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INVENTORY MANAGEMENT SYSTEM:
CASE OF FAST MOVING AUTOMOTIVE SERVICE PARTS

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วิทยานิพนธ์นี้ได้พัฒนาการจัดการสินค้าคงคลังของอะไหล่บริการสำหรับผู้ผลิตยานยนต์ในประเทศไทย การพัฒนาเริ่มด้วยการศึกษาระบบปัจจุบันของสินค้าคงคลังและพบว่าระบบปัจจุบันยังไม่มีประสิทธิภาพเพียงพอในการจัดการระดับสินค้าคงคลัง และบริษัทได้ประสบปัญหาการขาดแคลนสินค้าคงคลังและความไม่พึงพอใจของลูกค้า

การศึกษาครั้งนี้ได้เลือกอะไหล่หมุนเวียนเร็วจำนวน 9 รายการเพื่อทดสอบกลไกของระบบที่นำเสนอ ข้อมูลจากการสำรวจในปีค.ศ.2004 และปีค.ศ.2005 ถูกนำมาใช้เพื่อกำหนดตัวแปรในระบบ และการทดสอบระบบที่นำเสนอดำเนินการด้วยการจำลองสถานการณ์ของข้อมูลในปีค.ศ. 2006 ภายใต้ระบบใหม่

ระบบใหม่มีการตรวจสอบรูปแบบความต้องการของลูกค้าแล้วเลือกเทคนิคการพยากรณ์ให้สอดคล้องกัน ซึ่งได้ผลการพยากรณ์ที่ดีกว่าระบบปัจจุบันโดยมีค่าความคลาดเคลื่อนในการพยากรณ์ที่น้อยกว่า ในการจัดการสินค้าคงคลังได้นำเสนอระบบการติดตามอย่างต่อเนื่อง 2 ระบบ ซึ่งคือ ระบบจุดสั่งซื้อ และระบบกำหนดจุดต่ำสุดและสูงสุดของสินค้าคงคลัง ผลลัพธ์ของการจำลองสถานการณ์พบว่า ทั้งสองระบบน่าจะช่วยลดปัญหาสินค้าค้างส่งอย่างมากและช่วยเพิ่มอัตราการเติมเต็ม อันส่งผลต่อการเพิ่มความพึงพอใจของลูกค้า อย่างไรก็ตาม ทั้งสองระบบนี้ต้องการระดับสินค้าคงคลัง (safety stock) ที่สูงขึ้น อันส่งผลต่อ ค่าใช้จ่ายในการถือครองสินค้าที่มากกว่าระบบปัจจุบัน

ลายมือชื่อนิสิต.....

สาขาวิชาการจัดการด้านโลจิสติกส์ ลายมือชื่ออาจารย์ที่ปรึกษา.....

ปีการศึกษา 2549 ลายมือชื่ออาจารย์ที่ปรึกษาร่วม.....

4889090020 : MAJOR LOGISTICS MANAGEMENT
KEY WORD: INVENTORY MANAGEMENT / AUTOMOTIVE SERVICE PARTS / DEMAND FORECASTING / ORDERING POLICY

NARUMON BURAPACHAYANONT: INVENTORY MANAGEMENT SYSTEM: CASE OF FAST MOVING AUTOMOTIVE SERVICE PARTS. THESIS ADVISOR: ASSISTANT. PROFESSOR. SOMPONG SIRISOPONSILP, Ph.D., 159 pp.

This thesis attempts to develop an inventory management for managing spare parts for an automobile manufacturer in Thailand. The development begins with the investigation of existing inventory system and it is found that the system has been ineffective in managing the inventory level and the company presently faces serious problems of shortages and customer dissatisfaction.

This study selects nine fast-moving items to demonstrate the mechanics of the proposed system. The data observed in the years 2004 and 2005 are utilized to determine the system parameters and the performance of the resulting system is assessed by simulating the situations under the new system against the actual operational data experienced over the year 2006.

The new system requires that the demand patterns are carefully examined and suitable forecasting techniques are then selected correspondingly. The system testing indicates that the selected forecasting methods in most instances perform better than the existing one and result in lower forecast errors. In managing inventory, two continuous review models are proposed; the reorder point model and the min-max model. The results reveal that both models likely lead to a dramatic reduction in backorder quantity, and a significant improvement in the fill rate, thereby significantly increasing customer satisfaction. However, with greater safety stock required the two models are associated with higher cost than the present situation.

Student's signature.....

Field of study Logistics Management Advisor's signature.....

Academic year 2006 Co-advisor signature.....

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CHAPTER 1

Introduction

This thesis presents an inventory system of fast moving items in automotive service parts in order to improve first fill rate and to improve customer satisfaction under demand uncertainty. Data gathering, implementation, and validation will be carried out in the case study company; an automotive manufacturing company.

Automotive industry is currently the number one industry that has been generating the most revenue to Thailand. Thailand produces auto parts, vehicles, and exports them to many countries throughout Asia, Europe and America. Many automobile manufacturing companies set up Thailand as a production base center. As a result, Thailand has been considered as the "*Detroit of Asia*".

Thailand has advantages both in production and in location. Thailand has sufficient capacity in manufacturing and the ability to expand the production capacity. The Thai skilled labors are able to perform to the standards acceptable to international automakers so the brand image of cars produced from Thailand has been good. Moreover, Thailand also has sufficient auto part suppliers and thus has a more competitive price. Additionally, Thailand is also located in the center of many countries such as Lao, Burma, China, Cambodia, Singapore, Malaysia and Philippines. Consequently, Thailand benefits from the Asian cooperation in terms of low import duties for automotive parts under the AFTA agreement.

1.1. BUSINESS OVERVIEW

The case study company is an automobile manufacturer which is a production base center for pick-up vehicles in Southeast Asia. The company has two sales operations – pre-sales and post-sales. The pre-sales operation is the management of original equipment manufacturing (OEM) which produces the completed body unit (CBU) and completed knock down unit (CKD). The post-sales operation is the management of service parts for domestic and overseas dealers. Hence, the company has three product types; CKD, CBU and service parts. Figure 1.1 illustrates the company's product lines.

CKD	CBU	SPARE PARTS

Figure 1.1 Overview of the company's product lines

The above figure is an overview of the company's product lines. CBU is a completed body unit and CKD is a completed knock down unit. CKD is a product line exported to the overseas markets only if the overseas distributors have their own assembly line. The CKD is a good supply unit in terms of the lower import duty when compared to CBU. Both CBU and CKD are pre-sales products.

Service parts are supplied from automobile manufacturers and suppliers. They are stored at service part centers to be distributed to domestic dealers and overseas distributors. The overview of service parts center is shown in figure 1.2.

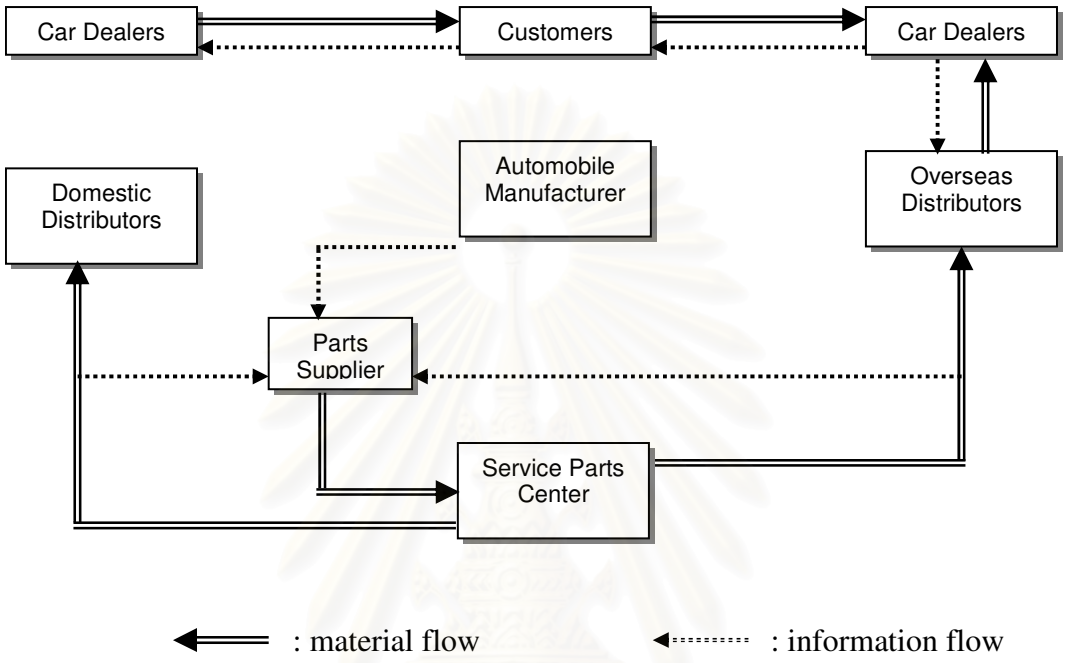


Figure 1.2 Overview of service parts center

1.2. PROBLEM IDENTIFICATION

In OEM, there is a production plan and material scheduling based on CBU demand forecasting. The CBU is forecasted at least one year ahead but that of service parts is not. Due to the lack of forecast, there is often insufficient stock to serve overseas markets, usually resulting in customer dissatisfaction, delayed delivery and finally the airfreight penalty that the company has to account for.

The change plan for CBU is either a minor change or a model change. These changes are concerned with auto parts modification or material changes. The change plan is provided to local suppliers in order to prepare production capacity and the import of raw materials in the case that parts require imported materials for manufacturing. Since the OEM is given a long-term plan and forecast, the OEM has made agreements for penalty with all suppliers if the auto parts are not delivered on schedule. On the other hand, the operation of service parts does not provide a long-term forecast to suppliers because of unseen future demand. Besides that, service parts team does not received updated information for CBU model change such as parts modification, the launching date to overseas market, and even quality issues that leads to a short lead-time in preparing stocks. Without forecast for service parts, suppliers are unable to plan production capacity so when the demands for service parts rapidly escalate, the service parts team is not able to produce the required date by deadline.

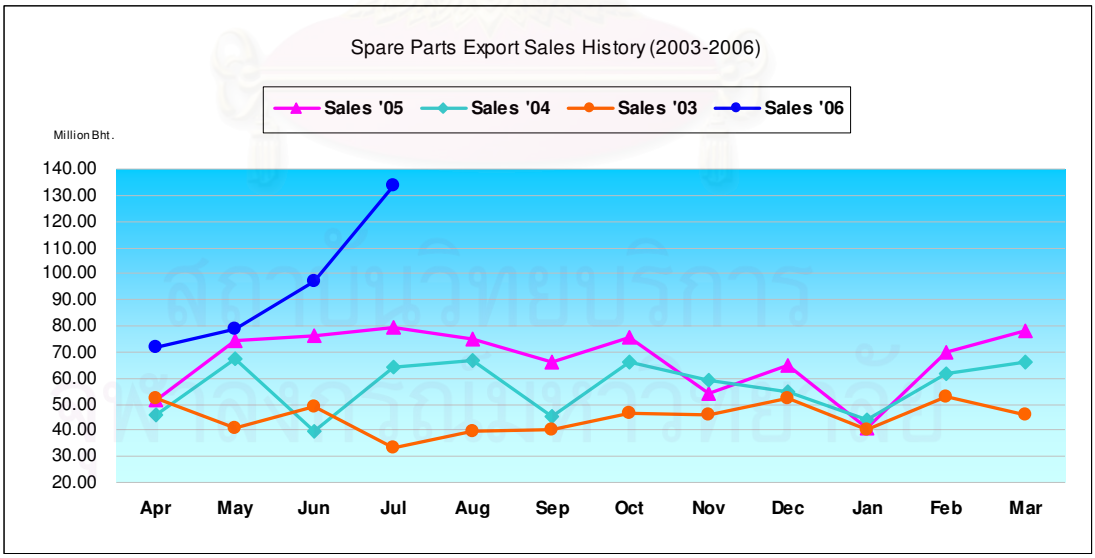


Figure 1.3 Spare parts export sales history (2003-2006)

Moreover, the customers are also dissatisfied and since the company made delayed a delivery, the customers have to change their mode of shipment from sea freight to airfreight and the additional transportation charge is absorbed by the company as a penalty. The amount of airfreight penalty is over ten million baht since the beginning of 2006 until August 2006.

This paper will focus on service parts' supply problem in the overseas market which is the major source of service parts revenue. The export amount of service parts in the overseas market is over 100 million baht per month. Figure 1.3 illustrates the export sales revenue from the year 2003 until mid 2006. The export is continuously expanding whereas the service rate still has not improved. The low service rate is due to the lack of an appropriate inventory system. Figure 1.4 illustrates the export first fill rate during week 14-week 38 in the year 2006. The first fill rate ranges are between 50-60%.

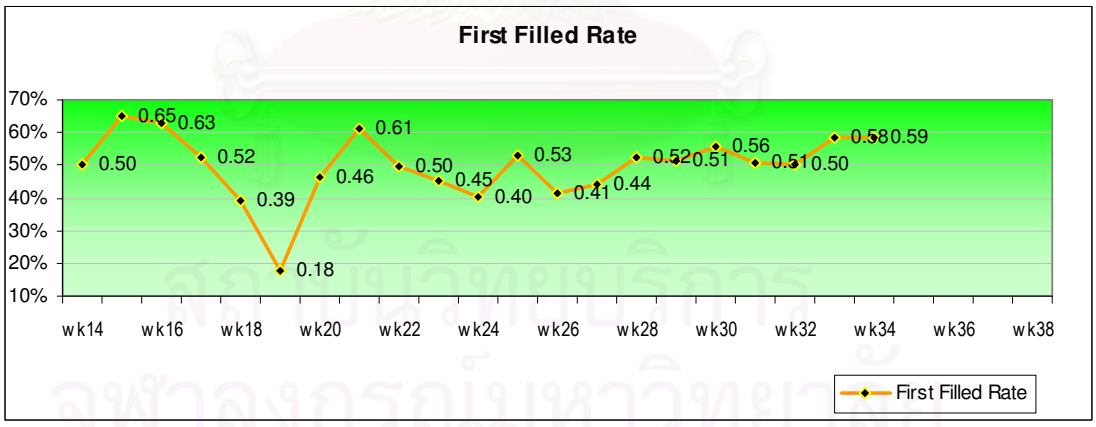


Figure 1.4 Export first fill rate (week 14-week 38 '06)

To improve the first fill rate, the service parts' operation requires an appropriate inventory system and demand forecasting techniques. Service parts are post-sales services and are operated under the "make to stock" model. There is certainly a need

to develop a system that assists the company in setting the stock policy in a systematic fashion.

1.3. THE OBJECTIVES OF THE STUDY

The objective of the study is to develop an inventory management system for automotive service parts to be supplied to overseas market. The main objectives are as follow.

(1) To investigate the current system for managing the service parts for the overseas market

(2) To develop an inventory management system that improves the service level of the supply of service parts to the overseas market

1.4. THE SCOPE OF THE STUDY

The scope of this study is concerned with developing an appropriate inventory management system of service parts by selecting nine fast moving items as case data. The historical data used in the study are acquired from the service parts inventory division in the past 36 months in order to explore demand fluctuation.

1.5. CONTRIBUTION OF THE STUDY

The developed inventory system ultimately would help the company in maximizing the service level of filling the orders of service parts export, resulting in better business performance in the long run.

CHAPTER 2

Literature Review

Nowadays the competition in global market is rising. The trend for trading market has been changed to customization focusing on customer orientation. Therefore, customer satisfaction is a crucial factor for company competitiveness. An important driver in expanding market is after-sales services especially in automotive business. To keep customer satisfaction high, appropriate amount of service parts have to be stocked in order to maintain service level. Since most parts are expensive, this requires a large amount investment on inventory. In other words, inventory cost and service level have to be balanced in determining the right stock level.

The review of relevant literature indicates that the inventory of service parts have been investigated in a number of studies and research. The presentation of past studies will be organized around key issues to be addressed in developing an inventory system for service parts namely, classification of items to be stocked, identification of stocking strategy, the selection of forecasting techniques, and the development of ordering policy.

2.1. ABC CLASSIFICATION

Given the large number of items in service parts to be managed, it would be unwise to apply the same treatment to all items. One scheme for classifying items for the inventory management is the ABC analysis, which is based on the idea that only a

small percentage of items represent the majority of inventory value. This analysis is called Parelo's law.

This classification suggests that the higher of inventory value an item has, the more rigorous analysis and attention that should be given to the item. Flowers and Neill (1978) performs the ABC analysis by multiplying annual usage by value of each items, arrange items in decreasing order and cumulative percentages of value spent including that item. Their analysis showed that 20% of the items represent 80% of dollars value. The results of analysis are summarized in table 2.1.

Table 2.1 Example of ABC analysis

EXAMPLE OF THE ABC ANALYSIS

	Number of Items	Annual Dollar Usage
Class A Items	33	$ 73,403.58
Class B Items	330	$7,081.64
Class C Items	974	$ 20,106.78
Totals	1337	$150,592.00

Source: Flowers and Neill, (1978)

Based on the concept of the ABC analysis, Hiraki (1999) classified automobile repair parts into three classes according to the mean value of monthly demand. Class A parts are supplied from the distributors to the dealers almost every day, Class B parts are supplied from the distributors to the dealers in small quantity at short periods and

Class C parts are supplied from the distributors to the dealers in small quantity at long period. Table 2.2 illustrates this classification of automobile repair parts.

Table 2.2 Classification of automobile repair parts

Class	Class A	Class B	Class C
Mean value of monthly Demand (Q)	$10^2 \leq Q$	$1 \leq Q \leq 10^2$	$0 \leq Q \leq 1$

Class A = Regular order parts

Class B = Production and supply parts

Class C = Stock and supply parts

Source: Hiraki, (1999)

Sandvig and Allaire (1998) applied Pareto's principle to spare parts classification in an aviation industry based on urgency of spare parts maintenance if there is any failure and machine downtime. The analysis of their data revealed that 20% of the SKUs are accounted by 88% of the inventory value as shown in below figure.

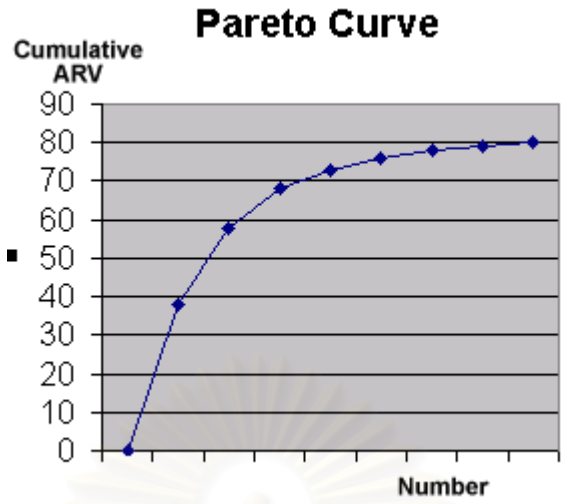


Figure 2.1 Pareto Curve

Source: Sandvig and Allaire, (1998)

On the other hand, Yeh (1997) classified spare parts in a mid-size electronics industrial company in Taiwan based on demand movement. He collected a sample of 200 items and classified them into four demand classes as slow, medium, medium-fast, and fast turnover. The data showed that over half of the spare parts are slow moving items with demand occurrences that are less than 10 times per year and only 10-20% of the parts are fast movers. The collected data is shown in table 2.3.

Table 2.3 Item classification by slow, medium, medium-fast and fast

Demand Frequency	**2-5 (*N*=75)**	**6-10 (*N*=48)**	**11-15 (*N*=46)**	**Over 15 (*N*=31)**
Unit per demand	72.0-140.1 (1195.6-8733.3)	66.9-102.4 (968.2-6626.1)	64.3-108.3 (871.8-7067.0)	71.5-113.4 (300.3-3959.4)
Time interval between two successive demands	72.8-165.0 (913.2-6008.9)	36.6-64.1 (114.0-1244.1)	24.3-38.4 (129.8-445.3)	17.4-24.3 (66.2-216.7)
Replenishment lead time	28.3-41.0 (164.3-587.9)	30.6-48.3 (194.4-506.7)	29.1-37.2 (204.4-324.2)	24.2-40.5 (104.6-304.7)

Source: Yeh, (1997)

Graglia, Grassi and Montanari (2004) studied additional assortment of ABC analysis according to Pareto's principle by conducting a criticality analysis in order to obtain a first reduction of problem dimensions. They considered criticality of items by defining items as very important (A-class), important (B-class) and less important (C-Class). They did a crossed analysis for consumption rate and defined class C for the lowest consumption rate and class A for the highest consumption rate. The consumption-inventory matrix is shown in table 2.4.

Table 2.4 Consumption-inventory matrix

	Inventory level		
Consumption	A (high)	B (medium)	C (low)
A	Just-in-time		OK
B			
C	Reduction or eliminate of stocks		Not important

Source: Graglia, Grassi and Montanari, (2004)

The same concept of criticality and consumption rate is applied by Bangash and Bollapragada (2004) to develop an inventory requirement planning (IRP) at Lucent Technologies. They implemented IRP system by using a generalized concept of ABC classification and categorized items according to their criticality. They determined the product's final class based on the higher of its classes obtained from the two classification schemes. For example, if a part was in Class B based on its value and Class A based on its criticality, they assigned it to be Class A overall. They discriminated the large number of Class C items and to better manage the large range of products, they introduced Class D to represent parts with extremely low value and minimal criticality.

Fortuin and Martin (1999) mentioned in their research of service parts for the Royal Dutch Air Force that the classification of service parts as “fast mover” or “slower mover” is no longer sufficient. There should be other classification criteria such as the criticality of the function to be performed by a system that has defective, price, delivery lead-time and life cycle phase of the spare parts. Three phases in the life cycle of service parts were introduced in their study as follows:

(1) *Initial phase*: This phase is a new type of parts and components that have never been used before in products. There is very little known about their demand.

(2) *Normal phase*: There are some historical demand data much more than initial phase.

(3) *Final phase*: Production of the system has stopped but the service period continues. Usually at the beginning of the final phase, the service managers have to place a final order.

Kumar (2004) developed an IT automation program for spare part management. To implement the supply chain management, he recommended a multi-model based to manage spare parts inventory across the service network and provided inventory visibility. The multi-models are composed of an ABC (Cost based), FSN (Movement based), VED (Criticality based) or a mix of the three models.

Fortuin and Botter (2000) mixed these three criteria classifications on their study in stocking strategy of service parts. They studied many literature dealing with electronic industry including computers, automotive industry, aviation industry and

production companies keeping stock of parts for maintenance. They mentioned that considering criticality of items is difficult task because the distinction between huge loss and moderate loss is difficult to make. Thus, they narrowed down the criticality into two levels, which were class E (Essential) and class D (Desirable). Class E meant functional and class E meant cosmetic. They gathered VED analysis with consumption of service parts and made up a service parts classification matrix as shown in figure 2.2. The VED analysis was viewed more important than consumption analysis because a cheap service part might cause a serious breakdown for a customer.

Functionality

D Desirable (Cosmetic)	DX	DY	DZ
E Essential (Functional)	EX	EY	EZ
	X Fast moving	Y	Z Slow moving

Percentage consumption in units

Figure 2.2 Item classification matrixes by functionality and consumption rate

Source: Fortuin and Botter, (2000)

2.2. STOCKING STRATEGY

Spare parts consist of both fast-moving and slow-moving items. Conventional inventory theory is inapplicable for slow-moving parts because demand frequency is low whereas number of items is very high. Much literature applied a two-echelon

network for spare parts inventory policy. Most of them are stocking fast moving service parts in local warehouses and centrally stocking for slow movers.

Ashayeri, Heuts and Jansen (1997) studied 10,000 items of PC parts inventory problem in Netherland using a two level distribution inventory policy. They stocked repairable parts locally and centralized non-repairable parts stock.

Botter and Fortuin (2000) used a two-echelon distribution and created a three-dimensional service parts stocking policy categorizing by consumption rate, price and response time resulting in eight different segments. The segments are shown as below.

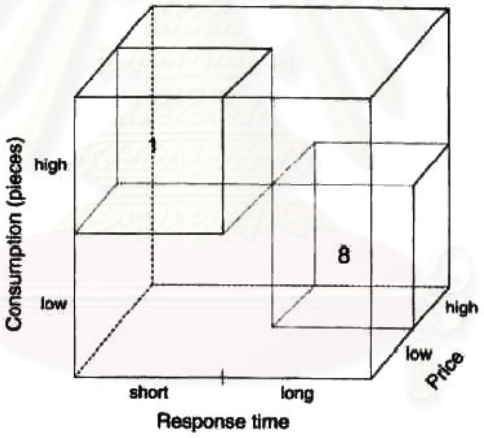


Figure 2.3 A three-dimension of service parts stocking proposed by Botter and Fortuin

(1) Low price, short response time, high usage. These cheap, fast moving items have to be stocked in large quantities in local warehouse.

