, has a 40% risk of being unsold, with a 8% chance to sell more if holding more inventory, then the company should use a continuous review system (the order quantity) as its ordering policy.

Item D: AMB.LAID 220G 70x100cm.B/W

Step 1: Collecting data, demand of item from Jul 2006 to Jun 2007, total 12 months

| AMB.LAID 220G 7 | Jul | Aug | Sep | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Avg Demand | Std Deviation |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sales | 4,127 | 7,545 | 6,524 | 9,343 | 5,945 | 7,072 | 3,577 | 3,141 | 8,516 | 8,736 | 3,394 | 8,070 | 6,333 | 2,258 |

Step 2: Calculation and result of each scenario

Scenario # 1 Continuous (Perpetual) Review System

Scenario #1.1 Q by the order quantity

| Continuous Review System (The Order Quantity) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Lead time (3Mths) | Safety Stock | Avg DD during LT | Reorder Level s | Q | Order-up-to level | Avg. Inv Level | Months for Sales | Avg. Inv Cost |
| sqrt 3 | Z 90% = 1.29 | L x AVG | Z 90% = 1.29 | | S = Q+s | Z 90% = 1.29 | Z 90% = 1.29 | Z 90% = 1.29 |
| 1.73 | 5,046 | 18,998 | 24,044 | 6,544 | 30,588 | 8,318 | 1.31 | 98,408 |

Scenario #1.2.1 Q with opportunity cost (-) : 01

| | | Continuous Review System (with Opportunity "-") | | | | | | |
|---|---|---|---|---|---|---|---|---|
| CO1 | Q | Safety Stock | Avg DD during LT | Reorder Level s | Order-up-to level | Avg. Inv Level | Months for Sales | Avg. Inv Cost |
| | | Z 90% = 1.29 | L x AVG | Z 90% = 1.29 | S = Q+s | Z 90% = 1.29 | | |
| 3.55 | 3,778 | 5,046 | 18,998 | 24,044 | 27,822 | 6,935 | 1.10 | 82,048 |

Scenario #1.2.2 Q with opportunity cost (+) : 02

| | | Continuous Review System (will Opportunity "+") | | | | | | |
|---|---|---|---|---|---|---|---|---|
| CO2 | Q | Safety Stock | Avg DD during LT | Reorder Level s | Order-up-to level | Avg. Inv Level | Months for Sales | Avg. Inv Cost |
| | | Z 90% = 1.29 | L x AVG | Z 90% = 1.29 | S = Q+s | Z 90% = 1.29 | | |
| 0.59 | 8,014 | 5,046 | 18,998 | 24,044 | 32,058 | 9,053 | 1.43 | 107.108 |

Scenario # 2 Periodic Review System

| Periodic Review System | | | | | |
|---|---|---|---|---|---|
| Next Order Arrive | base-stock level | Safety Stock | Avg. Inv Level | Months for Sales | Avg. Inv Cost |
| r + L | | Z 90% = 1.29 | Z 90% = 1.29 | Z 90% = 1.29 | Z 90% = 1.29 |
| 4.00 | 25,330 | 5,827 | 8,993 | 1.42 | 106,394 |

Scenario #1.1: Q = 6,544 sheets, average inventory level is 8,318 sheets

Scenario #1.2.1: Q = 3,778 sheets, average inventory level is 6,935 sheets

Scenario #1.2.2: Q = 8,014 sheets, average inventory level is 9,053 sheets

Scenario #2: average inventory level is 8,993 sheets

Item D: AMB.LAID 220G 70x100cm. Brilliant White has moderate demand. All scenarios show the average inventory level between 1.10 – 1.43 months for sales. Since item "D" has low risk of being unsold and the demand trend will be more stable, has a 30% risk of being unsold with 5a % chance to sell more if holding more inventory, then the company should use a continuous review system (with opportunity cost "+") as its ordering policy.