(2) Low price, short response time, low usage. These cheap, slow moving items have to be stocked close to the market but in lower quantities.

(3) Low price, long response time, high usage. These items have to be stocked locally with larger quantities.

(4) Low price, long response time, low usage. These items have to be stocked centrally.

(5) High price, short response time, high usage. They have to be stocked locally with lower quantities.

(6) High price, short response time, low usage. Centrally stocking with lower quantities.

(7) High price, long response time, high usage. They have to be stocked centrally.

(8) High price, long response time, low usage. They have to be stocked centrally.

Chamberlain and Nunes (2004) studied inventory problem of semi-conductor companies and adapted four steps processes of SSCM (service supply chain management). They applied multi-echelon fulfillment process in local, regional and global facilities. Kumar (2004) implemented an IT Automation Perspective for service parts and recommended optimization models for multi-echelon inventory to deploy inventory at various locations based on need, criticality, service response and etc.

In a multi-echelon stock system, when there is an item shortage at any facilities, it may be more efficient to expedite shipment from neighboring site that has stock rather than from a higher echelon supply site. This strategy is called stock pooling (Cohen and Lee 1990). Pooling inventory is to create a pool of service parts rather than each keeping stock of certain vital parts (Fortuin and Martin 1999)

2.3. FORECASTING METHOD

Many literature mentioned that spare parts demand is unpredictable. It depends on failure rate of car maintenance and from the quality of parts being produced by suppliers. There was a study in designing of a production ordering system for automobile repair parts by applying time series with exponential autocorrelation (Hiraki 1999). Future demand for the repair parts was determined using the exponential autocorrelation method as follows:

$F_{t:t+j} = \lambda_j D_t + (1\lambda_j)\mu$.....(2.1)

$F_{t:t+j}$ = the forecasted demand for the repair parts during the *(t+j)*th period forecasted at the end of the *t* th period

D_t = demand for the repair part in period *t* at the market

λ = autocorrelation coefficient

Exponential smoothing method has mentioned as an efficient method for forecasting spare part demand. Strijbosh (2005) used Exponential Smoothing (ES) in forecasting model for spare parts machining in production plant. The Exponential Smoothing is a good forecasting choice because it places the most weight on the more recent data, giving estimates that are the highest just after a demand and the lowest just before a demand. (Silver, 1981).

The work by Willemain et al. (2004) indicated that Exponential smoothing had proven to be a robust forecasting method and was probably the most used of the statistical approaches to forecasting intermittent demand. They assumed that lead

time demand (LTD) is a normally distributed and use the smoothing process to estimate the mean variance of the normal distribution.

Although Exponential Smoothing is frequently used for the forecasts in stock control systems but there are observations that it may produce inappropriate stock levels when demand is intermittent. An example of the pattern of intermittent demand is shown in figure 2.4.

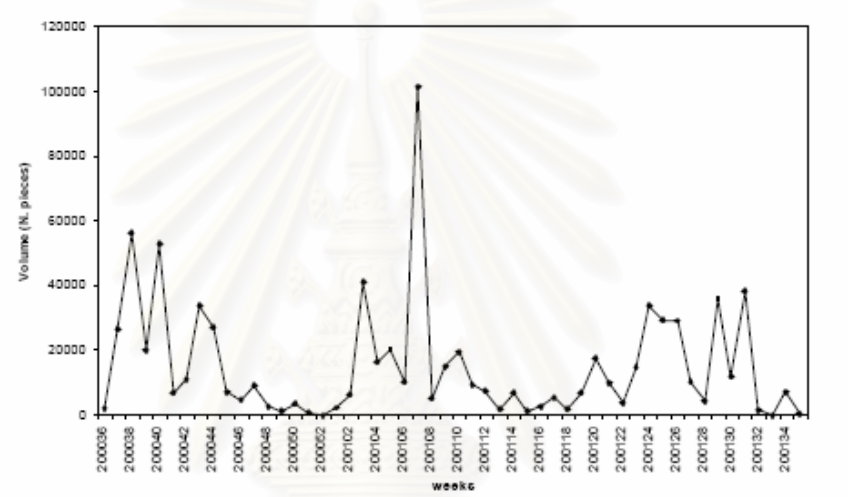


Figure 2.4 Intermittent demand

Source: Croston, (1970)

Refer to above reason; Croston (1970) proposed a new forecasting technique to cope up with intermittent demand. He developed a method in overcoming this bias by using a separate estimate of the size of demand and of the demand frequency. Croston observed that the use of traditional exponential smoothing for intermittent demand was not suitable and seemed to overestimate the demand levels. This method attempts to break the intermittent demand time series into two series; one series for the non-zero demand values and another series for the time interval between non-zero demand values. Croston's algorithm proceeds as follows.

If the actual demand at time $t = 0$ ($x_t = 0$)

(1) Transaction size estimates are not updated

(2) $\hat{n}_t = \hat{n}_{t-1}$

If $x_t > 0$ (that is, a transaction occurs),

(1) $\hat{z}_t = \alpha x_t + (1-\alpha)\hat{z}_{t-1}$

(2) $\hat{n}_t = \alpha n_t + (1-\alpha)\hat{n}_{t-1}$

Where

n_t = number of periods since the last transaction

$\hat{n}_t$ = estimate value of n at the end of period t

$\hat{z}_t$ = estimate at the end of period t, of the average transaction size

Gokul (2003) applied Croston's model in forecasting demand of military aircraft parts. He found that Croston's model dealt with the problem of forecasting demand when the demand patterns were irregular. Senstone (2003) used a simple modification of Croston's model for intermittent demand forecasting. The method separately forecasted the non-zero demand size and the inter-arrival time between demands using exponential smoothing (ES), with forecasts being updated only after demand occurrences. Eaves and Kingsman (2004) compared Croston's method and ES. Their results indicated that the estimates of demand per period are not unbiased. Thomas (2004) compared the accuracy of the forecasting methods by applying them to over 28,000 items owned by nine industrial companies. He found that Croston's method provided more accurate estimates of the mean level of demand when demand occurred but it did not provide an overall improvement on exponential smoothing as far as the entire distribution of lead time demand was concerend. He proposed a

bootstrap method that outperformed exponential smoothing, especially for short lead times. He applied the model to three difficult features of intermittent demand involving autocorrelation, frequent repeated values and short series. His bootstrapping method completed the following steps:

Step 0 Obtain historical demand data in chosen time buckets

Step 1 Estimate transition probabilities for two-states (zero vs. nonzero) Markov model

Step 2 Conditional on last observed demand, use Markov model to generate a sequence of zero/ nonzero values over forecast horizon

Step 3 Replace every nonzero state marker with a numerical value sampled at random with replacement from the set of observed nonzero demands

Step 4 Get the nonzero demand values

Step 5 Sum the forecast values over the horizon to get one predicted value of lead time demand (LTD)

Step 6 Repeat steps 2-5 many times

Step 7 Sort and use the resulting distribution of LTD values

The result of his experiment showed that the bootstrapping method was the most accurate forecasting methods. Croston's method had no statistically significant advantage over exponential smoothing at forecasting the entire LTD distribution. Croston's method was slightly less accurate at every lead time. The table below illustrates the better performance of bootstrapping method.

Chi-square values by lead time and forecasting method

Dataset	Lead time	No. of series	Expo smooth	Croston's method	Bootstrap
A	1	8335	2481	2853	43
B	1	999	602	648	9
C	1	4633	3747	4896	50
D	1	967	559	561	32
E	1	598	493	586	10
F	1	219	143	131	18
G	1	1446	1068	1210	4
H	1	1058	778	760	100
I	1	9758	7758	10706	6
	3	8333	1239	1935	130
A					
B	3	999	495	537	65
C	3	4571	3504	6130	175
D	3	967	569	555	193
E	3	570	416	526	29
F	3	214	157	203	61
G	3	1378	628	770	44
H	3	1057	739	706	259
I	3	9608	4244	9277	228
	6	8332	2768	4646	3030
A					
B	6	998	339	385	168
C	6	4484	3333	7987	388
D	6	951	924	1109	790
E	6	539	360	559	67
F	6	211	236	118	110
G	6	1278	422	563	176
H	6	1055	778	839	528
I	6	9347	2838	10239	441

Figure 2.5 Chi-square values by lead time and forecasting method

Source: Thomas (2004)

Although Croston's method has been mentioned in many demand forecasting in providing a good result when demand is intermittent but it fails to produce accurate estimates of demand per period. Syntetos and Boylan (1998) formulated an approximation for the forecast bias and subsequently developed three modifications to Croston's method that theoretically eliminated the bias.

An modification that was found to perform well in research was proposed by Eaves and Kingsman (2004). They referred to the approximation method by Syntetos and Boylan. The method, derived from a Taylor series expansion, used a deflator based on the interval smoothing constant to remove the bias. The modification was formulated as follows:

$$\hat{y}_t = \left(1 - \frac{\alpha_i}{2}\right)\frac{z_t}{p_t} \quad \text{.....(2.2)}$$

Their research compared the result of four forecasting methods; approximation method, exponential smoothing, Croston's method and moving average. The results indicated that the simpler forecasting methods could still provide the best results for intermittent and slow-moving demand classifications, while the approximation method, which mostly outperforms Croston's method, can provide the best results for smooth and irregular demand. Forecasting performance of the approximation method provides the best result in terms of average mean absolute percentage error (MAPE). It provides many of the best results when lead time demand forecasts are measured in periods of demand only. Figure 2.6 illustrates forecasting performance of four traditional methods.

		Forecasting method				
Demand aggregation	*Error measure*	*Approx'n method*	*Expon'l smooth*	*Croston's method*	*Moving average*	*Prev. year average*
		One-period ahead demand				
Quarterly	MAD	19.43	20.08	20.79	*19.37*	20.83
	RMSE	*26.68*	26.96	27.62	27.15	28.83
	MAPE	*110.68*	117.62	127.30	119.25	123.25
Monthly	MAD	9.50	9.22	9.81	*8.71*	9.20
	RMSE	14.22	14.04	14.38	*13.92*	14.41
	MAPE	*95.94*	101.06	98.46	102.96	104.51
Weekly	MAD	3.47	3.11	3.52	*2.94*	3.04
	RMSE	6.44	6.28	6.46	*6.24*	6.32
	MAPE	*90.32*	94.20	90.42	95.68	95.74
		Lead-time demand (measured in all periods)				
Quarterly	MAD	16.88	*14.88*	18.60	15.29	16.66
	RMSE	21.56	*19.56*	25.16	19.86	21.45
	MAPE	200.20	*173.29*	303.95	181.07	204.63
Monthly	MAD	5.30	*5.00*	5.77	5.18	5.69
	RMSE	6.66	*6.63*	7.16	6.79	7.36
	MAPE	300.78	*174.76*	342.52	182.48	212.49
Weekly	MAD	1.36	*1.17*	1.45	1.21	1.33
	RMSE	1.72	*1.56*	1.81	1.59	1.73
	MAPE	322.50	*171.29*	348.63	179.25	211.12
		Lead-time demand (measured in periods with demand only)				
Quarterly	MAD	16.61	16.46	18.00	*16.43*	17.32
	RMSE	21.09	*19.95*	24.42	20.69	21.71
	MAPE	*144.40*	254.14	216.74	233.80	218.81
Monthly	MAD	*5.46*	5.71	6.02	5.66	5.87
	RMSE	7.19	*6.93*	8.24	7.16	7.39
	MAPE	*172.05*	256.78	222.70	233.42	211.27
Weekly	MAD	1.57	1.38	1.79	*1.34*	1.38
	RMSE	2.27	*1.66*	2.76	1.70	1.74
	MAPE	*173.84*	252.72	226.30	228.12	215.83

Figure 2.6 Forecasting performances by traditional method

Source: Kingsman, (2004)

2.4 ORDERING POLICY

An objective in inventory management is to keep sufficient inventory at a minimum cost. The ordering policy have significant impacts on the performance of an inventory system as the quantity ordered during each replenishment cycle can affect the average inventory level and the investment in this inventory. Many research in inventory management for service parts referred to an order-up-to-level policy. The order-up-to-level is to place an order for a quantity to raise the inventory to predetermined target when the remaining stock level drops below the lower level. Yeh (1997) studied the procurement system of spare parts in a mid-size electronics industrial company in Taiwan. He collected the data for many items and found that over half of the spare parts are slow-moving items and only 10% to 20% of the parts are fast movers. The distinct feature of his model is to relate the possible future demand to the remaining stock level *(on-hand + on-order – backorders – the current demand).* The model used a simple rule to decide whether to reorder at the time when demand occurs. If the service level is less than the preset lower service level, an order for a quantity to raise the service level to the upper level will be introduced, otherwise no replenishment order is required.

Service level for a remaining stock position is calculated by

$$1 - P_s(S) \qquad (2.3)$$

where $P_s(S)$ = The stock out probability during an order cycle with a given stock level of *S*.

Three variables = (1) Time between two demands

(2) The size per demand

(3) The lead time for replenishment - gamma distribution.

The replenishment order will be placed if ;

$P(\text{Demand in time } Z > S\text{-}A_1) > P_{s_t}$ ……..…(2.4)

where Z = lead time, i.e., time interval between order placed and receipt of the order; assumed to be gamma-distributed with parameter (γ, δ)

S = current stock level

(on-hand + on-order – backorders – A_0)

A_1 = amount of the i^{th} demand, i = 0,1,2,…, where each A_i is gamma distributed with parameter (μ, σ) and A_0 represents the amount of the current demand

Below table is the result of the slow-moving items, in which the reorder quantities (order-up-to-level policy) for four subcategories of different mean and variance combination is shown as following.

Size per Demand			Time Interval Between Two Successive Demands			Lead Time for Replenishment			Service Level							
Mean	Variance	μ σ	Mean	Variance	α β	Mean	Variance	γ δ	0.99	0.95	0.90	0.85	0.80	0.75	...	0.50
L	L		L	L		L	L									
72.0–	1195.6–	0.034	72.8–	913.2–	0.053	28.3–	164.3–	0.127	275	201	168	148	133	122	...	82
106.1	4097.8	3	118.8	2901.7	5	34.6	343.4	4								
L	L		L	L		L	H									
72.0–	1195.6–	0.034	72.8–	913.2–	0.053	28.3–	343.5–	0.065	283	206	171	151	136	124	...	83
106.1	4097.8	3	118.8	2901.7	5	34.6	587.9	2								
:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:
:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:
:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:
H	H		H	H		H	L									
106.2–	4097.9–	0.017	118.9–	2901.8–	0.035	34.7–	164.3–	0.158	404	287	235	204	181	162	...	101
140.1	8733.3	2	165.0	6008.9	5	41.0	343.4	6								
H	H		H	H		H	H									
106.2–	4097.9–	0.017	118.9–	2901.8–	0.035	34.7–	343.5–	0.080	410	291	237	205	182	164	...	102
140.1	8733.3	2	165.0	6008.9	5	41.0	587.9	3								

L: low in mean/variance; H: high in mean/variance; μ, σ, α, β, γ, δ: gamma parameters.

Figure 2.7 Re-order Quantity by Service Levels and Items Sub-Categories for the Slow Moving Items

Source: Yeh, (1997)

Cohen and Lee (1990) also recommended the order-up-to level to control stock replenishment for a mainframe computer company. The desired service level in service parts is different from general products because service parts are expensive and demand is lumpy. Thus, the use of equal part fill rates can lead to higher cost and lower levels of service. Thonemann and Brown (2002) assigned a low fill rate to parts with high costs and high fill rate to parts with low costs. Service level is considered separately at different items classification because the relation between service level and inventory cost are relatively exponential rather than linear. That means there are some areas on the curve where service can be improved dramatically with minimal inventory investment and other areas where a small improvement in service level can be extremely costly (as shown in Figure 2.8).

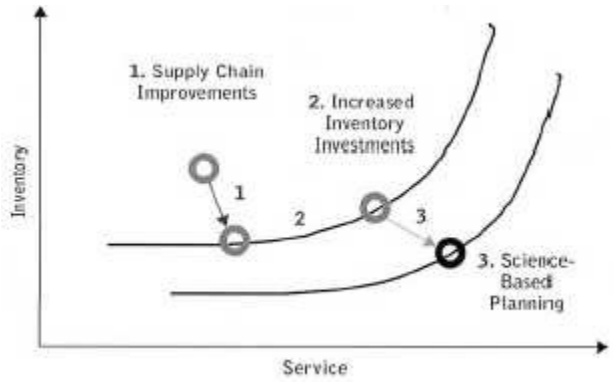


Figure 2.8 Inventory-service tradeoff

Eaves and Kingsman (2004) did a simulation of an order-up-to level in a periodic review inventory system. The order-up-to level is determined quarterly as the product of the forecast and lead-time plus the review period, rounded up to a whole unit. A replenishment quantity will be ordered if the closing inventory position is at or below the order-up-to level. The replenishment quantity is calculated as the difference between the reorder point and the closing inventory level plus any outstanding orders.

Order-up-to-level (R) = F_{t-1} x $\sum(LT_{3q} + LT_q)$ ……..…..….(2.5)

F_{t-1} = Forecast of end previous period

LT_{3q} = Lead time of three-quarters

LT_q = Lead time of review period of one-quarter

Replenishment Qty = $R - \sum OpenStock$ ……...……...(2.6)

Their methodology was to add the maximum stock-out to the order-up-to-level until no further stock-outs occurred. The final quantity required became the safety margin

and the implied stock-holdings were calculated as the average of the opening stock plus deliveries and the closing stock. The table below is shown the order-up-to level (*R*) and order quantity (replenishment quantity) simulation.

Qtr	*Stock on-hand open*	*Delivery qty*	*Demand qty*	*Stock on-hand close*	*Forecast qty*	*Stock on order*	*Order-up-to level (R)*	*Order qty*
1			3					
2			3					
3			2					
4			4	7	3.000	2		
5	7	2	1	8	2.640		12	3
6	8		1	7	2.345	3	11	
7	7		2	5	2.283	3	10	
8	5	3		8	1.872		10	2
9	8			8	1.535	2	8	
10	8		3	5	1.799	2	7	
11	5	2	3	4	2.015		8	1
12	4		6	−2	2.732	1	9	4
13	−2		4	−6	2.960	5	11	8
14	−6	1	1	−6	2.608	12	12	5
15	−6	4		−2	2.138	13	11	
16	−2	8	3	3	2.293	5	9	
17	3	5	1	7	2.061		10	2
18	7		3	4	2.230	2	9	
19	4			4	1.828	2	9	3
20	4	2	1	5	1.679	3	8	
21	5		1	4	1.557	3	7	
22	4	3	3	4	1.817		7	
23	4			4	1.490		8	4
24	4		1	3	1.402	4	6	

Figure 2.9 Order-up-to level and order quantity simulation

Source: Eaves and Kingsman, (2004)

Nagen (1994) designed an ordering system for spare parts in a computer service company. His model called a BFI (business factor index) order point model that was given by:

Order Point = $(Dem \times LT) + (Dem \times LT)(D\% + V\% + E\% + L\%)$……...(2.7)

where,

Dem = Average historical demand over a reasonable period of time, or the forecast demand

LT = Normal current replenishment time

D = The effect the shortage of items will have on profit or production

V = The collar value of the item

E = The deviation of demand from average usage

L = The lead time and lead time variation in replenishing the stock

The value of *D, V, E* and *L* in the above formula was provided by the managers involved in the decision making. He applied the ABCD classification to the values of *D, V, E* and *L*. The input values are:

D = 18% (the variation in demand is not more than 100%)

V = 5% (the value of each order is more than 80,000 baht)

E = 5% (this is a common stock)

V = 25% (for A and B items)

= 5% (for C and D items)

(the lead time for overseas procurement is 3 months and for local procurement is 1 week).

These values result in the following formulas.

For *A* and *B* class items:

Order Point = (*Dem x LT*) + (*Dem x LT*) (*D*% + *V*% + *E*% + *L*%)

= (*Dem x LT*) + (*Dem x LT*) (18% + 5% + 5% + 25%)

= (*Dem x LT*) + (*Dem x LT*) (53%)

= 1.53 (*Dem x LT*)

For *C* and *D* class items:

Order Point = (*Dem x LT*) + (*Dem x LT*) (*D*% + *V*% + *E*% + *L*%)

= (*Dem x LT*) + (*Dem x LT*) (18% + 5% + 5% + 5%)

= (*Dem x LT*) + (*Dem x LT*) (33%)

= 1.33 (*Dem x LT*)

He suggested the replenishment quantity per order in order to minimize total inventory cost for *A* and *C* items. The formula was given by:

$$Q = \sqrt{\frac{2xC_p xDem}{C_h}} \quad \text{.....(2.8)}$$

where,

Q = economic order quantity

C_p = ordering set-up cost

C_h = holding cost, cost of the spare part x [interest rate + insurance rate (per month)]

Dem = average monthly demand

2.5. CONCLUSION

There are alternative strategies and techniques for managing inventory of spare parts. Below is the summary of our findings in each of the issues addressed:

(1) Item classification

In order to develop a new inventory system, it is critical to come up with a suitable scheme for classifying items. Classification of service parts by consumption based is

no longer sufficient. Other classification criteria such as criticality, price and life cycle phase of service parts should be given serious consideration.

(2) Stocking strategy

A two-echelon system is usually recommended as effective strategy for managing service parts. A high price item and low usage should be kept in a central warehouse but low price items and high usage should be kept at local warehouses. If there is an item shortage in any distribution centers, it will be more efficient if the centers pull in a shortage item from neighboring site rather than from a higher echelon site.

(3) Forecasting techniques

The selection of demand forecasting method for spare parts inventory management is relatively difficult because demand of service part is different from finished goods because it derives from failure rate. Related literature in demand forecasting of service parts referred to an exponential smoothing (ES) as a fundamental technique that provides a good result. However, ES may result in a bias when demand is intermittent and it may also lead to higher stock level. To eliminate this bias, Croston developed his model to separate demand forecasting for the periods during which demand is zero. Although Croston's model has been mentioned in many research works as theoretically an appropriate method for irregular demand but we have not found any real-life cases showing the practical implementation of his model.

(4) Ordering policy

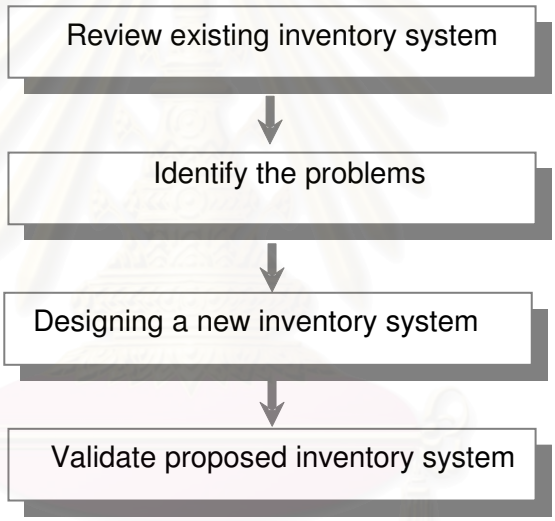
The final task for inventory management is to define an ordering policy. The method mostly mentioned in literature is a periodic review policy and an order-up-to level

policy. The stock level is examined at a specified time, and the amount needed to bring up to a target level is ordered. This method is simple and allows the consolidation of orders for several items into a single order. This periodic review requires less administrative attention but usually results in higher inventory level than the continuous review.

CHAPTER 3

Methodology

This chapter discusses the methodology adopted in the development of the inventory management system for spare parts. The discussion deals only with the concepts and the theoretical framework of the system while the detailed analysis will be provided in the following chapters. The methodology is composed of the following four tasks:



3.1 REVIEW EXISTING INVENTORY SYSTEM

The existing system is reviewed to identify the activities related to the fulfillment of customers' orders. The activities reviewed include the order processing, demand forecasting, the safety stock determination and the control of stock replenishment.

The investigation of the existing system will provide information about the problems inherent in the existing system.

3.1.1 Order Processing

The company now receives orders from customers via online system. In some cases when online system is not applicable, customers are suggested to place orders via emails. After receiving an order, the system will activate stock allocation process starting from printing picking slip and printing packing information. Both picking slip and packing information are instruction slips for performing warehousing activities. After packing has been completed, the export staff manages shipping to customers. Shipping document is automatically generated by the system and shipping data will be sent back via online network to the hub program in the central database. Figure 3.1 illustrates the order receiving and allocation process.

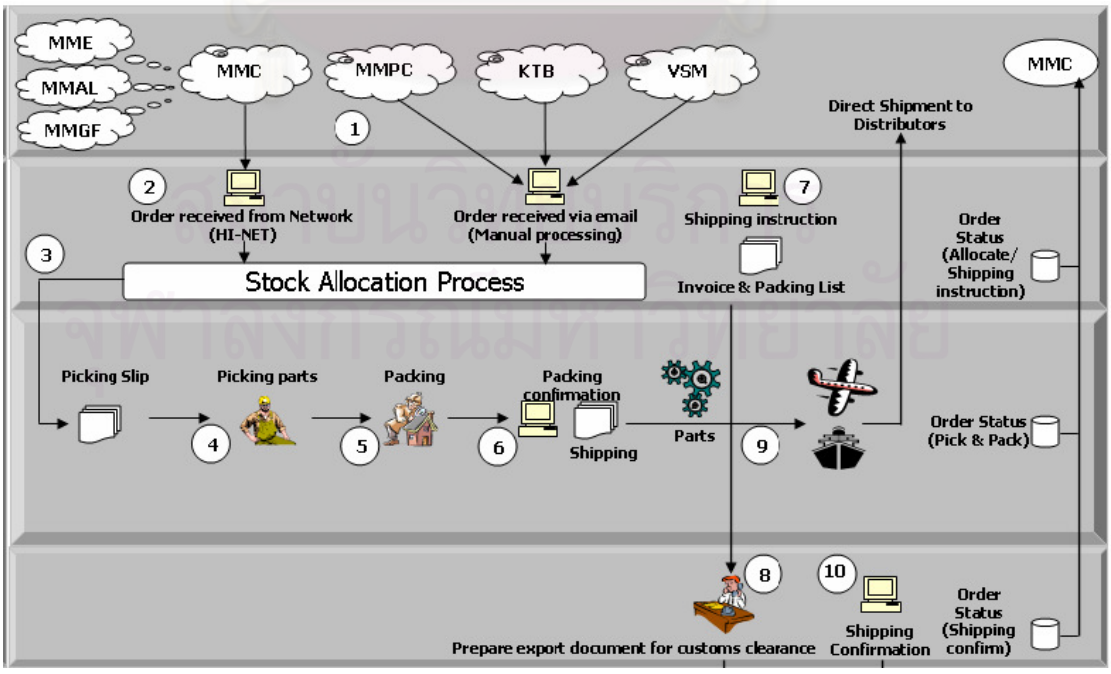


Figure 3.1 Order receiving and allocation process

3.1.1.1 Order types

There are two types of orders that have been processed in the current system.

- Stock allocation orders

These are orders that will be fulfilled by the readily available stocks. Orders with greater priority will be assigned the available stock before the one with lower priority. The priority of orders will be described later.

- Order to order

The fulfillment of these orders is similar to the make-to-order model. These orders are not satisfied directly from the available stock but once the company receives this type of orders, it will place the corresponding orders to the supplier for the required service parts. This order is rarely found in current system except a special order for a seasonal campaign. In this study, we will mention only stock allocation order.

3.1.1.2 Order class

In allocating stock to the incoming orders, orders are classified into three priority classes as shown in table 3.1.

Table 3.1 Order class

Order class	Order code	Order mode	Order class description
VOR	VOR	AIR	The order placed is for urgent replacement for off-road vehicles.
Emergency Charge	E/O C/O	AIR SEA	The class refers to urgent replacement due to stock out. This class of order refers to the replenishment for stocks at distributors'sites.

Order receiving from customers is categorized into three classes. The first class is VOR order or vehicle off road (code: VOR) which is shipped under airfreight. This

urgent maintenance or replacement purpose due to vehicles is off road. Second is an emergency order (code: E/O) which is shipped under airfreight. This order class has an less priority than VOR but it is also need an urgent delivery as well. Third is a charge order (code: C/O) shipping under sea freight, purposing to replenish stock level.

3.1.1.3 Stock allocation scenarios

The issues related to the stock allocation scenarios that are following:

- If stock of part number being ordered is available, system automatically generates a picking slip for packing process in the next step.
- If stock of part number being ordered is unavailable, system automatically allocates a substituted part number according to the predetermined replacement condition.
- If stock cannot be allocated to the order, order will be given a status as backorder (B/O).

3.1.1.4 Prioritization of stock allocation

The system will allocate stock in the following orders reflecting the priority assigned to the order:

	Order class	Short name
1st priority	VOR order	(VOR)
2nd priority	Emergency order	(E/O)
3rd priority	Charge order	(C/O)

3.1.2 Demand forecasting

Currently, the company owns and operates a computerized system for managing service parts inventory. The system conducts demand analysis based on historical data of order received during the last 6 months and provides updates on average demand quantity, safety stock quantity and demand coefficient value on a monthly basis. The determination of demand forecasts is completed as follows.

3.1.2.1 Average demand quantity ($\overline{D}$)

The system generates average demand quantity ($\overline{D}$) for all order types in last six months. Equation is shown as follow.

$$\overline{D} = \frac{Q}{6} \quad \text{..... (3.1)}$$

Where,

Q = Total order quantity received in last six months

$\overline{D}$ = Average demand quantity in the last six months

3.1.2.2 Safety stock determination

The system generates safety stock calculation using the following formula.

$$SS = SD \times (PLT / 20) \times DSR \quad \text{..... (3.2)}$$

$$SD = \sqrt{(M1-\overline{D})^2 + (M2-\overline{D})^2 + (M3-\overline{D})^2 + (M4-\overline{D})^2 + (M5-\overline{D})^2 + (M6-\overline{D})^2} \quad \text{..... (3.3)}$$

Where,

SS = Safety stock

SD = Standard deviation

M1 = Demand in the 1st month of the last six months

M2 = Demand in the 2nd month of the last six months

M3 = Demand in the 3rd month of the last six months

M4 = Demand in the 4th month of the last six months

M5 = Demand in the 5th month of the last six months

M6 = Demand in the 6th month of the last six months

$\overline{D}$ = Average demand of the last six months from 3.1.2.1

PLT = Production lead time

DSR = Delivery service rate

3.1.2.3 Delivery service rate

Delivery service rate is a factor used to calculate safety stock and is supposed to relate to fill rate. The currently adopted delivery service factor is 0.66 (Figure 3.2) or which is equivalent to the fill rate of 74.5%. (Table 3.2)

ZHH725F2 ** DELIVERY SERVICE RATE MAINTENANCE ** 15/02/2006
PURCHASE ORDER CONTROL CODE [F]
DEMAND CLASSIFICATION CODE [ ]
INPUT PERSON [nm]

PURCHASE ORDER	DEMAND	DELIVERY SERVICE RATE EXPORT	DOMESTIC	MODIFY DATE
[F]	[A1]	[0.66]	[2.05]	[05/09/2002]
[F]	[A2]	[0.66]	[2.05]	[05/09/2002]
[F]	[A3]	[0.66]	[2.05]	[05/09/2002]
[F]	[A4]	[0.66]	[2.05]	[05/09/2002]
[F]	[B1]	[0.66]	[2.05]	[05/09/2002]
[F]	[B2]	[0.66]	[2.05]	[05/09/2002]
[F]	[B3]	[0.66]	[2.05]	[05/09/2002]
[F]	[B4]	[0.66]	[2.05]	[05/09/2002]
[F]	[C1]	[0.66]	[1.89]	[05/09/2002]
[F]	[C2]	[0.66]	[1.89]	[05/09/2002]
[F]	[C3]	[0.66]	[1.65]	[05/09/2002]
[F]	[C4]	[0.66]	[1.65]	[05/09/2002]
[F]	[D]	[0.33]	[0.53]	[06/05/2003]
[F]	[E]	[0.00]	[0.53]	[06/05/2003]

Figure 3.2 Delivery service rate

Table 3.2 Conversion fill rate to coefficient of safety stock

Fill Rate (%)	Coefficient of safety stock
98.0	2.17
97.5	2.05
97.0	1.96
96.5	1.89
96.0	1.81
95.5	1.76
95.0	1.70
94.5	1.65
94.0	1.60
93.5	1.52
93.0	1.48
92.5	1.44
92.0	1.41
91.5	1.38
91.0	1.35
90.5	1.32
90.0	1.29
89.5	1.26
89.0	1.23
88.5	1.20
88.0	1.18
87.5	1.15
87.0	1.13
86.5	1.11
86.0	1.09
85.5	1.06
85.0	1.04
84.5	1.02
84.0	1.00

Fill Rate (%)	Coefficient of safety stock
83.5	0.98
83.0	0.96
82.5	0.94
82.0	0.92
81.5	0.90
81.0	0.88
80.5	0.86
80.0	0.85
79.5	0.83
79.0	0.81
78.5	0.79
78.0	0.78
77.5	0.76
77.0	0.74
76.5	0.73
76.0	0.71
75.5	0.69
75.0	0.68
74.5	0.66
74.0	0.65
73.5	0.63
73.0	0.62
72.5	0.60
72.0	0.59
71.5	0.57
71.0	0.56
70.5	0.54
70.0	0.53

3.1.2.4 Cycle ordering point (COP)

The COP is the point of inventory level in units for reordering to supplier. The COP is reviewed on every 10 days. The equation for the COP is shown as follow.

$$\overline{D}x(LT_p + LT_x x\frac{1}{3}) + SS \quad \text{..... (3.4)}$$

Where,

$\overline{D}$ = Average demand (3.1.2.1)

LT_p = Production lead time

LT_s = Storing lead time

SS = Safety stock (3.1.2.2)

The production lead time is set as 45 or 60 days and the storing lead time is set as 5 days in current system. For example, if $\overline{D}$ is 200 units, LT_p is 45 days, LT_s is 5 days, SS is 100 units, the result of the COP is shown as follow.

$$200x\left[(\frac{45+5}{20})x\frac{1}{3}\right]+100 = 266.67 \text{ units}$$

Thus, when inventory level is 267 units, the current system will generate a purchase order placing to supplier.

3.1.2.5 Demand class

The system classified items into demand classes using historical consumption analysis. There are five main classes and four sub-classes in each main class except class D and E. Following is the description of each class.

Class A = orders have been received every month during the past 12 months

Class A1 = demand is equal or more than 100 pieces per month

Class A2 = demand is less than 100 pieces per month

Class A3 = demand is less than 50 pieces per month

Class A4 = demand is less than 10 pieces per month

Class B = orders are received every month during the past 6 months

Class B1 = demand is equal or more than 100 pieces per month

Class B2 = demand is less than 100 pieces per month

Class B3 = demand is less than 50 pieces per month

Class B4 = demand is less than 10 pieces per month

Class C = orders are received only for months 1-5 during the past 6 months

Class C1 = demand is equal or more than 100 pieces per month

Class C2 = demand is less than 100 pieces per month

Class C3 = demand is less than 50 pieces per month

Class C4 = demand is less than 10 pieces per month

Class D = No orders are received during the past 6 months

Class E = No orders are received during the past 12 months

In generally, above classified demand classes on consumption basis are a factor in identifying a different service fill rate but the current system regulated the same service fill rate for all item classes. (Figure 3.2)

3.1.3 Stock replenishment control

In every ten days the system will automatically generate the calculation of demand forecasting and release purchase order quantity as following equation.

POQ = COP-POB-BOQ……... (3.5)

Where;

POQ = Purchase order quantity

COP = Cycle order point

POB = Purchase order balance quantity

BOQ = Backorder quantity

3.2 IDENTIFY THE PROBLEMS

Given the above examination of existing system, we can summarize the key problems related to inventory management faced by the case company.

3.2.1 Stock cover

Currently, the average stock cover is three-and-a-half months. The stock cover is significantly high in the beginning of the year and decreases in the end of the year due to overseas customers placed more orders for stocking purpose during long holiday before end of the year so the stock month of the company decreased at the end of year. Consequently, the customers had more stock in the early of the year due to they just ordered before year end so they placed fewer orders to the company, resulting a high stock cover in this period.

The average stock amount is valued more than 400 million baht (Figure 3.4) and it tends to be increasing every year. It is interesting to note that despite the high stock level, the company has still experienced poor service performance due to frequent stock shortages.

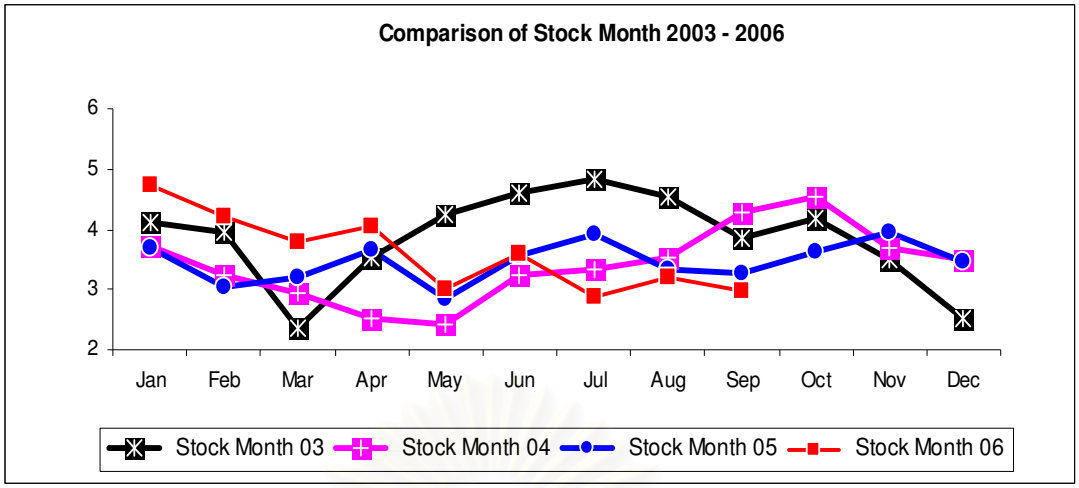


Figure 3.3 Comparison of stock cover in 2003-2006

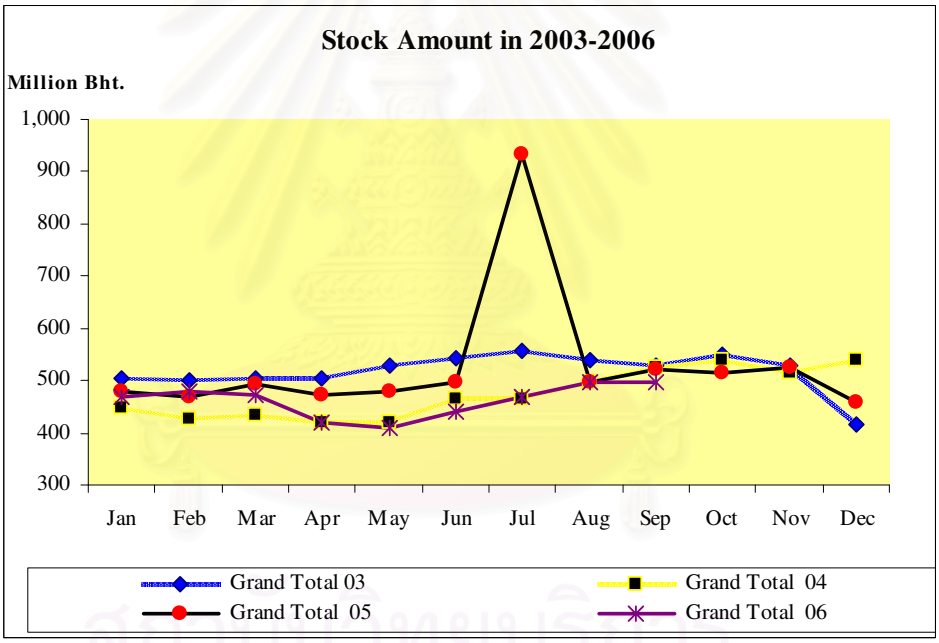


Figure 3.4 Comparison of stock amount in 2003-2006

3.2.2 Backorder quantity

Referring to Figure 3.5, it is apparent that the backorder quantity has increased continually since the beginning of 2006 until September 2006. The backorder quantity reached as high as 90,000 units in August 2006. Service parts shortage is certainly the critical problem faced by the case study company affecting not only customer satisfaction but also the company revenues.

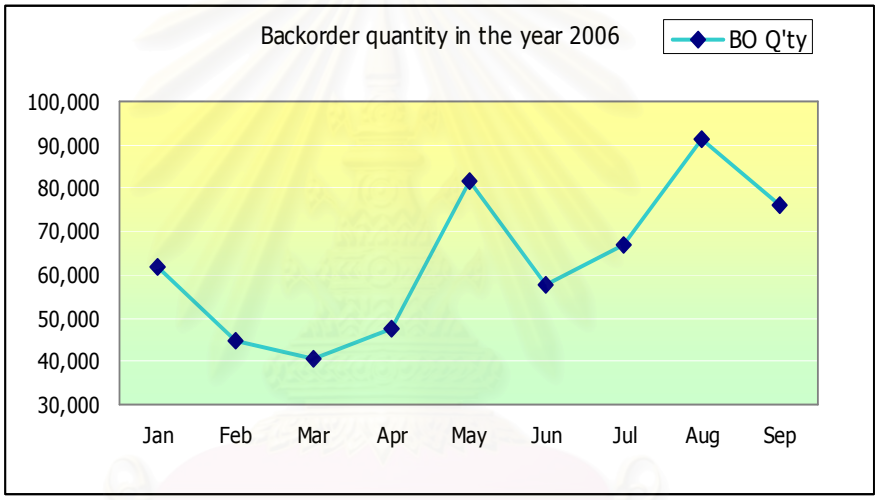


Figure 3.5 Backorder quantities from Jan to Sep'06

3.2.3 Customer dissatisfaction

Recent years the automotive industry has given serious attention to the management of service parts stock. The industry demands quality service parts with timely repairs or replacement, since a slow repair or replacement can lead to loss of future business to competitors who can serve customers better. A higher customer satisfaction is achieved through the availability of service parts on the market. For the case study

company that has worldwide operation, the problem of stock shortage becomes a business threatening issue.

3.2.4 First fill rate

First fill rate is the quantity to be filled for a specific order on the first date of receiving such order. First fill rate is a measurement of how well the inventory is managed. In the case study company, the first fill rate is presently less than 60%, a significantly sub-optimal performance considering an agreed acceptable rate ranging between 90-95%. Figure 3.6 illustrates first fill rate experienced in the year 2006.

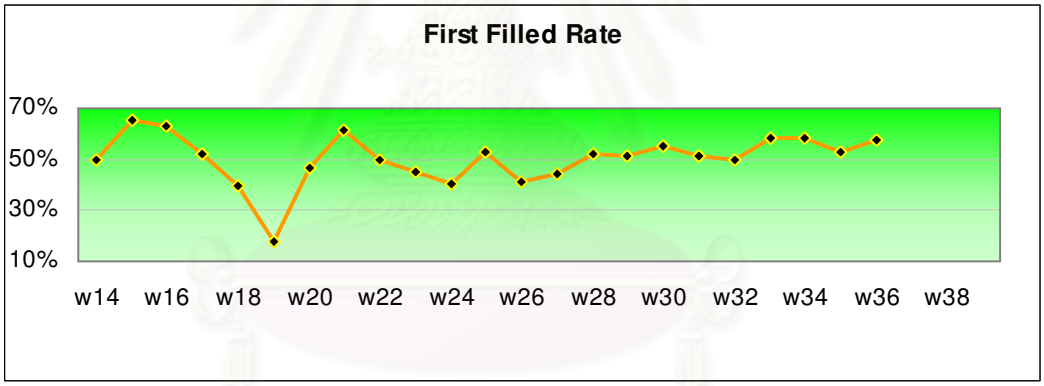


Figure 3.6 First fill rate experienced in the year 2006

3.3 DESIGNING A NEW INVENTORY SYSTEM

This section will only briefly outline the process adopted to design a new inventory system to cope with problems faced by the company as mentioned earlier. The detailed explanation of the technical issues of the system will be presented in the next chapter. There are four areas of consideration in developing a new inventory system.

The first consideration is to establish a workable scheme for classifying items. The second consideration is to design a demand forecasting system that matches with the patterns of spare parts demand. The third consideration is to design a method for setting safety stock and the last consideration is to establish a policy governing the replenishment of service parts. Figure 3.7 summarizes the procedure for the development of new inventory system.

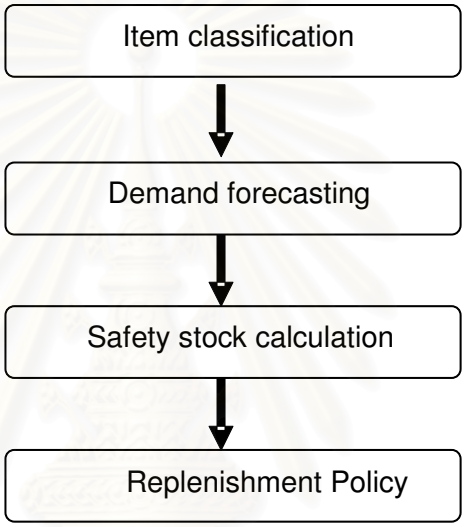


Figure 3.7 Four tasks in developing a new inventory system

3.3.1 Item classification

In classifying the items, this study applies the consumption rate together with functionality, as the criteria to classify the items due to items in criticality class will have more effect with customer satisfaction when there is a stock out. The classification by considering functionality will be helpful when managing safety stock since the service rate will be paid more weight and classification by consumption will

balance the inventory level with the customer service level. The result of this concept is shown in Figure 3.8 as the matrix of functionality and consumption.

Functionality			
D Desirable (Cosmetic)	DX	DY	DZ
E Essential (Functional)	EX	EY	EZ
	X	Y	Z
	fast moving		slow moving
	Percentage consumption in units		

Figure 3.8 Matrix tables of functionality and consumption

The classification adopted can be briefly described as follows:

- Classification by Functionality

The VED analysis considers the criticality of service parts and then classifies items into vital, essential and desirable. However, our study decides to classify items into two criticality types as essential (Class E) and desirable (Class D) because there is a difficulty in drawing the distinction between the huge loss and the moderate loss.

- Classification by Consumption

In this study, we adopted the Pareto's law in classify service parts as fast (Class X), medium (Class Y) and slow moving (Class Z). The criterion adopted in the classification is the order frequency over the last 12 months.

- *Fast* moving item (Class X) means the items having a consumption rate in every month in past 12 months.
- *Medium* moving item (Class Y) means the items having a consumption rate at least 6 months in past 12 months.

- *Slow* moving item (Class Z) means the items having a consumption rate less than 6 months in past 12 months.

3.3.2 Demand forecasting

The review of past literature as presented in Chapter 2 indicated that many researchers proposed that exponential smoothing could give good forecasts of service parts demand. However, in selecting an appropriate forecasting technique, it is necessary to analyze the demand patterns of sample historical demand over a relatively long period in order to investigate the patterns inherent in the demand i.e. trends and seasonal affect. In our study, the patterns of past demand will be thoroughly investigated and the forecasting method will be selected accordingly.

3.3.3 Safety stock

Since there are both fluctuation in demand and variability in the replenishment lead time, there is certainly a need to maintain certain amount of safety stock to protect the company against these uncertainties. Safety stock calculation will be performed in the following steps:

(1) Define an appropriate service level for each item class

(2) Calculate safety stock based on service level

3.3.4 Replenishment policy

A replenishment policy usually addresses two key questions related to the stock replenishment; when to place an order and what quantity to be ordered. Two basic types of inventory control systems that have been widely used are *continuous-review systems* and *periodic-review systems* (Evans, 1993). The continuous-review systems require continuously monitoring and accurate records of inventory position so it offer tighter control of inventory level, since orders may be placed to ensure that stock out is minimized. Thus, this system is usually controlled high-value items. The period-review system is useful when a large number of items are ordered from the same supplier, since individual orders will be placed at the same time. This allows shipments to be consolidated, resulting in lower freight rates. This type of system is often used in controlling low-value items.

In this thesis, we aim to increase stock availability when service parts are demanding so the continuous-review system is the most suitable to implement in this study as above mentioned reason.

3.4 VALIDATE PROPOSED INVENTORY SYSTEM

The effectiveness of the proposed system will be validated and assessed against the following three metrics:

(1) First fill rate

(2) Holding cost

(3) Backorder quantity

CHAPTER 4

Implementation

In this chapter, we will provide a full explanation of the development in an inventory system for managing fast-moving service parts items. The development of the system utilizes the data covering the operation during the years 2004 and 2005. The resulting system is validated by comparing the solutions generated by the system against the actual operation experienced in the year 2006. The results of the system validation will be presented in Chapter 5.

The development applies a number of theoretical frameworks and can be completed through four main tasks; item classification, demand forecasting, inventory control and ordering policy.