Item E: ACQ 200G 72x101cm. White

Step 1: Collecting data demand of item from Jul 2006 to Jun 2007, total 12 months

| ACQ 200G 72x101c | Jul | Aug | Sep | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Avg Demand | Std Deviation |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sales | 2,015 | 3,583 | 4,795 | 5,846 | 9,407 | 4,890 | 4,818 | 1,635 | 2,135 | 3,958 | 2,272 | 9,728 | 4,590 | 2,689 |

Step 2: Calculation and result of each scenario

Scenario # 1 Continuous (Perpetual) Review System

Scenario #1.1 Q by the order quantity

| Continuous Review System (The Order Quantity) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Lead time (3Mths) | Safety Stock | Avg DD during LT | Reorder Level s | Q | Order-up-to level | Avg. Inv Level | Months for Sales | Avg. Inv Cost |
| sqrt 3 | Z 90%= 1.29 | L x AVG | Z 90%= 1.29 | | S = Q+s | Z 90%= 1.29 | Z 90%= 1.29 | Z 90%= 1.29 |
| 1.73 | 6,008 | 13,771 | 19,779 | 5,502 | 25,280 | 8,759 | 1.91 | 106,270 |

Scenario #1.2.1 Q with opportunity cost (-) : 01

| Continuous Review System (with Opportunity "-") | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| COI | Q | Safety Stock | Avg DD during LT | Reorder Level s | Order-up-to level | Avg. Inv Level | Months for Sales | Avg. Inv Cost |
| | | Z 90% = 1.29 | L x AVG | Z 90% = 1.29 | S = Q+s | Z 90% = 1.29 | | |
| 2.43 | 3,602 | 6,008 | 13,771 | 19,779 | 23,380 | 7,809 | 1.70 | 94,744 |

Scenario #1.2.2 Q with opportunity cost (+) : 02

| • Continuous Review System (with Opportunity | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| CO2 | Q | Safety Stock | Avg DD during LT | Reorder Level s | Order-up-to level | Avg. Inv Level | Months for Sales | Avg. Inv Cost |
| | | Z 90% = 1.29 | L x AVG | Z 90% = 1.29 | S = Q+s | Z 90% = 1.29 | | |
| 0.61 | 6,738 | 6,008 | 13,771 | 19,779 | 26,517 | 9,377 | 2.04 | 113.770 |

Scenario # 2 Periodic Review System

| Periodic Review System | | | | | |
|---|---|---|---|---|---|
| Next Order Arrive | base-stock level | Safety Stock | Avg. Inv Level | Months for Sales | Avg. Inv Cost |
| r + L | | Z 90% = 1.29 | Z 90% = 1.29 | Z 90% = 1.29 | Z 90% = 1.29 |
| 4.00 | 18,361 | 6,938 | 9,233 | 2.01 | 112,018 |

Scenario #1.1: Q = 5, 502 sheets, average inventory level is 8,759 sheets

Scenario #1.2.1: Q = 3,602 sheets, average inventory level is 7,809 sheets

Scenario #1.2.2: Q = 6,738 sheets, average inventory level is 9,377 sheets

Scenario #2: average inventory level is 9,233 sheets

Item E: ACQ 200G 72x101cm. White has moderate demand. All scenarios show the average inventory level between 1.70 – 2.04 months for sales. Since item "E" has low risk of being unsold and the demand trend will be more stable, has a 20% risk of being unsold with a 5% chance to sell more if holding more inventory, the company should use a continuous review system (with opportunity cost "+") as its ordering policy.

Item F: DUTCH B/W 300g 70x100cm.

Step 1: Collecting data, demand of item from Jul 2006 to Jun 2007, total 12 months

| DUTCH B/W 300g | Jul | Aug | Sep | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Avg Demand | Std Deviation |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sales | 6,859 | 4,164 | 3,908 | 11,557 | 5,286 | 4,077 | 5,193 | 2,623 | 3,953 | 5,195 | 3,513 | 1,229 | 4,796 | 2,559 |

Step 2: Calculation and result of each scenario

Scenario # 1 Continuous (Perpetual) Review System

Scenario #1.1 Q by the order quantity

| Continuous Review System (The Order Quantity) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Lead time (3Mths) | Safety Stock | Avg DD during LT | Reorder Level s | Q | Order-up-to level | Avg. Inv Level | Months for Sales | Avg. Inv Cost |
| sqrt 3 | Z 90% = 1.29 | L x AVG | Z 90% = 1.29 | | S = Q+s | Z 90% = 1.29 | Z 90% = 1.29 | Z 90% = 1.29 |
| 1.73 | 5,718 | 14,389 | 20,107 | 5,543 | 25,650 | 8,489 | 1.77 | 106,011 |

Scenario #1.2.1 Q with opportunity cost (-) : 01

| | | Continuous Review System (with Opportunity" | | | | | | |
|---|---|---|---|---|---|---|---|---|
| CO1 | Q | Safety Stock | Avg DD during LT | Reorder Level s | Order-up-to level | Avg. Inv Level | Months for Sales | Avg. Inv Cost |
| | Z 90% = 1.29 | | L x AVG | Z 90% = 1.29 | S = Q+s | Z 90% = 1.29 | | |
| 3.75 | 3,200 | 5,718 | 14,389 | 20,107 | 23,307 | 7,318 | 1.53 | 91,383 |

Scenario #1.2.2 Q with opportunity cost (+) : 02

| | | Continuous Review System (with Opportunity "+") | | | | | | |
|---|---|---|---|---|---|---|---|---|
| CO2 | Q | Safety Stock | Avg DD during LT | Reorder Level s | Order-up-to level | Avg. Inv Level | Months for Sales | Avg. Inv Cost |
| | | Z 90% = 1.29 | L x AVG | Z 90% = 1.29 | S = Q+s | Z 90% = 1.29 | | |
| 1.50 | 12,395 | 5,718 | 14,389 | 20,107 | 32,502 | 11,915 | 2.48 | 148,793 |

Scenario # 2 Periodic Review System

| Periodic Review System | | | | | |
|---|---|---|---|---|---|
| Next Order Arrive | base-stock level | Safety Stock | Avg. Inv Level | Months for Sales | Avg. Inv Cost |
| r + L | | Z 90% = 1.29 | Z 90% = 1.29 | Z 90% = 1.29 | Z 90% = 1.29 |
| 4.00 | 19,186 | 6,602 | 9,000 | 1.88 | 112,394 |

Scenario #1.1: Q = 5, 543 sheets, average inventory level is 8,489 sheets

Scenario #1.2.1: Q = 3,200 sheets, average inventory level is 7,318 sheets

Scenario #1.2.2: Q = 12, 395 sheets, average inventory level is 11,915 sheets

Scenario #2: average inventory level is 9,000 sheets

Item F: DUTCH B/W 300g 70x100cm. is smooth paper which has lumpy demand. All scenarios show the average inventory level between 1.53 – 2.48 months for sales. Since item "F" has high potential while the demand is low in some months, a 30% risk of unsold with 12% chance to sell more if holding more inventory, the company should use a continuous review system (with opportunity cost "+") as its ordering policy.

Item G: DCO 115g. 64x90cm.

Step 1: Collecting data, demand of item from Jul 2006 to Jun 2007, total 12 months

| DCO 115g. 64x90cr | Jul | Aug | Sep | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Avg Demand | Std Deviation |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sales | 1,210 | 540 | 255 | 1,941 | 68,507 | 77,000 | - | 51,760 | 77,150 | 23,540 | 44,846 | 16,250 | 30,250 | 31,777 |

Step 2: Calculation and result of each scenario

Scenario # 1 Continuous (Perpetual) Review System

Scenario #1.1 Q by the order quantity

| Continuous Review System (The Order Quantity) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Lead time (3Mths) | Safety Stock | Avg DD during LT | Reorder Level s | Q | Order-up-to level | Avg. Inv Level | Months for Sales | Avg. Inv Cost |
| sqrt 3 | Z 90%= 1.29 | L x AVG | Z 90%= 1.29 | | S = Q+s | Z 90%= 1.29 | Z90%= 1.29 | Z 90%= 1.29 |
| 1.73 | 71,001 | 90,750 | 161,751 | 30,934 | 192,685 | 86,468 | 2.86 | 218,672 |