4.1. ITEM CLASSIFICATION

As service parts items comprise of a large number of items with different characteristics and requirements, it is therefore important to classify the available items into different categories of items with similar characteristics in each category. In this thesis, we study nine fast moving items as sample data to evaluate the performance of proposed system and existing system. To classify items, we started as following steps:

4.1.1 Select nine fast moving items from part master data

Part master data in existing system composed of thousand of part numbers of service parts. In this stage, we retrieved historical demand through out the year 2004-2006 since two years demand in 2004-2005 will be used to analyze demand patterns and historical demand in 2006 will be used to simulate the proposed inventory system. The criteria to select nine items of fast moving is demonstrates as follow.

- Fast moving items are items having demand in every month throughout three years (2004-2006).

The nine fast moving items are selected as shown in table 4.1.

Table 4.1 Historical demand of sample data in 2004-2006

Order received history in 2004-2006														
Part no	Part name	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
AA00001	OIL FILTER	2004	20	300	11	22	30	218	250	37	689	747	708	234
		2005	1159	555	1093	400	860	1657	1660	1670	1958	850	1000	1000
		2006	1050	1360	1882	1440	1765	1115	553	2383	1390	1846	8012	4253
AA00002	BUMPER KIT,FR CTR	2004	30	8	360	190	20	9	74	77	61	94	108	167
		2005	167	115	180	113	197	164	171	257	135	243	40	55
		2006	54	11	302	157	150	67	185	61	33	92	138	95
AA00003	LAMP KIT,COMBINATION,FR	2004	270	371	506	575	425	423	397	613	564	543	593	630
		2005	620	414	789	345	518	653	385	770	774	650	662	363
		2006	225	568	630	467	285	818	920	641	922	212	363	380
AA00004	MOULDING,WINDSHIELD	2004	270	3	24	160	15	295	244	349	18	13	63	293
		2005	291	81	573	230	92	117	110	88	351	184	94	201
		2006	330	316	91	135	82	105	493	164	245	215	66	120
AA00005	FENDER,FR	2004	11	83	47	8	50	13	46	97	74	98	105	203
		2005	73	128	112	32	131	117	131	145	112	129	121	76
		2006	118	234	136	108	213	107	525	96	68	61	60	52
AA00006	RADIATOR ASSY	2004	40	40	82	20	40	20	83	35	53	76	126	101
		2005	37	117	197	3	63	78	31	147	105	101	100	85
		2006	80	120	169	234	56	100	211	106	100	11	120	86
AA00007	TENSIONER ASSY, TIMING	2004	590	250	765	650	980	771	715	1339	700	1149	1187	1083
		2005	1288	174	1347	825	2023	1299	773	1124	868	1591	1193	680
		2006	1011	1404	1031	807	1568	1316	1181	901	1224	1452	1356	1418
AA00008	GATE,RR BODY,RR	2004	80	85	70	45	67	79	117	112	86	126	140	83
		2005	88	119	66	65	84	84	75	113	92	123	63	87
		2006	52	69	42	148	138	51	101	27	55	47	43	54
AA00009	BELT,A/C	2004	550	600	2130	160	1050	1689	695	1802	915	1446	2047	1602
		2005	1269	2486	2285	2080	1699	1718	2022	1181	1744	2950	1909	707
		2006	1335	2674	2078	1539	2721	1725	2996	1784	2014	1839	3751	2890

4.1.2 Classify nine items (table 4.1) in a matrix of consumption – functionality

As mentioned in Chapter 3, the conceptual analysis for the matrix of consumption and functionality are conducted in this section. Refer to nine items in table 4.1, we classified them in a matrix of consumption-functionality as shown in table 4.2.

Table 4.2 Classification matrix: consumption-functionality

Classification matrix : consumption-functionality					
Part no	**Part name**		X	Y	Z
AA00001	OIL FILTER	E			
		D	X		
AA00002	BUMPER KIT,FR CTR	E			
		D	X		
AA00003	LAMP KIT,COMBINATION,FR LH	E			
		D	X		
AA00004	MOULDING,WINDSHIELD	E			
		D	X		
AA00005	FENDER,FR	E			
		D	X		
AA00006	RADIATOR ASSY	E	X		
		D			
AA00007	TENSIONER ASSY, TIMING BELT	E	X		
		D			
AA00008	GATE,RR BODY,RR	E	X		
		D			
AA00009	BELT,A/C	E			
		D	X		

From table 4.2, three items that are part number AA00006, AA00007 and AA00008 are essential class (Class E) and the rest seven times are desirable class (Class D). Class E is an essential part that is required to be replaced immediately since it impacts

with functionality of vehicle on road but Class D is a cosmetic part that is required as soon as possible but vehicle can be on road during waiting this group of items.

All selected items are fast moving due to they have a continuous demand in every month for two years of analysis (2004-2005).

4.2 DEMAND FORECASTING

Current inventory system uses a simple moving average over the latest six months to forecast demand of the next period. This technique has universally been applied to all service parts serving the after-sales operations since the start of the export operation in 1995. Although the number of items and number of export customers are increasing but the company has not implemented any modifications to the existing system to keep up with the changes.

The development of demand forecast for the nine sample items will proceed through the following three steps.

1. Review historical demand data
2. Select forecasting technique
3. Develop forecasts

4.2.1. Review historical demand data

Prior to selecting forecasting technique, we need to first investigate the patterns of the demand for each item and then select the technique that matches the actual demand patterns.

With regards to time-series data, the demand may be characterized by the three general patterns as shown in Figure 4.1

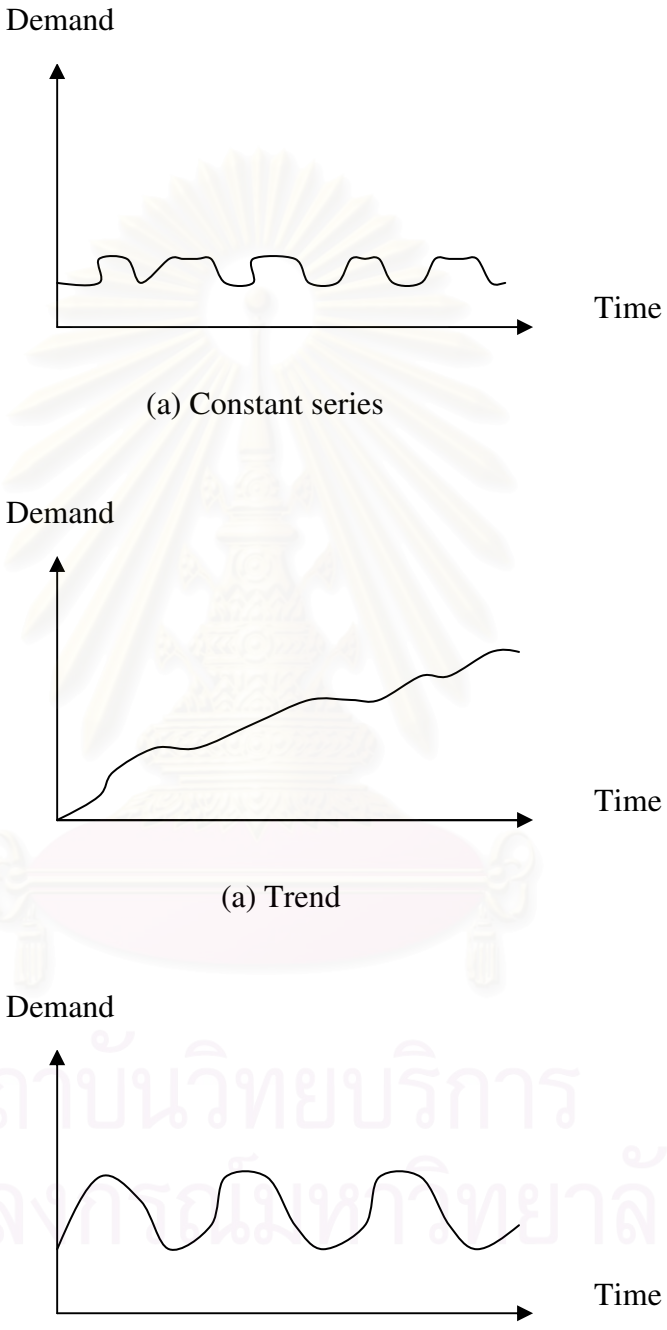
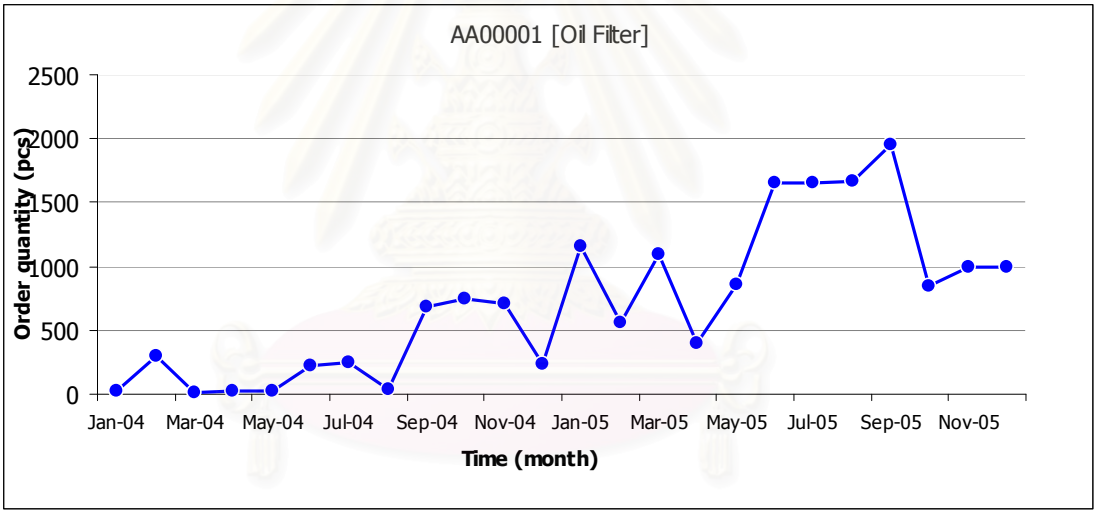
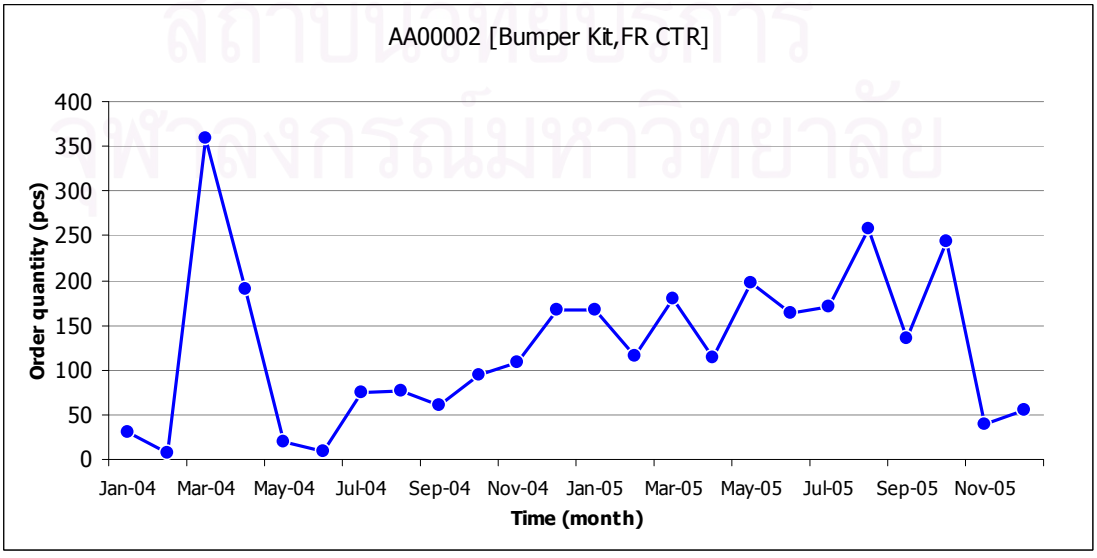


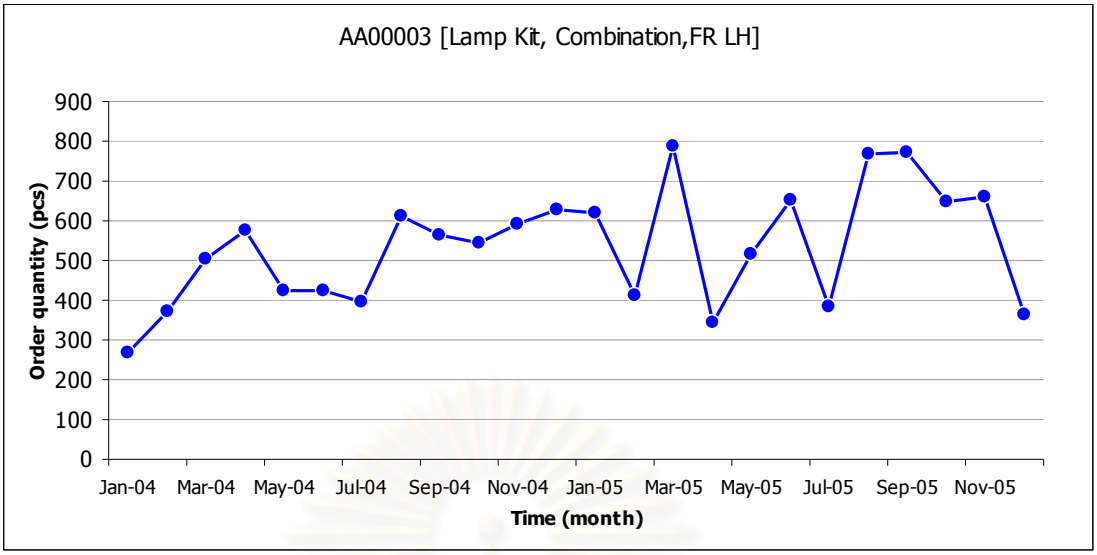
Figure 4.1 Demand patterns

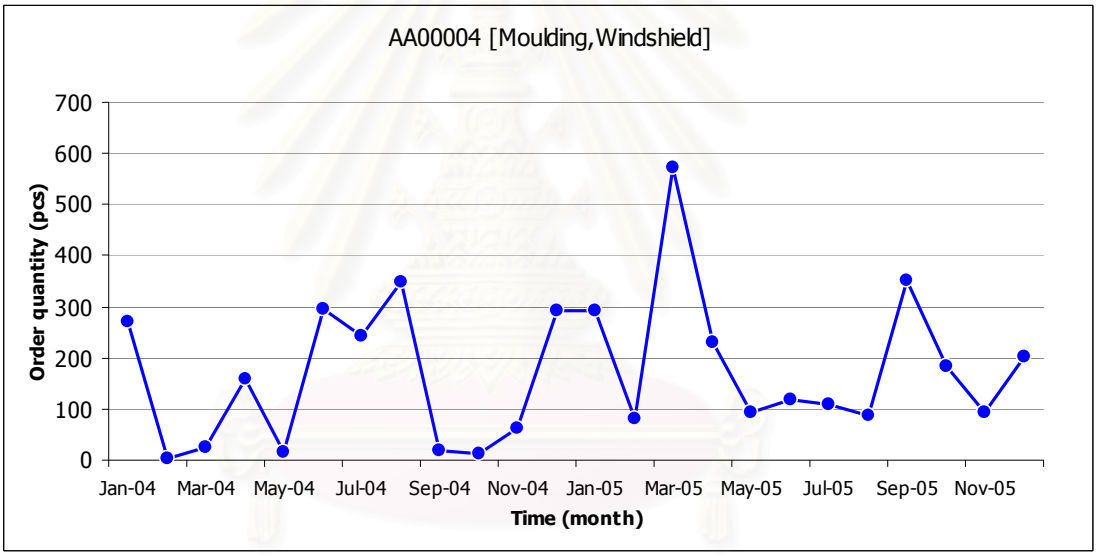
- **Constant (C)** is time series demand continually the same level over time.
- **Trend (T)** is a demand pattern that gradually rises or falls over the time.
- **Seasonality (S)** is a pattern of demand fluctuation above or below the trend line that repeats every year.

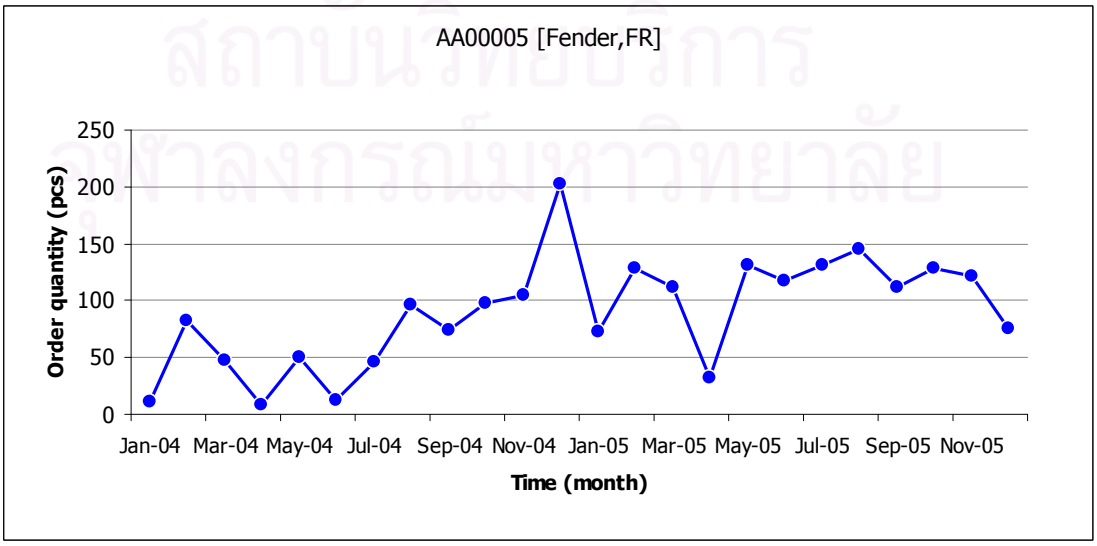
Our study acquired two years of historical demand data for the nine selected items. Given the limitation of available data, the granularity of the demand data is at the monthly level. Figure 4.2 illustrates historical monthly demand of the sample nine items.

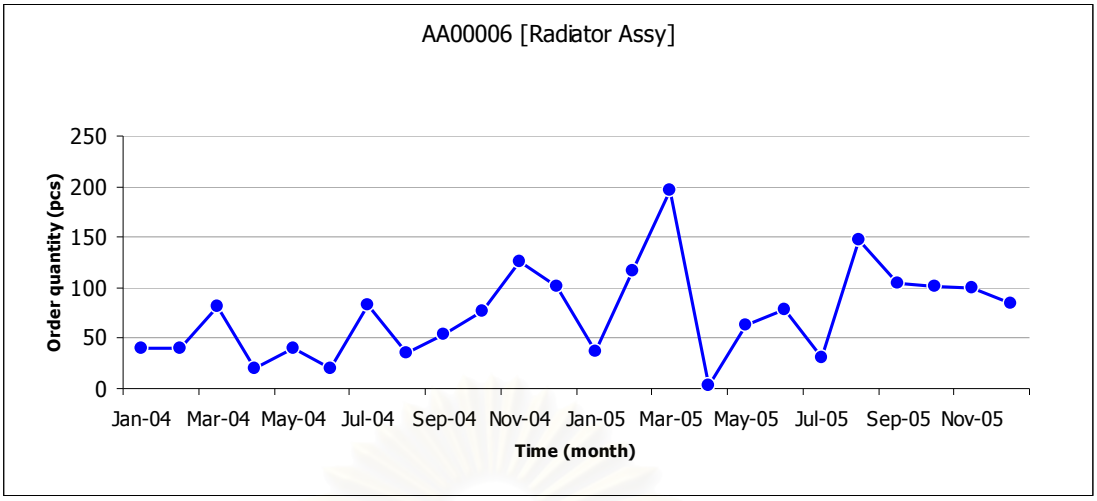


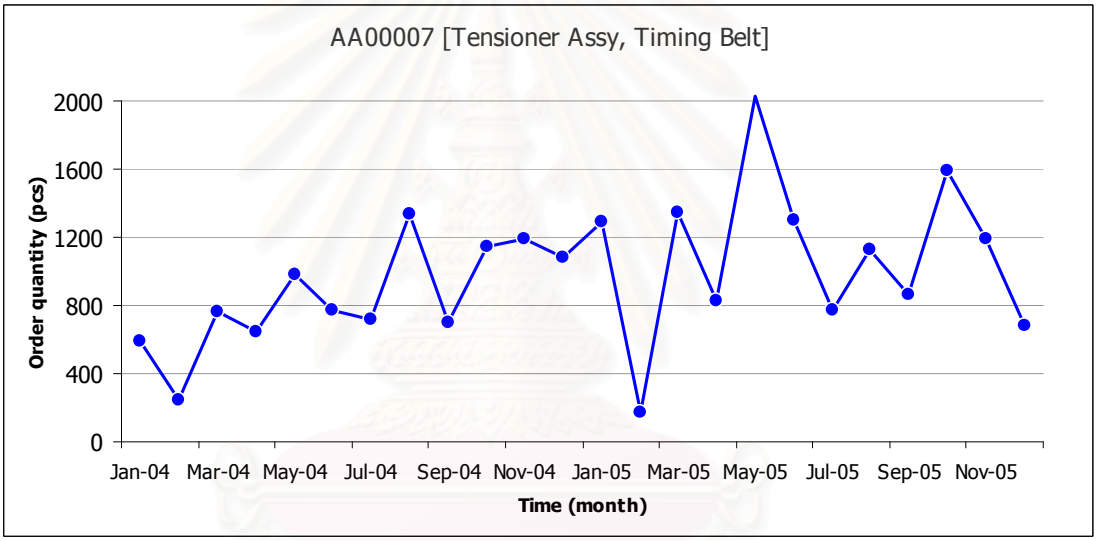


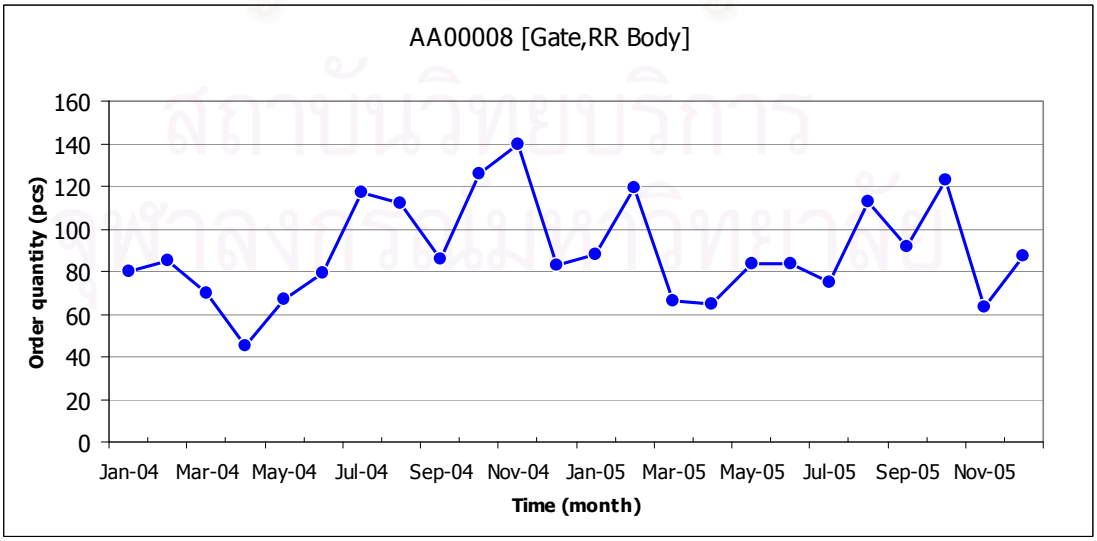







AA00006 [Radiator Assy]
Order quantity (pcs)
250
200
150
100
50
0
Jan-04 Mar-04 May-04 Jul-04 Sep-04 Nov-04 Jan-05 Mar-05 May-05 Jul-05 Sep-05 Nov-05
Time (month)


AA00007 [Tensioner Assy, Timing Belt]
Order quantity (pcs)
2000
1600
1200
800
400
0
Jan-04 Mar-04 May-04 Jul-04 Sep-04 Nov-04 Jan-05 Mar-05 May-05 Jul-05 Sep-05 Nov-05
Time (month)


AA00008 [Gate,RR Body]
Order quantity (pcs)
160
140
120
100
80
60
40
20
0
Jan-04 Mar-04 May-04 Jul-04 Sep-04 Nov-04 Jan-05 Mar-05 May-05 Jul-05 Sep-05 Nov-05
Time (month)

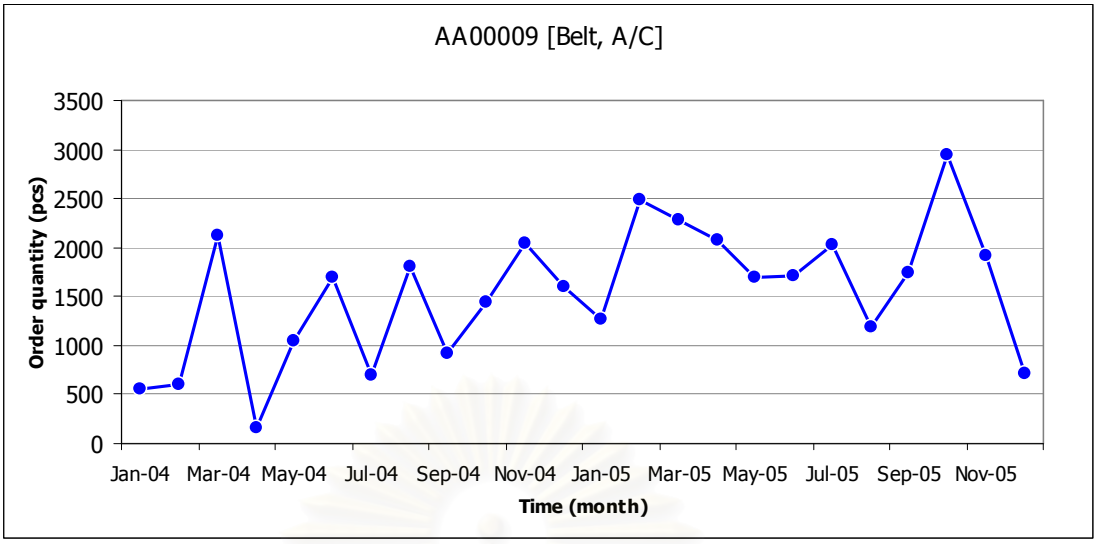


Figure 4.2 Demand patterns of example data

The observation from above figures illustrates that most of demand is irregular pattern, some contains a trend such as demand of part number AA00001 and AA00007 and there is no items having an indicator of seasonality pattern.