Scenario #1.2.1 Q with opportunity cost (-) : 01

| Continuous Review System (with Opportunity " ") | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| COI | Q | Safety Stock | Avg DD during LT | Reorder Level s | Order-up-to level | Avg. Inv Level | Months for Sales | Avg. Inv Cost |
| | | Z 90% = 1.29 | Lx AVG | Z 90% = 1.29 | S = Q+s | Z 90% = 1.29 | | |
| 2.02 | 12,292 | 71,001 | 90,750 | 161,751 | 174,043 | 77,147 | 2.55 | 195,100 |

Scenario #1.2.2 Q with opportunity cost (+) : 02

| Continuous Review System (with Opportunity | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| CO2 | Q | Safety Stock | Avg DD during LT | Reorder Level s | Order-up-to level | Avg. Inv Level | Months for Sales | Avg. Inv Cost |
| | | Z 90% = 1.29 | L x AVG | Z 90% = 1.29 | S = Q+s | Z 90% = 1.29 | | |
| 0.25 | 53,580 | 71,001 | 90,750 | 161,751 | 215,331 | 97,791 | 3.23 | 247,307 |

Scenario # 2 Periodic Review System

| Periodic Review System | | | | | |
|---|---|---|---|---|---|
| Next Order Arrive | base-stock level | Safety Stock | Avg. Inv Level | Months for Sales | Avg. Inv Cost |
| r + L | | Z 90% = 1.29 | Z 90% = 1.29 | Z 90% = 1.29 | Z 90% = 1.29 |
| 4.00 | 121,000 | 81,985 | 97,110 | 3.21 | 245,585 |

Scenario #1.1: Q = 30, 934 sheets, average inventory level is 86,468 sheets

Scenario #1.2.1: Q = 12,292 sheets, average inventory level is 77,147 sheets

Scenario #1.2.2: Q = 53,580 sheets, average inventory level is 97,791 sheets

Scenario #2: average inventory level is 97,110 sheets

Item G: DCO 115g. 64x90cm. is recycle paper which has lumpy demand. All scenarios show the average inventory level between 2.55 – 3.23 months for sales. Since item "G"

has high unsellable risk and the demand is low in some months, but a 80% risk of unsold with 10% chance to sell more if holding more inventory, then the company should use a continuous review system (with opportunity cost "-") as its ordering policy.

Item H: MAJESTIC 290g 72x102cm. Anthracite

Step 1: Collecting data demand of item from Jul 2006 to Jun 2007, total 12 months

| MAJESTIC 290g 72 | Jul | Aug | Sep | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Avg Demand | Std Deviation |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sales | 621 | 18 | 520 | 441 | 5 | 75 | 302 | 6 | 1,565 | 22 | 3 | 146 | 310 | 454 |

Step 2: Calculation and result of each scenario

Scenario # 1 Continuous (Perpetual) Review System

Scenario #1.1 Q by the order quantity

| Continuous Review System (The Order Quantity) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Lead time (3Mths) | Safety Stock | Avg DD during LT | Reorder Level s | Q | Order-up-to level | Avg. Inv Level | Months for Sales | Avg. Inv Cost |
| sqrt 3 | Z 90% = 1.29 | L x AVG | Z 90% = 1.29 | | S = Q+s | Z 90% = 1.29 | Z 90% = 1.29 | Z 90% = 1.29 |
| 1.73 | 1,013 | 931 | 1,944 | 808 | 2,753 | 1,418 | 4.57 | 53,853 |

Scenario #1.2.1 Q with opportunity cost (-) : $O_1$

| Continuous Review System (with Opportunity " ") | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| CO1 | Q | Safety Stock | Avg DD during LT | Reorder Level s | Order-up-to level | Avg. Inv Level | Months for Sales | Avg. Inv Cost |
| | Z 90% = 1.29 | | L x AVG | Z 90% = 1.29 | S = Q+s | Z 90% = 1.29 | | |
| 26.59 | 340 | 1,013 | 931 | 1,944 | 2,284 | 1,183 | 3.81 | 44,949 |

Scenario #1.2.2 Q with opportunity cost (+) : 02

| Continuous Review System (with Opportunity " ") | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| CO2 | Q | Safety Stock | Avg DD during LT | Reorder Level s | Order-up-to level | Avg. Inv Level | Months for Sales | Avg. Inv Cost |
| | Z 90% = 1.29 | | L x AVG | Z 90% = 1.29 | S = Q+s | Z 90% = **1.29** | | |
| **4.56** | **1,808** | **1,013** | **931** | **1,944** | **3,752** | **1,917** | **6.18** | **72,833** |

Scenario # 2 Periodic Review System

| Periodic Review System | | | | | |
|---|---|---|---|---|---|
| Next Order Arrive | base-stock level | Safety Stock | Avg. Inv Level | Months for Sales | Avg. Inv Cost |
| r + L | | Z 90% = 1.29 | Z 90% = 1.29 | Z 90% = 1.29 | Z 90% = 1.29 |
| 4.00 | 1,241 | 1,170 | 1,325 | 4.27 | 50,348 |

Scenario #1.1: Q = 808 sheets, average inventory level is 1,418 sheets

Scenario #1.2.1: Q = 340 sheets, average inventory level is 1,183 sheets

Scenario #1.2.2: Q = 1,808 sheets, average inventory level is 1,917 sheets

Scenario #2: average inventory level is 1,325 sheets

Item H: MAJESTIC 290g 72x102cm. Anthracite is metallic paper which has lumpy demand. All scenarios show the average inventory level between 3.81 – 6.18 months for sales. Since item "H" has a high unsold risk and the demand is low in some months, but 70% risk of unsold with a 12% chance to sell more if holding more inventory, the company should use a continuous review system (with opportunity cost "-") as its ordering policy.

Item I: SYMBOL PEARL 170g.70x100cm. White

Step 1: Collecting data demand of item from Jul 2006 to Jun 2007, total 12 months

| SYMBOL PEARL 1 | Jul | Aug | Sep | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Aug Demand | std Deviation |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sales | 5 | - | 1 | 1,753 | 1,352 | (640) | (150) | 33 | 74 | 170 | 1 | 170 | 231 | 658 |

Step 2: Calculation and result of each scenario

Scenario # 1 Continuous (Perpetual) Review System

Scenario #1.1 Q by the order quantity

| Continuous Review System (The Order Quantity) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Lead time (3Mths) | Safety Stock | Avg DD during LT | Reorder Level s | Q | Order-up-to level | Avg. Inv Level | Months for Sales | Avg. Inv Cost |
| sqrt 3 | Z 90% = 1.29 | L x AVG | Z 90% = 1.29 | | S = Q+s | Z 90% = 1.29 | Z 90% = 1.29 | Z 90% = 1.29 |
| 1.73 | 1,470 | 692 | 2,162 | 1,053 | 3,215 | 1,996 | 8.65 | 33,209 |

Scenario #1.2.1 Q with opportunity cost (-) : $O_1$

| | | Continuous Review System (with Opportunity " 1 | | | | | | |
|---|---|---|---|---|---|---|---|---|
| CO1 | Q | Safety Stock | Avg DD during LT | Reorder Level s | Order-up-to level | Avg. Inv Level | Months for Sales | Avg. Inv Cost |
| | | Z 90% = 1.29 | L x AVG | Z 90% = 1.29 | S = Q+s | Z 90% = 1.29 | | |
| 14.97 | 398 | 1,470 | 692 | 2,162 | 2,560 | 1,669 | 7.23 | 27,759 |