4.2.2. Select forecasting techniques

As indicated above the demand patterns of sample data can be categorized into two types; irregular without trend and irregular with trend.

(1) Irregular without trend

The forecasting technique that has been widely applied to forecast this type of demand is the exponential smoothing technique. *The Exponential smoothing* (ES) is one of the most widely used techniques in forecasting because it is relatively easy to calculate and understand. ES is based on the idea that as data gets older it becomes less relevant and should be given less weight. Therefore, this method gives higher

weight to the more recent data, and this weight declines exponentially with age (Waters, 2003).

In practice, we can get this declining weight using only the latest demand figure and the previous forecast. To be precise, we take a proportion, α of the latest demand and add a proportion, $1-\alpha$ of the previous forecast as following equation.

New forecast = α x latest demand + (1-α) x previous forecast

$F_t = \alpha \times A_{t-1} + (1-\alpha) \times F_{t-1}$ ..... (4.1)

Where;

F_t = Forecast for period t

F_{t-1} = Forecast for period t-1

α = smoothing constant

A_{t-1} = Actual demand for period t-1

If α is large, a greater weight is placed on the most recent data, meaning that the forecast is more responsive to current changes in demand. The exponential smoothing is a simple procedure and requires a small amount of historical data. Once the smoothing constant (α) has been selected, there are only two information required that are previous forecast and previous demand in order to compute forecast for the next period (Evans, 1993).

(2) Irregular with trend

Exponential smoothing is designed to deal with demand without a trend. To deal with the trend, the simple exponential smoothing is further enhanced as a double exponential smoothing usually called as the *Holt's* method. This enhanced method requires the specification of two smoothing constants, α and β, and uses two smoothing equations: one for the value of the series (the intercept) and one for the trend (the slope). The equations are:

New forecast with trend = Forecast resulting from ES + Trend adjustment

$FT_t = F_t + T_t$ ..... (4.2)

Trend adjustment can be computed as following.

$T_t = \beta(F_{t+1} - Ft) + (1- \beta)T_t$ ..... (4.3)

Where;

FT_t = Next forecast with trend

F_t = New forecast resulting from exponential smoothing

T_t = Trend adjustment factor

Trend adjustment factor uses constant value of α and β that are between zero and one. A high β is more responsive to recent changes in trend. A low β value gives less weight to the most recent trends.

In the nine sample data showing in Figure 4.2, there are two items having trend demands. Historical demands of both items are plotted in time series over 24 months

and the trend is evidently shown over this period as shown in the Figure 4.3 which illustrates the demand pattern together with a trend line.

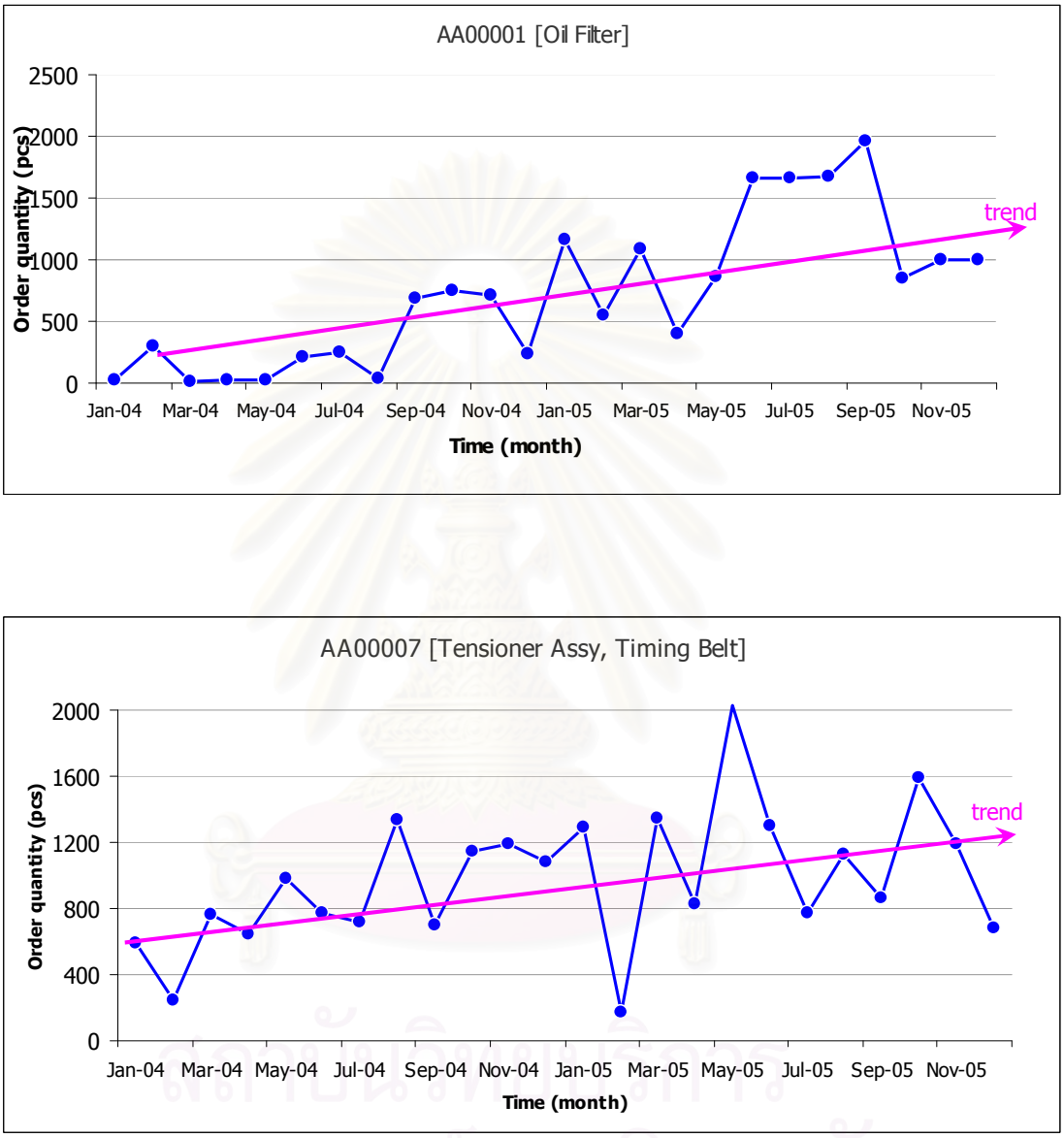


Figure 4.3 Demand pattern with trend

It is apparent that Items AA00001 and AA00007 have upward trends throughout 24 months historical demand. The Holt's method would be a suitable technique for forecasting the demand of these two items.

Given the demand patterns of the nine sample items as described earlier, the forecasting technique to be used in developing forecast for the these items can be summarized in Table 4.3.

Table 4.3 Forecasting method in each part numbers

Classification matrix : Consumption-Criticality

Part no	Part name	Criticality	Consumption X	Y	Z	Forecasting method
AA00001	OIL FILTER	E				HOLT
		D	X			
AA00002	BUMPER KIT,FR ETR	E				EXPONENTIAL SMOOTHING
		D	X			
AA00003	LAMP KIT,EOMBINATION,FR LH	E				EXPONENTIAL SMOOTHING
		D	X			
AA00004	MOULDING,WINDSHIELD	E				EXPONENTIAL SMOOTHING
		D	X			
AA00005	FENDER,FR	E				EXPONENTIAL SMOOTHING
		D	X			
AA00006	RADIATOR ASSY	E	X			EXPONENTIAL SMOOTHING
		D				
AA00007	TENSIONER ASSY, TIMING BELT	E	X			HOLT
		D				
AA00008	GATE,RR BODY,RR	E	X			EXPONENTIAL SMOOTHING
		D				
AA00009	BELT,A/E	E				EXPONENTIAL SMOOTHING
		D	X			

4.2.3 Develop forecasts

The implementation of the two techniques for forecasting the demand of the sample items is presented separately as follows.

4.2.3.1. Exponential Smoothing

Forecasting with the exponential smoothing technique involves the following steps:

(1) Determine the smoothing constant α. The smoothing constant is determined by applying the method to "simulate" the forecasts for the demand during the years 2004 and 2005. The error which is difference between the forecasts and the actual sales is then measured through the Mean Squared Error (MSE)

$$\text{MSE} = \frac{\sum (Y - \hat{Y})^2}{n} \quad \text{..... (4.4)}$$

Where;

Y = actual demand quantity

$\hat{Y}$ = forecast quantity

n = number of period

The best smoothing constant (α) that provides the minimum MSE value is then selected using the "Solver" analysis tool available in the software "Excel". Figure 4.5 illustrates the setting up of "solver" to compute the best α providing minimum MSE value.

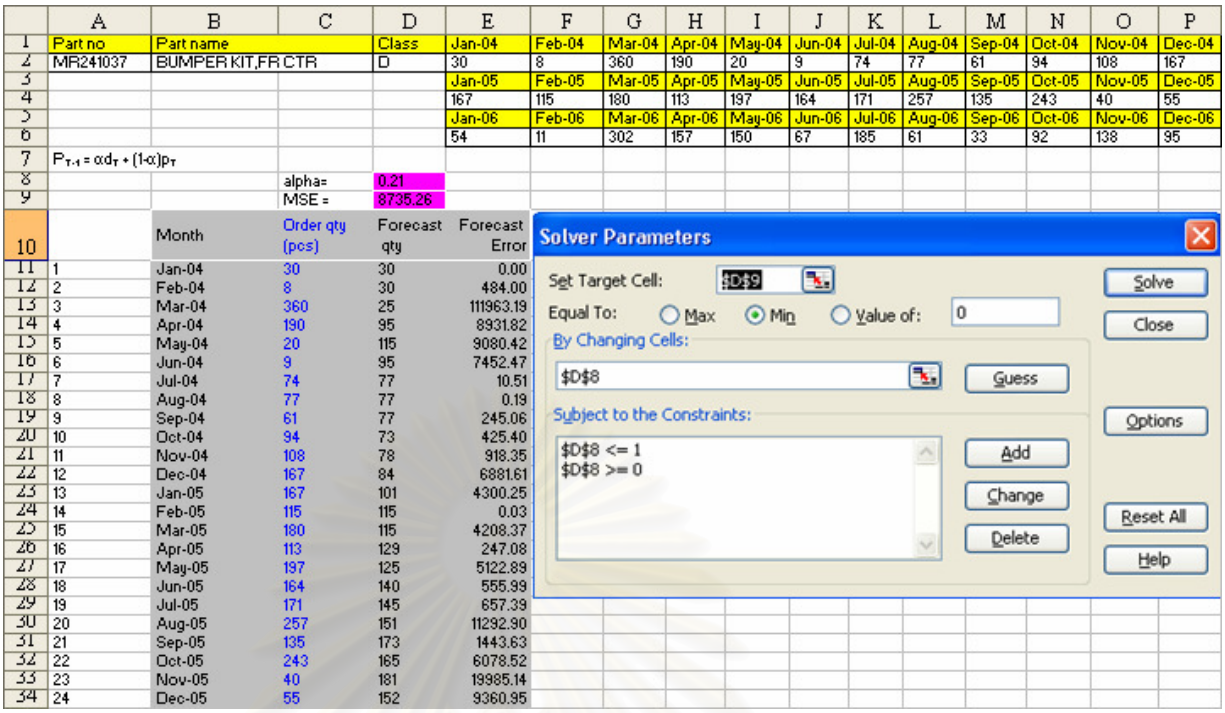


Figure 4.4 Exponential smoothing computation by excel spreadsheet

(2) Develop the forecasts for the year 2006 using the ES method with the smoothing constant obtained in step 1. Results of the demand forecast for seven items computing by ES are shown as follows.

Table 4.4 Forecast quantities by exponential smoothing

ITEM NO.	Jan-06	Feb-06	Mar-06	Apr-06	May-06	Jun-06	Jul-06	Aug-06	Sep-06	Oct-06	Nov-06	Dec-06	α
AA00002	131	115	93	137	141	143	127	139	123	104	102	109	0.21
AA00003	545	421	478	537	510	422	576	710	683	776	557	482	0.39
AA00004	191	204	214	203	197	186	179	207	203	207	208	195	0.09
AA00005	106	109	154	148	133	162	142	282	214	161	125	101	0.36
AA00006	90	88	94	107	130	117	114	131	127	122	103	106	0.17
AA00008	89	90	90	85	91	96	90	91	95	80	77	74	0.10
AA00009	1659	1574	1864	1920	1820	2057	1970	2240	2120	2092	2025	2480	0.26

4.2.3.2 Holt's method

The Holt's method or double smoothing is specifically designed for forecasting demand with a trend which will be applicable to the selected items AA00001 and AA00007. Similar to the ES method, the application of the Holt's method follows the following steps.

(1) Determine the smoothing constant α and the trend smoothing constant (β). The "Solver" is also applied to solve for these two constants that minimize the Mean Squared Error (MSE). Figures 4.5 and 4.6 demonstrate the setting of the spreadsheet to determine the two factors.

	A	B	C	D	E	F	G	H
8				Alpha =		0.37		
9				β =		0.05		
10				MSE =			172678.42	274973.14
11	Code	Month	Actual demand	Exp forecast (no trend)	Trend factor	Exp forecast (trend)	MSE (no trend)	MSE (trend)
12	1	Jan-04	20	20	0.00	20	0.00	78400.00
13	2	Feb-04	300	20	0.00	20	78400.00	81.00
14	3	Mar-04	11	123	5.67	129	12560.23	11392.89
15	4	Apr-04	22	82	3.09	85	3578.05	3014.34
16	5	May-04	30	60	1.71	62	887.88	24491.11
17	6	Jun-04	218	49	1.01	50	28619.02	40064.78
18	7	Jul-04	250	111	4.38	115	19292.33	6159.13
19	8	Aug-04	37	162	6.95	169	15683.38	270212.96
20	9	Sep-04	689	116	4.03	120	328176.68	392923.43
21	10	Oct-04	747	327	15.40	342	176387.90	133652.90
22	11	Nov-04	708	482	23.05	505	51248.91	73261.46
23	12	Dec-04	234	565	26.36	591	109529.67	322264.25
24	13	Jan-05	1159	443	18.22	461	512478.83	8771.66
25	14	Feb-05	555	707	31.70	738	22997.47	125776.06
26	15	Mar-05	1093	651	26.89	678	195519.00	77126.03
27	16	Apr-05	400	814	34.36	848	171062.02	145.06
28	17	May-05	860	661	24.10	685	39463.80	943913.59
29	18	Jun-05	1657	734	26.80	761	851055.92	807714.87
30	19	Jul-05	1660	1074	43.99	1118	343314.09	304638.58
31	20	Aug-05	1670	1290	53.43	1343	144582.40	377995.72
32	21	Sep-05	1958	1430	58.18	1488	279066.63	406936.21
33	22	Oct-05	850	1624	65.67	1690	599379.62	475919.84
34	23	Nov-05	1000	1339	46.40	1386	115058.15	148689.08
35	24	Dec-05	1000	1214	36.99	1251	45940.13	1565810.32

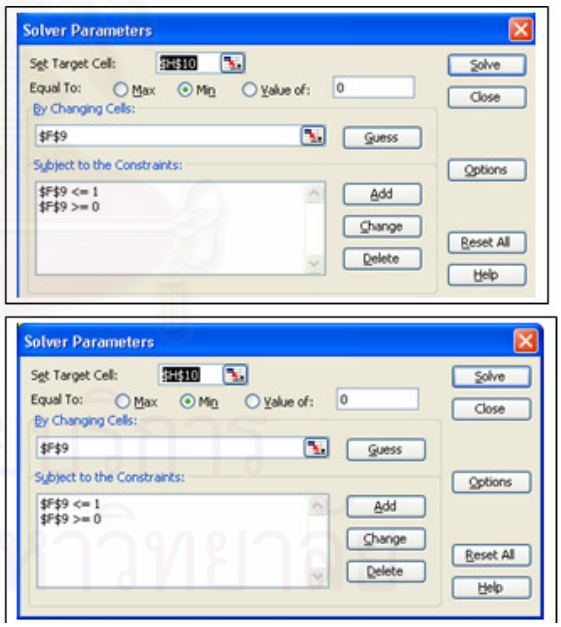


Figure 4.5 The Holt's method using the "Solver" in the software "Excel"

	A	B	C	D	E	F	G	H
8				Alpha =		0.37		
9				β =		0.05		
10				MSE =			172678.42	274973.14
11	Code	Month	Actual demand	Exp forecast (no trend)	Trend factor	Exp forecast (trend)	MSE (no trend)	MSE (trend)
12	1	Jan-04	20	20	0.00	20	0.00	78400.00
13	2	Feb-04	300	20	0.00	20	78400.00	81.00
14	3	Mar-04	11	123	5.67	129	12560.23	11392.89
15	4	Apr-04	22	82	3.09	85	3578.05	3014.34
16	5	May-04	30	60	1.71	62	887.88	24491.11
17	6	Jun-04	218	49	1.01	50	28619.02	40064.78
18	7	Jul-04	250	111	4.38	115	19292.33	6159.13
19	8	Aug-04	37	162	6.95	169	15683.38	270212.96
20	9	Sep-04	689	116	4.03	120	328176.68	392923.43
21	10	Oct-04	747	327	15.40	342	176387.90	133652.90
22	11	Nov-04	708	482	23.05	505	51248.91	73261.46
23	12	Dec-04	234	565	26.36	591	109529.67	322264.25
24	13	Jan-05	1159	443	18.22	461	512478.83	8771.66
25	14	Feb-05	555	707	31.70	738	22997.47	125776.06
26	15	Mar-05	1093	651	26.89	678	195519.00	77126.03
27	16	Apr-05	400	814	34.36	848	171062.02	145.06
28	17	May-05	860	661	24.10	685	39463.80	943913.59
29	18	Jun-05	1657	734	26.80	761	851055.92	807714.87
30	19	Jul-05	1660	1074	43.99	1118	343314.09	304638.58
31	20	Aug-05	1670	1290	53.43	1343	144582.40	377995.72
32	21	Sep-05	1958	1430	58.18	1488	279066.63	406936.21
33	22	Oct-05	850	1624	65.67	1690	599379.62	475919.84
34	23	Nov-05	1000	1339	46.40	1386	115058.15	148689.08
35	24	Dec-05	1000	1214	36.99	1251	45940.13	1565810.32

Figure 4.6 The Holt method computation in excel spreadsheet

(2) Develop the forecasts for the year 2006 using the Holt's method with the optimal smoothing values obtained earlier in Step 1. Results of the demand forecast for the year 2006 of the two sample items are shown as follows.

Table 4.5 Forecast quantities by the Holt's method

FORECAST	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	**α**	**β**
AA00001	1166	1131	1229	1481	1475	1597	1421	1092	1595	1525	1658	4136	0.37	0.05
AA00007	1083	1070	1140	1122	1059	1165	1198	1197	1138	1158	1219	1249	0.19	0.06

The finalized forecasts for the nine sample items can now be obtained and presented in table 4.6.

Table 4.6 Forecast quantities of nine items

Item number	Jan-06	Feb-06	Mar-06	Apr-06	May-06	Jun-06	Jul-06	Aug-06	Sep-06	Oct-06	Nov-06	Dec-06
AA00001	1166	1131	1229	1481	1475	1597	1421	1092	1595	1525	1658	4136
AA00002	131	115	93	137	141	143	127	139	123	104	102	109
AA00003	545	421	478	537	510	422	576	710	683	776	557	482
AA00004	191	204	214	203	197	186	179	207	203	207	208	195
AA00005	106	109	154	148	133	162	142	282	214	161	125	101
AA00006	90	88	94	107	130	117	114	131	127	122	103	106
AA00007	1083	1070	1140	1122	1059	1165	1198	1197	1138	1158	1219	1249
AA00008	89	90	90	85	91	96	90	91	95	80	77	74
AA00009	1659	1574	1864	1920	1820	2057	1970	2240	2120	2092	2025	2480

4.3 INVENTORY CONTROL

The continuous review models are adopted and can be explained as follow.

4.3.1 Reorder Point Model

Reorder Point Model assumes that demand *gradually* and *continuously* reduces on the inventory level. When inventory falls to the desired level called the reorder point (ROP), an order quantity at economic level is placed to suppliers to replenish the inventory.

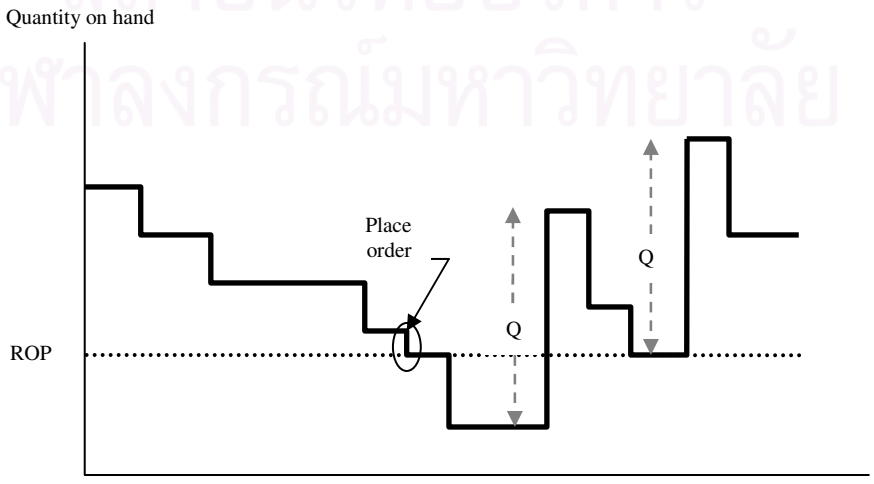


Figure 4.7 Reorder Point Model

Source: Ballou, (2550)

As shown in the above figure, the same amount Q is ordered every time the inventory reduces to the reorder point level. The operation of this model requires the determination of the following model parameters:

- Quantity to be ordered
- Time to order

The following section will describe the method and procedures adopted to determine these two parameters.

4.3.1.1 Determination of Order Quantity

(1) Order quantity

In managing inventory, we have to consider how many order quantity that providing the least cost including holding cost and ordering cost. This order quantity is known as an economic order quantity (EOQ). EOQ is the oldest model and most widely used in many industries. The EOQ is the order quantity that yields the lowest total cost including holding cost and ordering cost under the following assumptions:

- The demand is known exactly, is continuous and is constant over time.
- Quantity discounts do not exist.
- Replenishment is immediate, so when order arrives in stock it can be use at once.
- A single delivery is made for each order.

- There is no minimum order quantity (MOQ) in each order.
- Unit cost is purchasing cost only.
- Two variable costs; ordering cost and holding cost are known and do not vary.

Figure 4.8 graphically demonstrates the determination of EOQ.

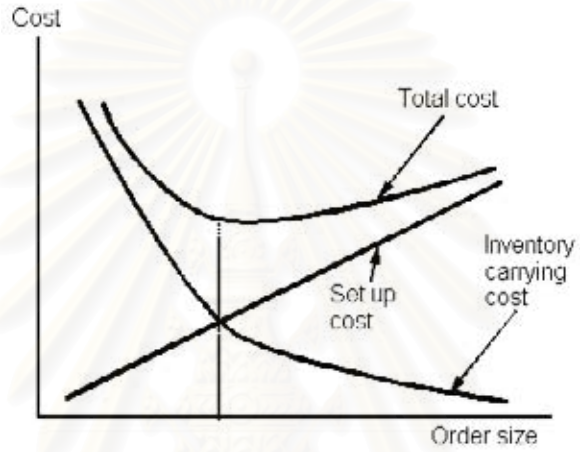


Figure 4.8 Economic order quantities

If the order quantity is large, there will be fewer order frequencies, resulting in low ordering cost or set up cost. However, large order quantity leads to higher inventory level and high inventory carrying cost. The EOQ is the order quantity that minimizes the sum of ordering cost and inventory carrying cost and can be derived from the following formula.

$$EOQ = \sqrt{\frac{2DC_0}{C_h}} \quad \text{..... (4.5)}$$

Where;

EOQ = Q^* = optimal number of units to order

D = annual demand in units for the inventory items

C_0 = ordering cost of each order

C_h = holding cost per unit per year

(2) Relevant costs

To determine EOQ, we should be knowledgeable about the following cost items:

- *Unit cost* (UC) is the purchase price per item. Table 4.7 shows unit costs of nine sample items.

Table 4.7 Unit cost of nine items

Part number	Unit cost (THB)
AA00001	135.00
AA00002	394.06
AA00003	226.66
AA00004	132.16
AA00005	530.00
AA00006	2396.00
AA00007	201.80
AA00008	45.00
AA00009	66.00

- *Order cost* (OC) is the cost of placing an order regardless of the order quantity. This cost includes allowances for pulling in an order, correspondence, telephone costs, receiving an item, quality checking and so on.

We determined the ordering cost by calculating the time cost of workers in completing ordering activities. In figure 4.10, ordering activities compose of releasing purchase order, sending purchase order through fax, counting and receiving orders, following up delivery schedule from suppliers and storing items and take up

about 3.5 hours. The workers performing the ordering activities earn an average wage of 11,500 baht per month (equivalent to 61.50 baht per hour). The ordering cost is then approximated as 215 baht per order. Figure 4.9 illustrates ordering cost calculation in an excel spreadsheet.

	A	B	C	D
1	**Ordering cost calculation**			
2				
3	**1. Man hours in ordering**			
4	Release P/O	0.25		
5	Fax P/O	0.25		
6	Counting & Receiving	1		
7	Follow up delivery schedule	1		
8	Storing items	1		
9	**Total Hours**	**3.5**		
10				
11	**2. Worker's Wages**	No. of person	Wages/Person	Total W.
12	Warehouse worker	2	8,000	16,000
13	Inventory staff	1	15,000	15,000
14	Follow up staff	1	15,000	15,000
15			TOT Wages:	46,000
16			Average wages:	11,500
17				
18	Cost per hour	*=D16/(22*8.5)*	61.50	Baht/hour
19	Ordering cost	*=C18*B9*	215	Baht/order

Figure 4.9 Ordering cost calculation

○ *Holding cost* (HC) is the cost of holding one unit of item in stock for a period. It includes all expenses incurred when carrying the inventory such as rent, electricity, heat, insurance, taxes, obsolescence and cost of capital.

To determine holding cost, we categorized all related costs as follow.

- Investment in the inventory
  - Costs associated with obtaining the funds to purchase the inventory.

- Warehousing cost
  - Rental and facility cost paying to the outsourcing company in operating warehouse.
- Insurance cost
  - It is insurance on the warehouse facility for fire or other hazard.
- Facility cost
  - It is other facility cost such as electricity, water and lights.

The above cost data are not readily available in the cast company. These costs are roughly estimated utilizing the experiences of person in charge and some historical data. Table 4.8 shows the breaking down of inventory carrying cost.

Table 4.8 Inventory Carrying Cost

Holding cost	**Amount (baht)/year**
Inventory value	73,000,000
Facility cost	1,200,000
Warehouse cost	12,000,000
Insurance cost	800,000
TOT holding cost	14,000,000
Holding cost ratio (%)	**19**

Total inventory carrying cost over a year is 14,000,000 baht equivalent to 19% of average inventory value.

Given the estimates of relevant costs and the demand forecasts throughout the year 2006, the EOQ is then determined as shown in Figure 4.10

	A	B	C	D	E	F	G
1	Inventory	EOQ Model					
2	Part number	AA00001					
3							
4	**Data**						
5	Demand rate, D	19508					
6	Ordering cost, O	215					
7	Holding cost rate	0.19					
8	Unit Price, P	135					
9							
10	**Results**						
11	Optimal Order Quantity, Q*	569	=SQRT((2*B5*B6)/(B8*B7))				

Figure 4.10 Example of EOQ computing on excel spreadsheet

The EOQs for the nine sample items are summarized in Table 4.9.

Table 4.9 EOQ result for nine items

Inventory	**EOQ Model**								
Part number	AA00001	AA00002	AA00003	AA00004	AA00005	AA00006	AA00007	AA00008	AA00009
Data									
Demand rate, D	19508	1466	6696	2394	1837	1330	13799	1049	23821
Ordering cost, O	215	215	215	215	215	215	215	215	215
Holding cost rate	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
Unit Price, P	135	394	226	132	530	2396	201	45	66
Results									
Optimal Order Quantity, Q*	569	91	258	202	88	35	392	229	900
Maximum Inventory	569	91	258	202	88	35	392	229	900
Average Inventory	285	46	129	101	44	18	196	114	450
Number of Ordering	34	16	26	12	21	38	35	5	26
Holding cost	฿32,263.26	฿12,106.13	฿14,508.07	฿7,399.84	฿11,541.77	฿40,595.15	฿31,766.35	฿1,176.45	฿13,299.15
Ordering cost	฿7,318.18	฿3,228.61	฿5,381.02	฿2,582.89	฿4,520.05	฿8,609.63	฿8,179.14	฿1,291.44	฿6,672.46

4.3.1.2 Time to Order

The Reorder Point dictates the time to order through the identification of reorder point. When placing the order, it is important that the outstanding inventory would be enough to satisfy the demand that would occur during the elapsed time between the placing of order and the receiving of the order. As a result, the reorder point is set as follow.

ROP = EDDLT + SS…….. (4.6)

Where,

EDDLT = Expected demand during lead time

SS = Safety stock

Above equation shown that EDDLT and SS are influenced with the ROP. The EDDLT is the result of demand forecasting and the safety stock is significantly considered carefully.

- Safety stock

The safety stock is provided to protect the company against the variability in the replenishment lead time (L) and the customer demand (D) in order to maintain the desirable of customer service level. The safety stock would clearly increase with service level. In theory, there are alternative definitions of service level of an inventory system. In this study, we define the service level by the “Fill Rate”. The fill rate refers to the proportion of total demand that can be satisfied immediately from

the stock on hand. It reflects not only the stock out *event* but also the *amount* of backorder. For example, if order has been placed for 100 units and only 90 units can be filled by the stock, then the fill rate is determined as 90%. It is usually a good measure of the effectiveness of an inventory system as far as finished goods are concerned.

In this study, different service levels are adopted for different item classes:

Class	Service level
Essential (Class E)	95%
Desirable (Class D)	90%

Given the service level, the safety stock is then determined as follows:

(1) Find the standard deviation of lead time demand σ_L

$$\sigma_L = \sqrt{L * \sigma_D + D * \sigma_{LT}{}^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (4.7)$$

Where;

L = Mean replenishment lead time

σ_D = Standard error of demand per period or Root mean squared error of forecasts

D = Mean demand per period

σ_{LT} = Standard deviation of replenishment lead-time

(2) From the table of "normal loss integral", determine the "k" factor that corresponds to the value L(k) from the following formula (*Table of "normal loss integral" is shown the appendix G.*)

$$L(k) = \frac{(1-\alpha)Q^*}{\sigma_L} \quad \text{..... (4.8)}$$

Where;

α = Fill rate

Q* = Economic order quantity

σ_L = Standard deviation of lead-time demand

(3) Formulate safety stock quantity as following equation.

$$k * \sigma_L \quad \text{..... (4.9)}$$

Figure 4.11 is a spreadsheet showing the calculation of safety stock for Part AA00001.

Part number: AA00001

	A	B	C	D	E	F	G	H	I	J	K	L	M
17	**2006**	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
18	Forecast with T	1166	1131	1229	1481	1475	1597	1421	1092	1595	1525	1658	4136
19													
20	Safety stock												
21	Fill Rate	90%											
22	α	0.10											
23	Q*	569											
24	LT (month)	2											
25	MSE Demand	353535.70											
26	Mean demand	1626	=AVERAGE(B18:M18)										
27	STDV LT	0											
28	σ_L	841	=SQRT((B24*B25)+(B26)^2*(B27)^2)										
29	L(k)	0.0677	=B22*B23/B28										
30	k	1.11											
31	**Safety stock**	**933**	=B30*B28										

Figure 4.11 Example of safety stock computation in excel spread sheet

The resulting safety stock for nine sample items are summarized in Table 4.10.

Table 4.10 Result of safety stock for nine items

Part no	Part name	Safety stock (pcs)
AA00001	OIL FILTER	933
AA00002	BUMPER KIT,FR CTR	144
AA00003	LAMP KIT,COMBINATION,FR LH	194
AA00004	MOULDING,WINDSHIELD	204
AA00005	FENDER,FR	42
AA00006	RADIATOR ASSY	99
AA00007	TENSIONER ASSY, TIMING BELT	839
AA00008	GATE,RR BODY,RR	4
AA00009	BELT,A/C	904
AA00010	HARNESS,BODY MAIN,RR	1

Given the safety stock, the corresponding Reorder Points for nine items are given in Table 4.11.

Table 4.11 Reorder Point for nine items

Part no	Part name	ROP (pcs)
AA00001	OIL FILTER	4185
AA00002	BUMPER KIT,FR CTR	388
AA00003	LAMP KIT,COMBINATION,FR LH	1310
AA00004	MOULDING,WINDSHIELD	603
AA00005	FENDER,FR	348
AA00006	RADIATOR ASSY	320
AA00007	TENSIONER ASSY, TIMING BELT	3139
AA00008	GATE,RR BODY,RR	179
AA00009	BELT,A/C	4874

4.3.2 Min-Max Model (M*)

Min-Max model or M* is one of pull inventory control method to place an order *at any quantity* in order to meet the maximum level when inventory falls to the ROP.

In figure 4.16, when an order is placed, it is for the amount determined by the differences between the target quantity, *M** (the max level), and the quantity on hand, *q*, when the inventory level reaches the reorder point. The max level (M*) is simply the reorder point quantity (ROP) *plus* an economic order quantity (Q*) found by the reorder point model. The reorder quantity is not always the same because the amount of the quantity on hand drops the reorder point is added to Q*. Figure 4.12 illustrates the mechanism of Min-Max Model.

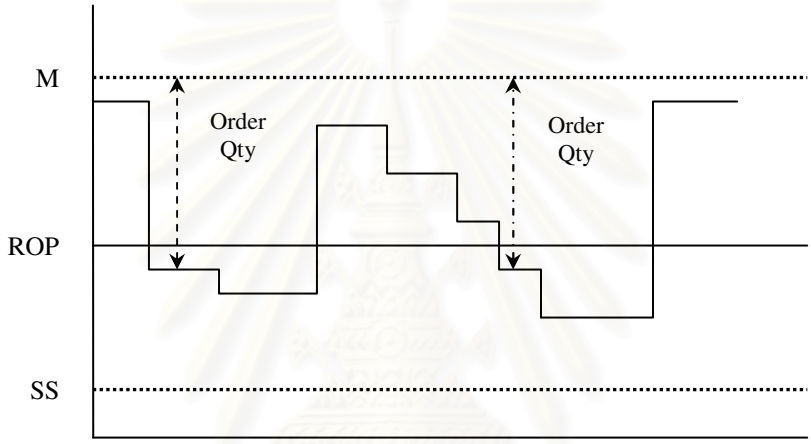


Figure 4.12 Min-Max Model

This model is appropriate when a lumpy demand occurs. Actually, the lumpy demand characteristic is relevant to half of service parts carried by the case study company. Using this model, the min-max approach can give a better result in managing inventory as a larger order quantity is placed when the inventory level is apparently dropped at once.

CHAPTER 5

Simulation & Evaluation

This chapter presents the validation of the system proposed in Chapter 4. The presentation begins with the simulation of operation in the year 2006 with the application of the proposed system to manage the inventory. The results provided by the system will then be compared with the actual operational data covering the same period.

5.1. SIMULATION

As indicated in Chapter 4, two inventory management models will be explored in our study. They are the reorder point model and the Min-Max model. The two models are applied to simulate the corresponding inventory situations in the Year 2006. This section will present the technicalities of the simulation in each model.

5.1.1 Reorder Point Model

This model is implemented on Excel spreadsheets as shown in Figure 5.1. The replenishment quantity is equal to an economic order quantity and a new replenishment order is placed whenever the outstanding stock falls to the reorder point level. The simulation is completed through the following steps.

(1) Input the following necessary data into the Excel spreadsheet.

- Quantity of opening stock (Stock OHO) in the beginning of the first week
- Stock quantity received from suppliers (Dlry Qty)
- Customer order quantity (Order Qty)
- Quantity of stock on order (Stock on order) or in transit stock
- Reorder point (ROP) determined using the formula (Equation 4.6 in Chapter 4)
- An economic order quantity (EOQ) determined using the formula (Equation 4.5 in Chapter 4)

(2) Ordering system will generate the results including

- Quantity of stock on hand closing (Stock OHC)
- Quantity of an outstanding stock (OSD stock)
- Purchase order quantity (PO Qty)

According to Figure 5.1, given all the input data, the system generates purchase order quantity whenever outstanding stock quantity (OSD stock) is less than reorder point quantity (ROP). The purchase order quantity is equal to the economic order quantity (EOQ).

5.1.2. Min-Max Model

This model provides a better result when there is a lumpy demand. Replenishment quantity is the difference between outstanding stock quantity and maximum level (M*). The maximum level (M*) is the sum of reorder point (ROP) and economic order quantity (EOQ). The steps for the simulation of the Min-Max Model are similar

to the reorder point. The input data include the set of data used in the reorder point model plus an additional information about the max level (M*). The ordering system will then generate the same set of result as the reorder point model; stock on hand quantity, stock on order quantity and purchase order quantity. Figure 5.2 illustrates a simulation results for the min-max model on an Excel spreadsheet.

Table 5.1 Ordering system in a Reorder Point Model

ORDER QUANTITY SIMULATION: REORDER POINT (Q*)
P/NO: AA00001

Wk	Month	Stock OHO	Dlry Qty	Order Qty	Stock OHC	Stock On order	OSD Stock	ROP	Q*	PO Qty
1	1	4185			4185		4185	4185	569	0
2	1	4185			4185	0	4185	4185	569	0
3	1	4185		500	3685	0	3685	4185	569	569
4	1	3685		500	3185	569	3754	4185	569	569
5	1	3185		50	3135	1138	4273	4185	569	0
6	2	3135			3135	1138	4273	4185	569	0
7	2	3135		60	3075	1138	4213	4185	569	0
8	2	3075		1300	1775	1138	2913	4185	569	569
9	2	1775			1775	1707	3482	4185	569	569
10	3	1775	0	844	931	2276	3207	4185	569	569
11	3	931	0	38	893	2845	3738	4185	569	569
12	3	893	569	1000	462	2845	3307	4185	569	569
13	3	462	569		1031	2845	3876	4185	569	569
14	4	1031	0		1031	3414	4445	4185	569	0
15	4	1031	0	68	963	3414	4377	4185	569	0
16	4	963	0	1338	-375	3414	3039	4185	569	569
17	4	-375	569	34	160	3414	3574	4185	569	569
18	4	160	569		729	3414	4143	4185	569	569
19	5	729	569	295	1003	3414	4417	4185	569	0
20	5	1003	569	460	1112	2845	3957	4185	569	569
21	5	1112	569	1000	681	2845	3526	4185	569	569
22	5	681	569	10	1240	2845	4085	4185	569	569
23	6	1240	0	55	1185	3414	4599	4185	569	0
24	6	1185	0		1185	3414	4599	4185	569	0
25	6	1185	569	60	1694	2845	4539	4185	569	0
26	6	1694	569	1000	1263	2276	3539	4185	569	569
27	7	1263	569		1832	2276	4108	4185	569	569
28	7	1832	0	300	1532	2845	4377	4185	569	0
29	7	1532	569	17	2084	2276	4360	4185	569	0
30	7	2084	569	154	2499	1707	4206	4185	569	0
31	7	2499	569	1302	1766	1138	2904	4185	569	569
32	8	1766	0	150	1616	1707	3323	4185	569	569
33	8	1616	0		1616	2276	3892	4185	569	569
34	8	1616	0	1000	616	2845	3461	4185	569	569
35	8	616	569	13	1172	2845	4017	4185	569	569
36	9	1172	569	360	1381	2845	4226	4185	569	0
37	9	1381	0	1000	381	2845	3226	4185	569	569
38	9	381	0	11	370	3414	3784	4185	569	569
39	9	370	0	19	351	3983	4334	4185	569	0
40	10	351	569		920	3414	4334	4185	569	0
41	10	920	569	1696	-207	2845	2638	4185	569	569
42	10	-207	569	150	212	2845	3057	4185	569	569
43	10	212	569	40	741	2845	3586	4185	569	569
44	11	741	569		1310	2845	4155	4185	569	569
45	11	1310	0		1310	3414	4724	4185	569	0
46	11	1310	569	7892	-6013	2845	-3168	4185	569	569
47	11	-6013	569	80	-5524	2845	-2679	4185	569	569
48	12	-5524	0	1450	-6974	3414	-3560	4185	569	569
49	12	-6974	0	2283	-9257	3983	-5274	4185	569	569
50	12	-9257	569	520	-9208	3983	-5225	4185	569	569
51	12	-9208	569		-8639	3983	-4656	4185	569	569
52	12	-8639	569		-8070	3983	-4087	4185	569	569

Table 5.2 Ordering system in A Min-Max model

ORDER QUANTITY SIMULATION: A MIN-MAX (M*)
P/NO: AA00001

Wk	Month	Stock OHO	Dlry Qty	Order Qty	Stock OHC	Stock On order	OSD Stock	ROP	Q*	PO Qty	M*
1	1	4185			4185		4185	4185	569		4754
2	1	4185			4185	0	4185	4185	569		4754
3	1	4185		500	3685	0	3685	4185	569	1069	4754
4	1	3685		500	3185	1069	4254	4185	569		4754
5	1	3185		50	3135	1069	4204	4185	569		4754
6	2	3135			3135	1069	4204	4185	569		4754
7	2	3135		60	3075	1069	4144	4185	569	610	4754
8	2	3075		1300	1775	1679	3454	4185	569	1300	4754
9	2	1775			1775	2979	4754	4185	569		4754
10	3	1775	0	844	931	2979	3910	4185	569	844	4754
11	3	931	0	38	893	3823	4716	4185	569		4754
12	3	893	1069	1000	962	2754	3716	4185	569	1038	4754
13	3	962	0		962	3792	4754	4185	569		4754
14	4	962	0		962	3792	4754	4185	569		4754
15	4	962	0	68	894	3792	4686	4185	569		4754
16	4	894	610	1338	166	3182	3348	4185	569	1406	4754
17	4	166	1300	34	1432	3288	4720	4185	569		4754
18	4	1432	0		1432	3288	4720	4185	569		4754
19	5	1432	844	295	1981	2444	4425	4185	569		4754
20	5	1981	0	460	1521	2444	3965	4185	569	789	4754
21	5	1521	1038	1000	1559	2195	3754	4185	569	1000	4754
22	5	1559	0	10	1549	3195	4744	4185	569		4754
23	6	1549	0	55	1494	3195	4689	4185	569		4754
24	6	1494	0		1494	3195	4689	4185	569		4754
25	6	1494	1406	60	2840	1789	4629	4185	569		4754
26	6	2840	0	1000	1840	1789	3629	4185	569	1125	4754
27	7	1840	0		1840	2914	4754	4185	569		4754
28	7	1840	0	300	1540	2914	4454	4185	569		4754
29	7	1540	789	17	2312	2125	4437	4185	569		4754
30	7	2312	1000	154	3158	1125	4283	4185	569		4754
31	7	3158	0	1302	1856	1125	2981	4185	569	1773	4754
32	8	1856	0	150	1706	2898	4604	4185	569		4754
33	8	1706	0		1706	2898	4604	4185	569		4754
34	8	1706	0	1000	706	2898	3604	4185	569	1150	4754
35	8	706	1125	13	1818	2923	4741	4185	569		4754
36	9	1818	0	360	1458	2923	4381	4185	569		4754
37	9	1458	0	1000	458	2923	3381	4185	569	1373	4754
38	9	458	0	11	447	4296	4743	4185	569		4754
39	9	447	0	19	428	4296	4724	4185	569		4754
40	10	428	1773		2201	2523	4724	4185	569		4754
41	10	2201	0	1696	505	2523	3028	4185	569	1726	4754
42	10	505	0	150	355	4249	4604	4185	569		4754
43	10	355	1150	40	1465	3099	4564	4185	569		4754
44	11	1465	0		1465	3099	4564	4185	569		4754
45	11	1465	0		1465	3099	4564	4185	569		4754
46	11	1465	1373	7892	-5054	1726	-3328	4185	569	8082	4754
47	11	-5054	0	80	-5134	9808	4674	4185	569		4754
48	12	-5134	0	1450	-6584	9808	3224	4185	569	1530	4754
49	12	-6584	0	2283	-8867	11338	2471	4185	569	2283	4754
50	12	-8867	1726	520	-7661	11895	4234	4185	569		4754
51	12	-7661	0		-7661	11895	4234	4185	569		4754
52	12	-7661	0		-7661	11895	4234	4185	569		4754

5.2. EVALUATION

To explore the validity and the performance of the proposed system, the system results are compared against the actual performance realized in the year 2006. The comparisons are made in the following areas reflecting the performance of the inventory system:

- **Forecasting errors:** The forecasting errors are measured by the Mean Squared Error (MSE)
- **Backorder quantity:** Backorder refers to the quantity unfulfilled due to the out-of-stock.
- **First fill rate:** First fill rate is the fraction of demand that are fulfilled immediately by the available stock.
- **Total costs:** Total costs include inventory holding cost and ordering cost. While the other two measures reflecting the customer service or the effectiveness of the system in satisfying customers' requirements, the cost measure reflects the efficiency of the inventory system.

The evaluation results associated with each metric can be presented as follows:

5.2.1 Forecasting errors

Forecasting technique in current system is a moving average for the latest six months. This same technique has been applied to every item in the inventory system without consideration given to the difference in the demand characteristics among items. New

inventory system proposes forecasting techniques by plotting history demand and analyzing the demand patterns. Demand of most items in the sample data exhibits uncertainty without trend and that of few items is characterized by a trend. The appropriate forecasting model for the demand without trend is an exponential smoothing and that with trend is the Holt's method. Table 5.3 demonstrates mean square error of nine items and Table 5.4 compares the MSE of the existing system and that of the proposed system. The proposed system seems to yield lower MSE than the current system.