Scenario #1.2.2 Q with opportunity cost (+) : 02

| | | Continu us Review System (witl Opportun ty " + ") | | | | | | |
|---|---|---|---|---|---|---|---|---|
| CO2 | Q | Safety Stock | Avg DD during LT | Reorder Level s | Order-up-to level | Avg. Inv Level | Months for Sales | Avg. Inv Cost |
| | | Z 90% = 1.29 | L x AVG | Z 90% = 1.29 | S = Q+s | Z 90% = 1.29 | | |
| 0.50 | 1,178 | 1,470 | 692 | 2,162 | 3,340 | 2,058 | 8.92 | 34,243 |

Scenario # 2 Periodic Review System

| Periodic Review System | | | | | |
|---|---|---|---|---|---|
| Next Order Arrive | base-stock level | Safety Stock | Avg. Inv Level | Months for Sales | Avg. Inv Cost |
| r + L | | Z 90% = 1.29 | Z 90% = 1.29 | Z 90% = 1.29 | Z 90% = 1.29 |
| 4.00 | 923 | 1,697 | 1,812 | 7.85 | 30,148 |

Scenario #1.1: Q*= 1,053 sheets, average inventory level is 1,996 sheets

Scenario #1.2.1: Q = 398 sheets, average inventory level is 1,669 sheets

Scenario #1.2.2: Q = 1,178 sheets, average inventory level is 2,058 sheets

Scenario #2: average inventory level is 1,812 sheets

Item I: SYMBOL PEARL 170g.70x100cm. White is metallic paper which has lumpy demand. All scenarios show the average inventory level between 7.23 – 8.92 months for sales. Since item "I" has high unsold risk and the demand is low in some months, but a 90% risk of unsold with 3% chance to sell more if holding more inventory, the company should use a continuous review system (with opportunity cost "-") as its ordering policy.

Item J: LINOVAC 175g. 78.7x109.2cm. Pink

Step 1: Collecting data, demand of item from Jul 2006 to Jun 2007, total 12 months

| LINOVAC 175g. 78 | Jul | Aug | Sep | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Avg Demand | Std Deviation |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sales | (50) | 427 | 110 | 135 | 118 | 100 | 250 | 372 | 15 | 33 | 107 | 127 | 145 | 140 |

Step 2: Calculation and result of each scenario

Scenario # 1 Continuous (Perpetual) Review System

Scenario #1.1 Q by the order quantity

| Continuous Review System (The Order Quantity) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Lead time (3Mths) | Safety Stock | Avg DD during LT | Reorder Level s | Q | Order-up-to level | Avg. Inv Level | Months for Sales | Avg. Inv Cost |
| sqrt 3 | Z 90% = 1.29 | L x AVG | Z 90% = 1.29 | | S = Q+s | Z 90% = 1.29 | Z 90% = 1.29 | Q 90% = 1.29 |
| 1.73 | 313 | 436 | 749 | 902 | 1,651 | 764 | 5.26 | 10,908 |

Scenario #1.2.1 Q with opportunity cost (-) : $O_1$

| Continuous Review System (with Opportunity " ) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| CO1 | Q | Safety Stock | Avg DD during LT | Reorder Level s | Order-up-to level | Avg. Inv Level | Months for Sales | Avg. Inv Cost |
| | | Z 90% = 1.29 | L x AVG | Z 90% = 1.29 | S = Q+s | Z 90% = 1.29 | | |
| 8.57 | 404 | 313 | 436 | 749 | 1,152 | 514 | 3.54 | 7,346 |

Scenario #1.2.2 Q with opportunity cost (+) : 02

| Continuous Review System (with Opportunity " ) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| CO2 | Q | Safety Stock | Avg DD during LT | Reorder Level s | Order-up-to level | Avg. Inv Level | Months for Sales | Avg. Inv Cost |
| | | Z 90% = 1.29 | L x AVG | Z 90% = 1.29 | S = Q+s | Z 90% = 1.29 | | |
| 0.43 | 1,009 | 313 | 436 | 749 | 1,757 | 817 | 5.62 | 11,668 |