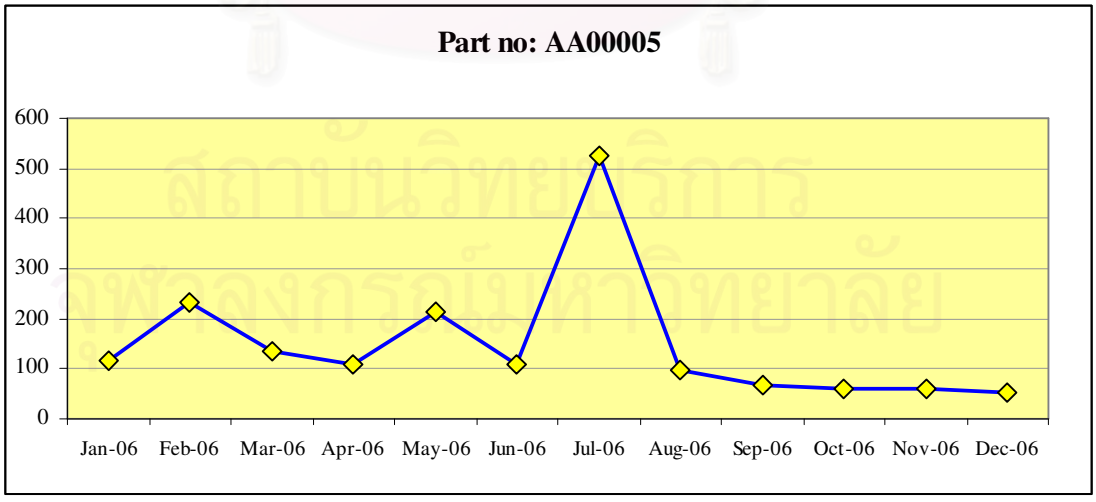
Table 5.3 Mean square error of nine items

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	MSE
AA00001	Actual demand	1050	1360	1882	1440	1765	1115	553	2383	1390	1846	8012	4253	
	HOLT	1166	1131	1229	1481	1475	1597	1421	1092	1595	1525	1658	4136	
	MSE	13468	52353	426253	1667	83943	232760	754078	1667244	41918	102783	40368953	13670	3646591
	D bar	1356	1255	1203	1190	1289	1416	1435	1353	1523	1441	1509	2550	
	MSE	93840	11095	461041	62333	226893	90701	778512	1061930	17689	164025	42293344	2900777	4013515
AA00002	Actual demand	54	11	302	157	150	67	185	61	33	92	138	95	
	ES	131	115	93	137	141	143	127	139	123	104	102	109	
	MSE	6004	10868	43510	396	76	5792	3345	6127	8078	145	1330	201	7156
	D bar	150	131	90	118	103	122	124	145	154	109	98	96	
	MSE	9248	14320	45085	1560	2193	2970	3782	7112	14560	283	1600	1	8560
AA00003	Actual demand	225	568	630	467	285	818	920	641	922	212	363	380	
	ES	545	421	478	537	510	422	576	710	683	776	557	482	
	MSE	102431	21688	23124	4900	50540	156430	118255	4719	57116	317917	37569	10310	75417
	D bar	601	574	540	516	486	423	499	615	627	676	633	646	
	MSE	141125	36	8040	2434	40334	156025	177381	693	87123	214832	72900	70756	80973
AA00004	Actual demand	330	316	91	135	82	105	493	164	245	215	66	120	
	ES	191	204	214	203	197	186	179	207	203	207	208	195	
	MSE	19252	12615	15067	4590	13151	6626	98529	1869	1734	63	20107	5639	16603
	D bar	171	208	246	203	195	193	177	204	178	204	217	215	
	MSE	25175	11664	24025	4579	12656	7656	100172	1573	4444	121	22902	8962	18661
AA00005	Actual demand	118	234	136	108	213	107	525	96	68	61	60	52	
	ES	106	109	154	148	133	162	142	282	214	161	125	101	
	MSE	148	15625	342	1581	6353	3059	146556	34418	21314	9970	4161	2404	20494
	D bar	119	117	132	136	132	148	153	221	198	186	178	153	
	MSE	1	13728	19	765	6534	1640	138632	15500	16770	15667	14003	10167	19452
AA00006	Actual demand	80	120	169	234	56	100	211	106	100	11	120	86	
	ES	90	88	94	107	130	117	114	131	127	122	103	106	
	MSE	100	1024	5625	16129	5476	289	9409	625	729	12321	276	408	4368
	D bar	95	103	99	109	131	124	127	148	146	135	97	108	
	MSE	220	289	4970	15583	5675	576	7140	1792	2116	15252	514	484	4551
AA00007	Actual demand	1011	1404	1031	807	1568	1316	1181	901	1224	1452	1356	1418	
	HOLT	1083	1070	1140	1122	1059	1165	1198	1197	1138	1158	1219	1249	
	MSE	5209	111469	11879	99028	258786	22864	286	87484	7324	86729	18655	28416	61511
	D bar	1038	1078	1125	1152	1021	1084	1190	1218	1134	1166	1274	1238	
	MSE	738	106385	8742	118795	299209	54056	72	100383	8100	81701	6779	32280	68103
AA00008	Actual demand	52	69	42	148	138	51	101	27	55	47	43	54	
	ES	89	90	90	85	91	96	90	91	95	80	77	74	
	MSE	1405	441	2304	3928	2169	2022	121	4105	1600	1106	1158	389	1729
	D bar	92	88	81	73	77	89	83	92	85	87	70	54	
	MSE	1613	374	1521	5675	3741	1469	312	4160	870	1573	720	0	1836
AA00009	Actual demand	1335	2674	2078	1539	2721	1725	2996	1784	2014	1839	3751	2890	
	ES	1659	1574	1864	1920	1820	2057	1970	2240	2120	2092	2025	2480	
	MSE	104976	1210961	45907	145344	812324	110473	1053232	208256	11239	64039	2977942	167790	576040
	D bar	1752	1638	1887	1942	1707	1842	2012	2289	2141	2130	2180	2352	
	MSE	174028	1073987	36672	162543	1028196	13767	968256	254857	16002	84584	2468565	289982	547620

Table 5.4 Mean square error between current system and proposed system

Part Number	Current system MSE	Proposed system MSE	Diff MSE	**MSE Improved (%)**
AA00001	4013515	3646591	366924	**9.14**
AA00002	8560	7156	1404	**16.40**
AA00003	80973	75417	5556	**6.86**
AA00004	18661	16603	2058	**11.03**
AA00005	19452	20467	-1015	**-5.22**
AA00006	4551	4368	183	**4.02**
AA00007	68103	61511	6592	**9.68**
AA00008	1836	1729	107	**5.83**
AA00009	547620	576040	-28420	**-5.19**

From Table 5.4, there are two items that the proposed system is failed to provide improvement over the existing system. When considering the actual demand in the year 2006 of these two items as shown in Figure 5.3, the demand of both items in the last six month fluctuates significantly from the first half of the year. This may be the reason that the Exponential smoothing method cannot perform well.



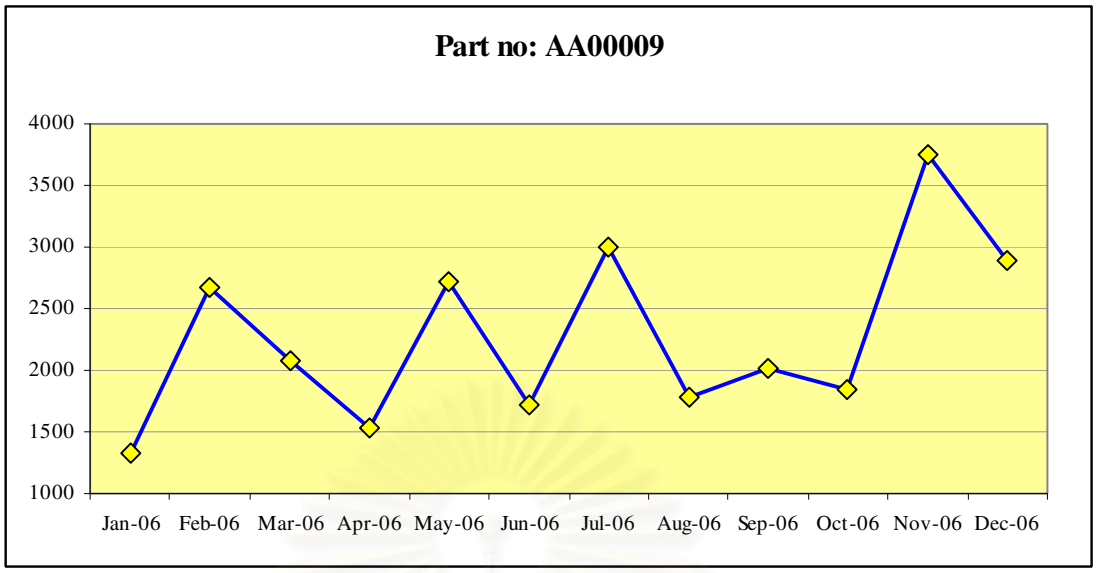


Figure 5.1 Demand of AA00005 and AA00009 the year 2006

Demand of part number AA00005 rose significantly in June 2006, amounting to more than two folds the average demand over the previous six months. As the exponential smoothing method develops demand forecasts using the historical data, it is impossible for the method to be able to predict such a big rise in the demand. The other part AA00009 experienced the same problem of the abrupt increase in demand in November 2006.

5.2.2. Backorder quantity

The case study company has faced a problem of increasing backorder due to the rise in order quantities and the presently inefficient inventory system. Table 5.3 illustrates the comparison of backorder quantities in current system and proposed system. The proposed system would clearly reduce the number of backorder quantities. The superior performance has been achieved under both the Reorder Point model and the Min-Max model.

Table 5.5 Comparison of backorder quantity in current and proposed system

Part Number	Current system	Proposed system	
		Reorder Point	Min-Max
ME201871	22080	11529	9387
MR241037	300	95	55
MR241069	3595	2294	1960
MR401336	1074	107	104
MR954765	1420	583	580
MR571147	892	761	342
MD329625	5106	310	0
MR125931	289	27	25
MR148321	19915	4075	3726
MR515644	0	0	0

5.2.3 First fill rate

As mentioned in chapter 1, the first fill rate in the current system is approximately 50-60%. The proposed system provides an apparent improvement on the first fill rate as illustrated by Table 5.4 and Figure 5.4. We separate the performance into two periods; the first six month and the last six month of year to investigate any occurrence of the bias caused by the beginning on hand quantity (BOH). If the actual BOH is much lower than the ROP and there becomes a high demand in the first 6 months, the proposed system will not perform well in the first half of the year which is the transition period from the old system to the new system. The last six month period which lies beyond this transition period should better reflect the true performance of the proposed system.

Table 5.6 Comparison first fill rate between current and proposed system

Part Number	First 6 months			Last 6 months		
	Current system	Proposed system		Current system	Proposed system	
		Q*	M*		Q*	M*
AA00001	44.00	93.64	100.00	6.40	40.44	49.09
AA00002	59.51	87.18	92.58	100.00	100.00	100.00
AA00003	91.45	94.69	87.57	2.88	37.84	53.81
AA00004	79.51	93.48	93.48	34.78	97.11	97.34
AA00005	34.99	94.32	94.00	4.29	38.40	39.10
AA00006	41.32	52.57	72.60	29.59	36.75	78.86
AA00007	63.72	100.00	100.00	66.58	95.88	100.00
AA00008	76.40	94.60	95.00	47.71	100.00	100.00
AA00009	61.56	100.00	100.00	0.00	73.32	75.61

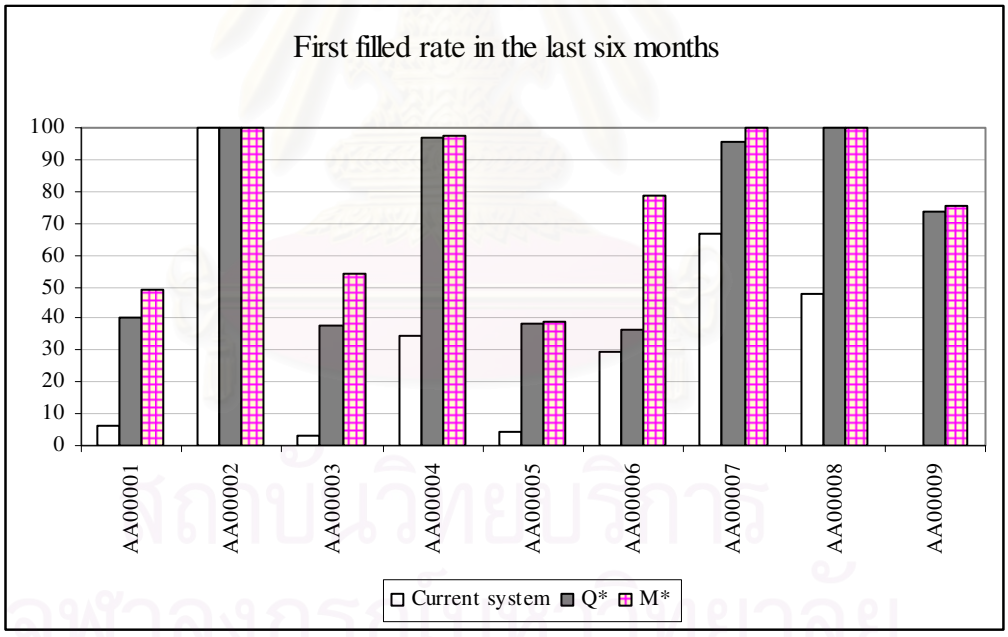
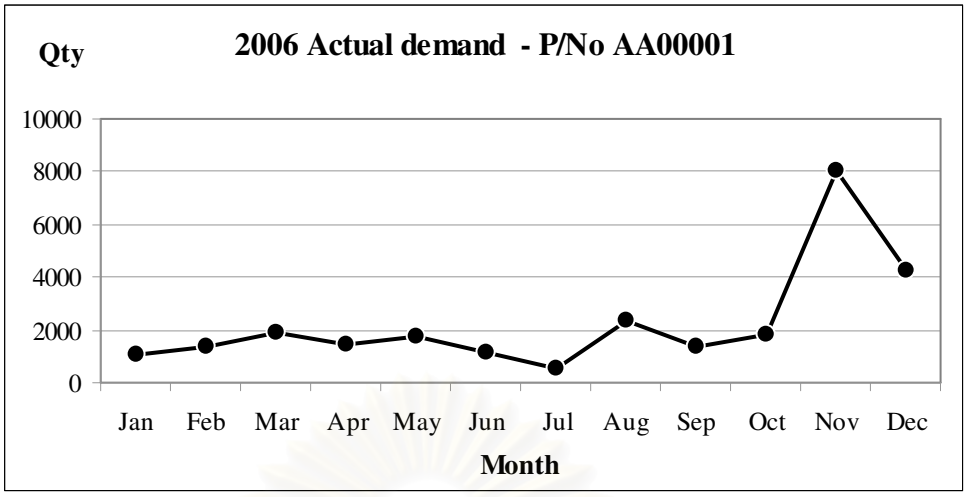
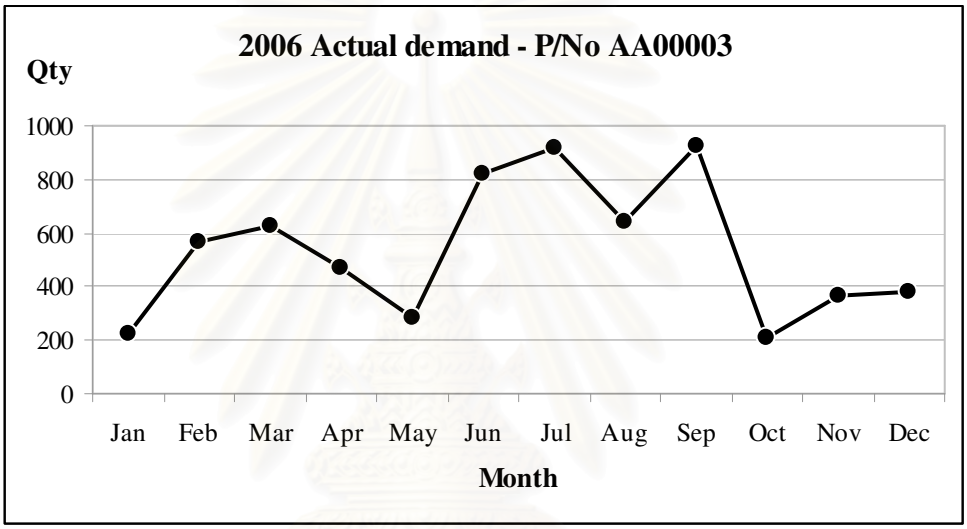


Figure 5.2 First fill rate in the last six months

The proposed system results in the first fill rate of at least 75% for all except three items; AA00001, AA00003 and AA00005. It should be noted that although service level is set at 95% when safety stock is determined, but the achieved results happen to

be much lower than the target level. Two factors may contribute to this underachievement. Firstly, the formula for determining the safety stock at a given service level as given in Chapter 4 is based on an assumption that the variability in the lead time demand will be characterized by a Normal Distribution while the actual fluctuation in the demand may not. Secondly, the demand in some period rises dramatically as shown in Figure 5.3. In this situation, mathematical model may be inadequate in predicting such a big change so that a qualitative method such as *sales force assessment* should be introduced. The dramatic rise in the demand may not be caused by the normal failure rate of the cars but may be due to a warranty campaign. Thus, communication between sales department and customers are required in this situation. Pre-notification by customers will allow the company to better prepare for the situation by preorder in large quantity from the suppliers.





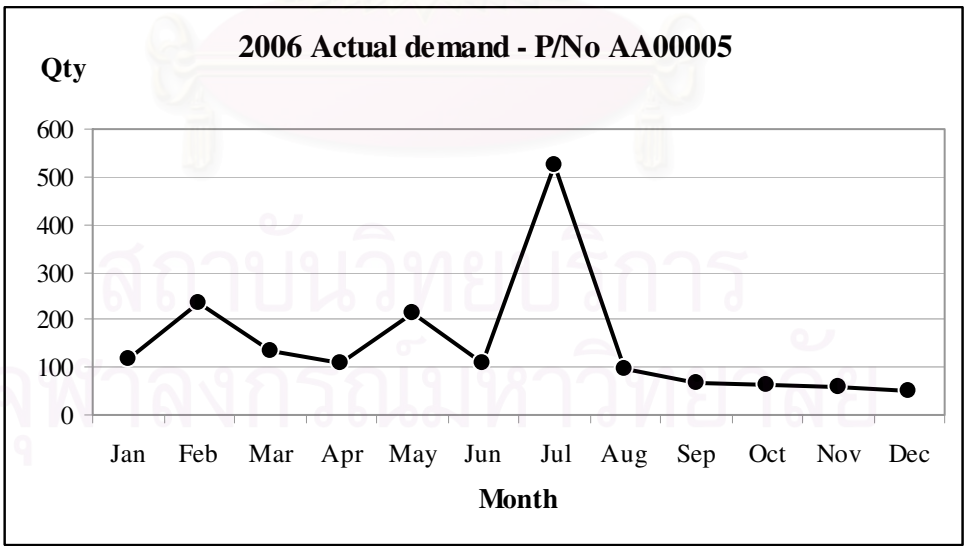


Figure 5.3 Demand of AA00001, AA00003, AA00004 in 2006

5.2.4 Total cost (TC)

The goal of a good inventory management is simultaneously increasing service level and minimizing total costs. The evaluated total costs are the sum of ordering cost and holding cost. Ordering cost is the number of orders per year times the cost of placing an order. Holding cost refers to the cost incurred when holding inventory over the time.

$$OC = Q_o \times C_o \quad \text{(5.1)}$$

$$HC = C_u \times Q_{OHC} \times C_h \quad \text{(5.2)}$$

Where;

OC = ordering cost (baht/year)

HC = holding cost (baht/year)

Q_o = number of orders placed to suppliers (orders/year)

C_o = ordering cost per order (baht/order)

C_u = unit cost per item (baht/piece)

Q_{OHC} = quantity of stock on hand closing (pieces)

C_h = holding cost ratio (%/year)

The total cost is given as:

$$TC = OC + HC \quad \text{(5.3)}$$

Table 5.7 compares the costs associated with the current system and the proposed system. Table 5.8 and Figure 5.4 compared the total cost between current and

proposed system. The current system seems to yield a lower cost than the proposed system. However, this lower cost is achieved at a much lower customer service. The Min-Max model results in a higher cost than the Reorder Point model as the former usually requires greater safety stock and provides a better customer service than the latter.

Table 5.7 Ordering cost and holding cost of current and proposed system

Part number	AA00001	AA00002	AA00003	AA00004	AA00005	AA00006	AA00007	AA00008	AA00009
Ordering cost, O	215	215	215	215	215	215	215	215	215
Holding cost rate	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
Unit Price, P	135	394	226	132	530	2396	201	45	66
Current system									
Annual ordering cost	2,152	1,937	2,368	2,152	2,583	2,583	2,368	2,152	2,368
Annual holding cost	14,778	5,562	8,760	1,515	2,079	9,402	12,977	617	7,313
Total cost, TC	16,930	7,500	11,128	3,668	4,662	11,984	15,345	2,770	9,681
Q*									
Annual order qty, D	19,346	1,365	6,450	2,424	1,848	1,400	14,896	1,374	27,900
Order quantity, Q	569	91	258	202	88	35	392	229	900
Annual ordering cost	7,318	3,229	5,381	2,583	4,520	8,610	8,179	1,291	6,672
Annual holding cost	32,263	12,106	14,508	7,400	11,542	40,595	31,766	1,176	13,299
Total cost, TC	39,581	15,335	19,889	9,983	16,062	49,205	39,945	2,468	19,972
M*									
Max order qty	8082	196	764	306	366	201	1057	279	2900
No.of order per year	16	20	13	10	13	19	24	3	19
Annual ordering cost	3,444	4,305	2,798	2,152	2,798	4,090	5,166	646	4,090
Annual holding cost	38,443	13,141	16,034	7,766	13,132	58,770	37,608	1,382	15,689
Total cost, TC	41,887	17,446	18,832	9,919	15,930	62,859	42,774	2,028	19,779

Table 5.8 Comparison total cost of current and proposed system

Part Number	Current system	Proposed system	
		Q*	M*
	TC (THB)	TC (THB)	TC (THB)
AA00001	16,930	39,581	41,887
AA00002	7,500	15,335	17,446
AA00003	11,128	19,889	18,832
AA00004	3,668	9,983	9,919
AA00005	4,662	16,062	15,930
AA00006	11,984	49,205	62,859
AA00007	15,345	39,945	42,774
AA00008	2,770	2,468	2,028
AA00009	9,681	19,972	19,779
Grand Total:	83,668	212,440	231,454

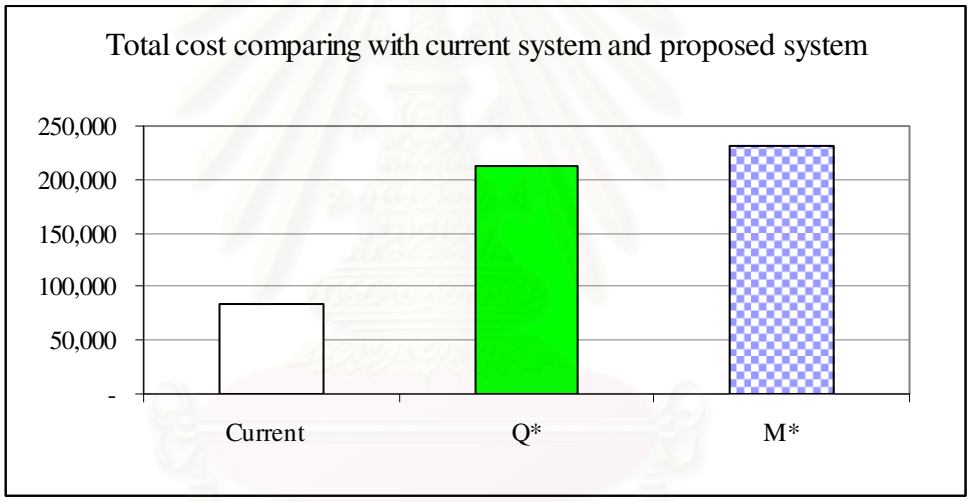


Figure 5.4 Comparison total cost between current and proposed system

CHAPTER 6

Conclusion and Recommendation

This thesis attempts to develop an inventory management for managing spare parts for an automobile manufacturer in Thailand. The development begins with the investigation of existing inventory system and it is found that the system applies a generic approach to all spare parts items even they exhibit varying demand characteristics. As a result, the system has become ineffective in managing the inventory level and the company presently faces serious problems of shortages and customer dissatisfaction.

The proposed system recommends the classification of spare parts along two aspects: consumption rate and functionality. Items with different consumption rates may require different demand forecasting techniques. The functionality would determine the appropriate service level governing the degree of stock availability to service customers' demand.

This study selects nine fast-moving items to demonstrate the mechanics of the proposed system. The proposed system is designed making use of the data observed in the years 2004 and 2005 and the performance of the system is assessed by simulating the situations under the new system against the actual operational data experienced over the year 2006.