Scenario # 2 Periodic Review System

| Periodic Review System | | | | | |
|---|---|---|---|---|---|
| Next Order Arrive | base-stock level | Safety Stock | Avg. Inv Level | Months for Sales | Avg. Inv Cost |
| r + L | | Z 90% = 1.29 | Z 90% = 1.29 | Z 90% = 1.29 | Z 90% = 1.29 |
| 4.00 | 581 | 361 | 434 | 2.98 | 6,194 |

Scenario #1.1: Q = 902 sheets, average inventory level is 764 sheets

Scenario #1.2.1: Q = 404 sheets, average inventory level is 514 sheets

Scenario #1.2.2: Q = 1,009 sheets, average inventory level is 817 sheets

Scenario #2: average inventory level is 434 sheets

Item J: LINOVAC 175g. 78.7x109.2cm. Pink has lumpy demand. All scenarios show the average inventory level between 2.98 – 5.62 months for sales. Since item "J" has high unsold risk and the demand is low in some months, but a 60% risk of unsold with 3% chance to sell more if holding more inventory, the company should use a continuous review system (with opportunity cost "-") as its ordering policy.

**4. Improvement of Average Inventory Cost**

Table 4.3: Compare and Improvement of Average Inventory Cost between the existing model and a new model

| Item | Product Name | Avg current Months of sales | Avg Current Inv Cost | Continuous Review System (The Order Quantity) | Continuous Review System (with Opportunity ...") | Continuous Review System (with Opportunity ...") | Periodic Review System | Avg New Model Inv Cost | Improvement % |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Avg. Inv Cost (B) | | | | | |
| A | IMPRESSION2000 | 3.00 | 2,890,276 | | | 677,962 | | 677,962 | 76.54 |
| B | COMET 250g. 72x102cm. White | 3.00 | 235,985 | 197,076 | | | | 197,076 | 16.49 |
| C | ACQ STUCCO 72x101cm. | 3.00 | 258,683 | 214,777 | | | | 214,777 | 16.97 |
| D | AMB.LAID 220G 70x100cm.B/W | 3.00 | 224,752 | | | 107,108 | | 107,108 | 52.34 |
| E | ACQ 200G 72x101cm. White | 3.00 | 167,072 | | | 113,770 | | 113,770 | 31.90 |
| F | DUTCH B/W 300g 70x100cm | 3.00 | 179,689 | | | 148,793 | | 148,793 | 17.19 |
| G | DCO I 15g. 64x90cm. | 3.50 | 267,750 | | 195,100 | | | 195,100 | 27.13 |
| H | MAJESTIC 290g 72x102cm. | 4.00 | 47,155 | | 44,949 | | | 44,949 | 4.68 |
| I | SYMBOL PEARL 170g.70x100cm. | 5.00 | 19,193 | | 27,759 | | | 27,759 | (44.63) |
| J | LINOVAC 175g. 78.7x109.2cm. Pink | 5.00 | 10,378 | | 7,346 | | | 7,346 | 29.21 |
| | Total | | 4,300,933 | 411,853 | 275,154 | 1,047,633 | | 1,734,640 | 59.67 |

If the company clusters items based on their characteristics and opportunity cost, it will be able to reduce average inventory cost of 59.67% or 2,566,193 Baht/Year.

# CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS

## 1. Conclusions

In most items of specialty paper, demand is not known and constant. However, if the company studies the characteristic of each item on a quarterly or annual basis, the company will be able to group or cluster those items.

For items "A", "D", "E", "F" which have characteristics of high sales, moderate to stable demand, with a risk of being unsold between 10% - 30% and a 3% - 12% chance to sell more, the company should apply a continuous review system (with opportunity cost "+") to increase the chance to sell more and increase profitability.

For item "B", "C" which high growth, moderate demand, have a risk of being unsold between 40% - 50% and an 8% chance to sell more, the company should apply a continuous review system (the order quantity) in order to balance between risk and the chance to sell the product.

For items "G", "H", "I", "J" which are lumpy demand items, having low growth, a risk of being unsold between 60% - 90% and a 3% - 12% chance to sell more, the company should apply a continuous review system (with opportunity cost "-") to lower inventory cost and increase profitability.

The result from each scenario can be used as an indicative idea to select an ordering policy based on the characteristics of each item which can improve average inventory cost of 59.67%. However, the result might be changed depending on the conservative or aggressive way of doing business by the company.

## 2. Recommendations

- None of the ordering policies shows the lowest inventory level in all items: each ordering policy show the outstanding result in specific characteristics or group of items. To specify the ordering policy based on each group of items will reduce inventory cost, and enhance the company's sales and profit.

- The company should apply a continuous review system as its order policy, which will result in lower level of inventory than the current system. In addition, customer satisfaction will also be guaranteed at a 90% service level.
- The company should check the readiness of its facility of ERP, process, manpower, etc., to support this new ordering policy. If current facilities cannot fully support the new policy, the company should study the trade-off between a continuous review system and a periodic review system as well as a management decision in investment in a new ERP system.
- The company should have a plan to review the ordering policy of each item, to ensure the suitability of each policy and an optimal level of inventory, since each item has a different product life cycle.

3. Limitations of the project

Cost

- Capital investment, storage location and operations may not immediate feasible to support the required change.
- This project focus concentrates on the ordering and holding costs for each item but does not take scrap cost into account.

Data

- Unpredictable demand pattern: demand is subject to users' preferences.
- Factors such as risk, growth chance, and average current inventory level, are estimated and make assumption based on experience.

Time

- Limitation of time to keep data for analysis. This project used data for a 24-month period, with the latest update being July 2007.

4. Future Research

This project studied only 10 items and use 12 months of data to design the ordering policy. Even though, those items were selected by ABC analysis, the result is only a preliminary idea and the result of other items might be different. In addition, there might

have been other factors that affect inventory cost. Therefore, future research should collect more data to be included in the calculation of each scenario in order to see the demand pattern of each item: and the result will be more precise. Future research should also study more about the parameters which affect to inventory policy and inventory management. With this additional study, the company might be able to confirm this project's result or achieve a better solution for the company.

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# APPENDIX

## Appendix: ABC Analysis

| Item | Product Name | 2005 Sale Amount | 2005 QTY | 2006 Sale Amount | 2006 QTY | % | Class |
|---|---|---|---|---|---|---|---|
| A | IMPRESSION2000 CB WHITE 55G.24x36" | 14,732,882 | 6,805,267 | 13,014,330 | 6,028,803 | | A |
| B | COMET 250g. 72x102cm. White | 1,272,813 | 29,255 | 2,644,507 | 62,479 | | A |
| C | ACQ STUCCO 72x101cm. | 1,254,729 | 47,237 | 2,423,695 | 94,674 | | A |
| D | AMB.LAID 220G 70x100cm.B/W | 1,991,523 | 71,174 | 2,116,313 | 75,230 | | A |
| E | ACQ 200G 72x101cm. White | 1,537,365 | 83,249 | 1,263,095 | 67,736 | | A |
| F | DUTCH B/W 300g 70x100cm | 452,366 | 17,731 | 1,142,290 | 46,339 | | A |
| G | DCO 115g. 64x90cm. | 773,608 | 150,028 | 1,121,706 | 215,017 | | A |
| H | MAJESTIC 290g 72x I 02cm. Anthracite | 135,296 | 1,655 | 131,583 | 1,936 | | B |
| I | SYMBOL PEARL 170g.70x100cm. White | 611,558 | 27,485 | 96,058 | 3,378 | | C |
| J | LINOVAC 175g. 78.7x109.2cm. Pink | 121,816 | 4,050 | 79,508 | 2,578 | | C |
| | Total | 99,722,055 | 22,906,378 | 104,472,755 | 21,905,042 | 100 | 237 |
| | CLASS A | 76,174,834 | 21,276,569 | 83,615,793 | 20,425,370 | 80.04 | 71 |
| | CLASS B | 15,371,667 | 1,127,432 | 15,659,223 | 1,221,546 | 14.99 | 67 |
| | CLASS C | 8,175,555 | 502,377 | 5,197,740 | 258,126 | 4.98 | 99 |