The new system requires that the demand patterns are carefully examined and suitable forecasting techniques are then selected correspondingly. For the nine sample items,

the historical demand patterns of seven items contain only a level and the exponential smoothing is then applied to forecast the demands of these items. The Holt's method is adopted to forecast the demands of the other two items which apparently contain a trend. The system evaluation indicates that the selected forecasting methods in most instances perform better than the existing system and result in lower forecast errors.

In managing inventory, two continuous review models are proposed; the reorder point model and the min-max model. The two models are basically identical except that the reorder point assumes that gradual customers' demand while the min-max model allows for the lumpy customer demand. The parameters for executing these two inventory models are determined on the basis of Economic Order Quantity (EOQ) and the safety stock required to protect the system against the variability in demand rate and replenishment lead time. The simulation results reveal that both models would likely lead to reduced backorder quantity, improved fill rate, thereby significantly increasing customer satisfaction. However, with larger safety stock required the two models would be associated with higher cost than the present situation.

- **RECOMMENDATION**

One of the key limitations of our study is that it deals specifically with only fast-moving items. In fact, service parts have both fast moving and slow moving. Thus, the future study should attempt to design the system to accommodate low moving item. Past research works on the inventory management of service parts had mentioned the difficulty in forecasting demands of slow moving items and the inadequacy of exponential smoothing techniques when demand is intermittent. Future

research may consider the possibility of applying the Croston's model in managing the inventory of these sporadic demands.

Our proposed system has an shortcoming in that it sets the required safety stock by assuming that the variability in lead time demand always follows a Normal Distribution. The results show that the customer service levels resulting from the safety stock as determined by the system are much lower than the expected level because the variability in the lead time demand may actually not resemble a Normal Distribution. The second enhancement to our proposed model is to thoroughly investigate the stochastic pattern of the variability in the lead time demand and applies an appropriate method to determine the safety stock.

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Appendices

Appendix A:
Exponential smoothing

Part no	Part name	Jan-04	Feb-04	Mar-04	Apr-04	May-04	Jun-04	Jul-04	Aug-04	Sep-04	Oct-04	Nov-04	Dec-04
AA00002	BUMPER KIT,FR CTR	30	8	360	190	20	9	74	77	61	94	108	167
		Jan-05	Feb-05	Mar-05	Apr-05	May-05	Jun-05	Jul-05	Aug-05	Sep-05	Oct-05	Nov-05	Dec-05
		167	115	180	113	197	164	171	257	135	243	40	55
		Jan-06	Feb-06	Mar-06	Apr-06	May-06	Jun-06	Jul-06	Aug-06	Sep-06	Oct-06	Nov-06	Dec-06
		54	11	302	157	150	67	185	61	33	92	138	95

α = 0.21
MSE = 8735.26

	Month	Order qty (pcs)	Forecast qty	Forecast Error
1	Jan-04	30	30	0.00
2	Feb-04	8	30	484.00
3	Mar-04	360	25	111963.19
4	Apr-04	190	95	8931.82
5	May-04	20	115	9080.42
6	Jun-04	9	95	7452.47
7	Jul-04	74	77	10.51
8	Aug-04	77	77	0.19
9	Sep-04	61	77	245.06
10	Oct-04	94	73	425.40
11	Nov-04	108	78	918.35
12	Dec-04	167	84	6881.61
13	Jan-05	167	101	4300.25
14	Feb-05	115	115	0.03
15	Mar-05	180	115	4208.37
16	Apr-05	113	129	247.08
17	May-05	197	125	5122.89
18	Jun-05	164	140	555.99
19	Jul-05	171	145	657.39
20	Aug-05	257	151	11292.90
21	Sep-05	135	173	1443.63
22	Oct-05	243	165	6078.52
23	Nov-05	40	181	19985.14
24	Dec-05	55	152	9360.95

AA00002	BUMPER KIT,FR CTR		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	α
24	Dec-05	Forecast qty	131	131	131	131	131	131	131	131	131	131	131	131	0.21
		Order qty	131	131	131	131	131	131	131	131	131	131	131	131	
25	Jan-06	Forecast qty	131	115	115	115	115	115	115	115	115	115	115	115	0.21
		Order qty	54	115	115	115	115	115	115	115	115	115	115	115	
26	Feb-06	Forecast qty	131	115	93	93	93	93	93	93	93	93	93	93	0.21
		Order qty	54	11	93	93	93	93	93	93	93	93	93	93	
27	Mar-06	Forecast qty	131	115	93	137	137	137	137	137	137	137	137	137	0.21
		Order qty	54	11	302	137	137	137	137	137	137	137	137	137	
28	Apr-06	Forecast qty	131	115	93	137	141	141	141	141	141	141	141	141	0.21
		Order qty	54	11	302	157	141	141	141	141	141	141	141	141	
29	May-06	Forecast qty	131	115	93	137	141	143	143	143	143	143	143	143	0.21
		Order qty	54	11	302	157	150	143	143	143	143	143	143	143	
30	Jun-06	Forecast qty	131	115	93	137	141	143	127	127	127	127	127	127	0.21
		Order qty	54	11	302	157	150	67	127	127	127	127	127	127	
31	Jul-06	Forecast qty	131	115	93	137	141	143	127	139	139	139	139	139	0.21
		Order qty	54	11	302	157	150	67	185	139	139	139	139	139	
32	Aug-06	Forecast qty	131	115	93	137	141	143	127	139	123	123	123	123	0.21
		Order qty	54	11	302	157	150	67	185	61	123	123	123	123	
33	Sep-06	Forecast qty	131	115	93	137	141	143	127	139	123	104	104	104	0.21
		Order qty	54	11	302	157	150	67	185	61	33	104	104	104	
34	Oct-06	Forecast qty	131	115	93	137	141	143	127	139	123	104	102	102	0.21
		Order qty	54	11	302	157	150	67	185	61	33	92	102	102	
35	Nov-06	Forecast qty	131	115	93	137	141	143	127	139	123	104	102	109	0.21
		Order qty	54	11	302	157	150	67	185	61	33	92	138	109	
36	Dec-06	Forecast qty	131	115	93	137	141	143	127	139	123	104	102	109	
		Order qty	54	11	302	157	150	67	185	61	33	92	138	95	

Part no	Part name	Jan-04	Feb-04	Mar-04	Apr-04	May-04	Jun-04	Jul-04	Aug-04	Sep-04	Oct-04	Nov-04	Dec-04
AA00003	LAMP KIT,COMBINATION,FR LH	270	371	506	575	425	423	397	613	564	543	593	630
		Jan-05	Feb-05	Mar-05	Apr-05	May-05	Jun-05	Jul-05	Aug-05	Sep-05	Oct-05	Nov-05	Dec-05
		620	414	789	345	518	653	385	770	774	650	662	363
		Jan-06	Feb-06	Mar-06	Apr-06	May-06	Jun-06	Jul-06	Aug-06	Sep-06	Oct-06	Nov-06	Dec-06
		225	568	630	467	285	818	920	641	922	212	363	380

α = 0.39
MSE = 26596.66

	Month	Order qty (pcs)	Forecast qty	Forecast Error
1	Jan-04	270	170	10000.00
2	Feb-04	371	209	26294.83
3	Mar-04	506	272	54835.55
4	Apr-04	575	363	45033.44
5	May-04	425	445	408.79
6	Jun-04	423	437	206.36
7	Jul-04	397	432	1210.01
8	Aug-04	613	418	37918.40
9	Sep-04	564	494	4912.40
10	Oct-04	543	521	478.03
11	Nov-04	593	530	4015.91
12	Dec-04	630	554	5738.95
13	Jan-05	620	584	1319.86
14	Feb-05	414	598	33775.76
15	Mar-05	789	526	68961.34
16	Apr-05	345	628	80315.13
17	May-05	518	518	0.10
18	Jun-05	653	518	18172.54
19	Jul-05	358	571	45180.57
20	Aug-05	770	488	79527.84
21	Sep-05	774	598	31140.37
22	Oct-05	650	666	258.53
23	Nov-05	662	660	4.69
24	Dec-05	363	661	88610.35

AA00003	LAMP KIT	**2006**	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	α
24	Dec-05	Forecast qty	545	545	545	545	545	545	545	545	545	545	545	545	0.39
		Order qty	545	545	545	545	545	545	545	545	545	545	545	545	
25	Jan-06	Forecast qty	545	421	421	421	421	421	421	421	421	421	421	421	0.39
		Order qty	225	421	421	421	421	421	421	421	421	421	421	421	
26	Feb-06	Forecast qty	545	421	478	478	478	478	478	478	478	478	478	478	0.39
		Order qty	225	568	478	478	478	478	478	478	478	478	478	478	
27	Mar-06	Forecast qty	545	421	478	537	537	537	537	537	537	537	537	537	0.39
		Order qty	225	568	630	537	537	537	537	537	537	537	537	537	
28	Apr-06	Forecast qty	545	421	478	537	510	510	510	510	510	510	510	510	0.39
		Order qty	225	568	630	467	510	510	510	510	510	510	510	510	
29	May-06	Forecast qty	545	421	478	537	510	422	422	422	422	422	422	422	0.39
		Order qty	225	568	630	467	285	422	422	422	422	422	422	422	
30	Jun-06	Forecast qty	545	421	478	537	510	422	576	576	576	576	576	576	0.39
		Order qty	225	568	630	467	285	818	576	576	576	576	576	576	
31	Jul-06	Forecast qty	545	421	478	537	510	422	576	710	710	710	710	710	0.39
		Order qty	225	568	630	467	285	818	920	710	710	710	710	710	
32	Aug-06	Forecast qty	545	421	478	537	510	422	576	710	683	683	683	683	0.39
		Order qty	225	568	630	467	285	818	920	641	683	683	683	683	
33	Sep-06	Forecast qty	545	421	478	537	510	422	576	710	683	776	776	776	0.39
		Order qty	225	568	630	467	285	818	920	641	922	776	776	776	
34	Oct-06	Forecast qty	545	421	478	537	510	422	576	710	683	776	557	557	0.39
		Order qty	225	568	630	467	285	818	920	641	922	212	557	557	
35	Nov-06	Forecast qty	545	421	478	537	510	422	576	710	683	776	557	482	0.39
		Order qty	225	568	630	467	285	818	920	641	922	212	363	482	
36	Dec-06	Forecast qty	545	421	478	537	510	422	576	710	683	776	557	482	
		Order qty	225	568	630	467	285	818	920	641	922	212	363	380	

Part no	Part name	Jan-04	Feb-04	Mar-04	Apr-04	May-04	Jun-04	Jul-04	Aug-04	Sep-04	Oct-04	Nov-04	Dec-04
AA00004	MOULDING,WINDSHIELD	270	3	24	160	15	295	244	349	18	13	63	293
		Jan-05	Feb-05	Mar-05	Apr-05	May-05	Jun-05	Jul-05	Aug-05	Sep-05	Oct-05	Nov-05	Dec-05
		291	81	573	230	92	117	110	88	351	184	94	201
		Jan-06	Feb-06	Mar-06	Apr-06	May-06	Jun-06	Jul-06	Aug-06	Sep-06	Oct-06	Nov-06	Dec-06
		330	316	91	135	82	105	493	164	245	215	66	120

α = 0.09
MSE = 23493.71

	Month	Order qty (pcs)	Forecast qty	Forecast Error
1	Jan-04	270	270	0.00
2	Feb-04	3	270	71289.00
3	Mar-04	24	246	49316.90
4	Apr-04	260	226	1144.20
5	May-04	15	229	45883.84
6	Jun-04	295	210	7223.27
7	Jul-04	244	218	695.58
8	Aug-04	349	220	16643.71
9	Sep-04	18	232	45603.67
10	Oct-04	13	212	39765.90
11	Nov-04	63	195	17303.92
12	Dec-04	293	183	12153.60
13	Jan-05	291	193	9675.56
14	Feb-05	81	201	14508.21
15	Mar-05	573	191	146186.57
16	Apr-05	230	225	25.82
17	May-05	92	225	17788.55
18	Jun-05	117	213	9297.22
19	Jul-05	110	205	8983.57
20	Aug-05	88	196	11726.35
21	Sep-05	351	187	27032.44
22	Oct-05	184	201	299.91
23	Nov-05	94	200	11186.44
24	Dec-05	201	190	114.74

AA00004	MOULDING,WINDSHIELD		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	α
24	Dec-05	Forecast qty	191	191	191	191	191	191	191	191	191	191	191	191	0.09
		Order qty	191	191	191	191	191	191	191	191	191	191	191	191	
25	Jan-06	Forecast qty	191	204	204	204	204	204	204	204	204	204	204	204	0.09
		Order qty	330	204	204	204	204	204	204	204	204	204	204	204	
26	Feb-06	Forecast qty	191	204	214	214	214	214	214	214	214	214	214	214	0.09
		Order qty	330	316	214	214	214	214	214	214	214	214	214	214	
27	Mar-06	Forecast qty	191	204	214	203	203	203	203	203	203	203	203	203	0.09
		Order qty	330	316	91	203	203	203	203	203	203	203	203	203	
28	Apr-06	Forecast qty	191	204	214	203	197	197	197	197	197	197	197	197	0.09
		Order qty	330	316	91	135	197	197	197	197	197	197	197	197	
29	May-06	Forecast qty	191	204	214	203	197	186	186	186	186	186	186	186	0.09
		Order qty	330	316	91	135	82	186	186	186	186	186	186	186	
30	Jun-06	Forecast qty	191	204	214	203	197	186	179	179	179	179	179	179	0.09
		Order qty	330	316	91	135	82	105	179	179	179	179	179	179	
31	Jul-06	Forecast qty	191	204	214	203	197	186	179	207	207	207	207	207	0.09
		Order qty	330	316	91	135	82	105	493	207	207	207	207	207	
32	Aug-06	Forecast qty	191	204	214	203	197	186	179	207	203	203	203	203	0.09
		Order qty	330	316	91	135	82	105	493	164	203	203	203	203	
33	Sep-06	Forecast qty	191	204	214	203	197	186	179	207	203	207	207	207	0.09
		Order qty	330	316	91	135	82	105	493	164	245	207	207	207	
34	Oct-06	Forecast qty	191	204	214	203	197	186	179	207	203	207	208	208	0.09
		Order qty	330	316	91	135	82	105	493	164	245	215	208	208	
35	Nov-06	Forecast qty	191	204	214	203	197	186	179	207	203	207	208	195	0.09
		Order qty	330	316	91	135	82	105	493	164	245	215	66	195	
36	Dec-06	Forecast qty	191	204	214	203	197	186	179	207	203	207	208	195	0.09
		Order qty	330	316	91	135	82	105	493	164	245	215	66	120	

Part no	Part name	Jan-04	Feb-04	Mar-04	Apr-04	May-04	Jun-04	Jul-04	Aug-04	Sep-04	Oct-04	Nov-04	Dec-04
AA00005	FENDER,FR	11	83	47	8	50	13	46	97	74	98	105	203
		Jan-05	Feb-05	Mar-05	Apr-05	May-05	Jun-05	Jul-05	Aug-05	Sep-05	Oct-05	Nov-05	Dec-05
		73	128	112	32	131	117	131	145	112	129	121	76
		Jan-06	Feb-06	Mar-06	Apr-06	May-06	Jun-06	Jul-06	Aug-06	Sep-06	Oct-06	Nov-06	Dec-06
		118	234	136	108	213	107	525	96	68	61	60	52

α = 0.36
MSE = 1837.23

	Month	Actual demand	Forecast qty	Forecast Error
1	Jan-04	11	11	0.00
2	Feb-04	83	11	5184.00
3	Mar-04	47	37	95.89
4	Apr-04	8	41	1074.01
5	May-04	50	29	447.61
6	Jun-04	13	37	554.33
7	Jul-04	46	28	324.93
8	Aug-04	97	35	3901.81
9	Sep-04	74	57	279.81
10	Oct-04	98	63	1199.85
11	Nov-04	105	76	842.76
12	Dec-04	203	87	13563.73
13	Jan-05	73	129	3128.04
14	Feb-05	128	109	377.49
15	Mar-05	112	116	13.27
16	Apr-05	32	114	6776.09
17	May-05	131	84	2175.86
18	Jun-05	117	101	245.46
19	Jul-05	131	107	574.29
20	Aug-05	145	116	855.06
21	Sep-05	112	126	207.43
22	Oct-05	129	121	61.47
23	Nov-05	121	124	9.08
24	Dec-05	76	123	2201.18

AA00005	FENDER,FR		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	α
24	Dec-05	Forecast qty	106	106	106	106	106	106	106	106	106	106	106	106	0.36
		Order qty	106	106	106	106	106	106	106	106	106	106	106	106	
25	Jan-06	Forecast qty	106	110	110	110	110	110	110	110	110	110	110	110	0.36
		Order qty	118	110	110	110	110	110	110	110	110	110	110	110	
26	Feb-06	Forecast qty	106	110	155	155	155	155	155	155	155	155	155	155	0.36
		Order qty	118	234	155	155	155	155	155	155	155	155	155	155	
27	Mar-06	Forecast qty	106	110	155	148	148	148	148	148	148	148	148	148	0.36
		Order qty	118	234	136	148	148	148	148	148	148	148	148	148	
28	Apr-06	Forecast qty	106	110	155	148	134	134	134	134	134	134	134	134	0.36
		Order qty	118	234	136	108	134	134	134	134	134	134	134	134	
29	May-06	Forecast qty	106	110	155	148	134	163	163	163	163	163	163	163	0.36
		Order qty	118	234	136	108	213	163	163	163	163	163	163	163	
30	Jun-06	Forecast qty	106	110	155	148	134	163	142	142	142	142	142	142	0.36
		Order qty	118	234	136	108	213	107	142	142	142	142	142	142	
31	Jul-06	Forecast qty	106	110	155	148	134	163	142	282	282	282	282	282	0.36
		Order qty	118	234	136	108	213	107	525	282	282	282	282	282	
32	Aug-06	Forecast qty	106	110	155	148	134	163	142	282	214	214	214	214	0.36
		Order qty	118	234	136	108	213	107	525	96	214	214	214	214	
33	Sep-06	Forecast qty	106	110	155	148	134	163	142	282	214	161	161	161	0.36
		Order qty	118	234	136	108	213	107	525	96	68	161	161	161	
34	Oct-06	Forecast qty	106	110	155	148	134	163	142	282	214	161	125	125	0.36
		Order qty	118	234	136	108	213	107	525	96	68	61	125	125	
35	Nov-06	Forecast qty	106	110	155	148	134	163	142	282	214	161	125	101	0.36
		Order qty	118	234	136	108	213	107	525	96	68	61	60	101	
36	Dec-06	Forecast qty	106	110	155	148	134	163	**142**	282	214	161	125	101	0.36
		Order qty	118	234	136	108	213	107	525	96	68	61	60	52	

Part no	Part name	Jan-04	Feb-04	Mar-04	Apr-04	May-04	Jun-04	Jul-04	Aug-04	Sep-04	Oct-04	Nov-04	Dec-04
AA00006	RADIATOR ASSY	40	40	82	20	40	20	83	35	53	76	126	101
		Jan-05	Feb-05	Mar-05	Apr-05	May-05	Jun-05	Jul-05	Aug-05	Sep-05	Oct-05	Nov-05	Dec-05
		37	117	197	3	63	78	31	147	105	101	100	85
		Jan-06	Feb-06	Mar-06	Apr-06	May-06	Jun-06	Jul-06	Aug-06	Sep-06	Oct-06	Nov-06	Dec-06
		80	120	169	234	56	100	211	106	100	11	120	86

α = 0.17
MSE = 2085.20

	Month	Order qty (pcs)	Forecast qty	Forecast Error
1	Jan-04	40	40	0.00
2	Feb-04	40	40	0.00
3	Mar-04	82	40	1764.00
4	Apr-04	20	47	734.90
5	May-04	40	43	6.35
6	Jun-04	20	42	488.14
7	Jul-04	83	38	1993.25
8	Aug-04	35	46	119.05
9	Sep-04	53	44	79.85
10	Oct-04	76	46	925.57
11	Nov-04	126	51	5666.13
12	Dec-04	101	63	1408.69
13	Jan-05	37	70	1077.18
14	Feb-05	117	64	2780.97
15	Mar-05	197	73	15328.62
16	Apr-05	3	94	8307.88
17	May-05	63	79	247.10
18	Jun-05	78	76	3.77
19	Jul-05	31	76	2060.01
20	Aug-05	147	69	6130.12
21	Sep-05	105	82	530.96
22	Oct-05	101	86	229.29
23	Nov-05	100	88	134.08
24	Dec-05	85	90	28.95

AA00006	RADIATOR ASSY	2006	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	α
24	Dec-05	Forecast qty	89	89	89	89	89	89	89	89	89	89	89	89	0.17
		Order qty	89	89	89	89	89	89	89	89	89	89	89	89	
25	Jan-06	Forecast qty	90	88	88	88	88	88	88	88	88	88	88	88	0.17
		Order qty	80	88	88	88	88	88	88	88	88	88	88	88	
26	Feb-06	Forecast qty	90	89	94	94	94	94	94	94	94	94	94	94	0.17
		Order qty	80	120	94	94	94	94	94	94	94	94	94	94	
27	Mar-06	Forecast qty	90	89	94	107	107	107	107	107	107	107	107	107	0.17
		Order qty	80	120	169	107	107	107	107	107	107	107	107	107	
28	Apr-06	Forecast qty	90	88	94	109	130	130	130	130	130	130	130	130	0.17
		Order qty	80	120	169	234	130	130	130	130	130	130	130	130	
29	May-06	Forecast qty	90	88	94	107	130	118	118	118	118	118	118	118	0.17
		Order qty	80	120	169	234	56	118	118	118	118	118	118	118	
30	Jun-06	Forecast qty	90	88	94	107	130	118	115	115	115	115	115	115	0.17
		Order qty	80	120	169	234	56	100	115	115	115	115	115	115	
31	Jul-06	Forecast qty	90	88	94	107	130	118	115	131	131	131	131	131	0.17
		Order qty	80	120	169	234	56	100	211	131	131	131	131	131	
32	Aug-06	Forecast qty	90	88	94	107	130	117	114	131	127	127	127	127	0.17
		Order qty	80	120	169	234	56	100	211	106	127	127	127	127	
33	Sep-06	Forecast qty	90	88	94	107	130	117	114	131	127	122	122	122	0.17
		Order qty	80	120	169	234	56	100	211	106	100	122	122	122	
34	Oct-06	Forecast qty	90	88	94	107	130	117	114	131	127	122	103	103	0.17
		Order qty	80	120	169	234	56	100	211	106	100	11	103	103	
35	Nov-06	Forecast qty	90	88	94	107	130	117	114	131	127	122	103	106	0.17
		Order qty	80	120	169	234	56	100	211	106	100	11	120	106	
36	Dec-06	Forecast qty	90	88	94	107	130	117	114	131	127	122	103	106	0.17
		Order qty	80	120	169	234	56	100	211	106	100	11	120	86	

Part no	Part name	Jan-04	Feb-04	Mar-04	Apr-04	May-04	Jun-04	Jul-04	Aug-04	Sep-04	Oct-04	Nov-04	Dec-04
AA00008	GATE,RR BODY	80	85	70	45	67	79	117	112	86	126	140	83
		Jan-05	Feb-05	Mar-05	Apr-05	May-05	Jun-05	Jul-05	Aug-05	Sep-05	Oct-05	Nov-05	Dec-05
		88	119	66	65	84	84	75	113	92	123	63	87
		Jan-06	Feb-06	Mar-06	Apr-06	May-06	Jun-06	Jul-06	Aug-06	Sep-06	Oct-06	Nov-06	Dec-06
		52	69	42	148	138	51	101	27	55	47	43	54

α = 0.10
MSE = 586.68

	Month	Order qty (pcs)	Forecast qty	Forecast Error
1	Jan-04	80	80	0.00
2	Feb-04	85	80	25.00
3	Mar-04	70	80	109.97
4	Apr-04	45	79	1187.90
5	May-04	67	76	83.00
6	Jun-04	79	75	14.26
7	Jul-04	117	76	1714.67
8	Aug-04	112	80	1048.31
9	Sep-04	86	83	10.40
10	Oct-04	126	83	1841.41
11	Nov-04	140	87	2780.90
12	Dec-04	83	92	88.35
13	Jan-05	88	91	12.14
14	Feb-05	119	91	775.89
15	Mar-05	66	94	776.00
16	Apr-05	65	91	683.56
17	May-05	84	89	21.16
18	Jun-05	84	88	17.24
19	Jul-05	75	88	162.51
20	Aug-05	113	87	701.89
21	Sep-05	92	89	8.49
22	Oct-05	123	89	1131.00
23	Nov-05	63	93	878.73
24	Dec-05	87	90	7.60

MR125931	GATE,RR BODY	2006	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	α
24	Dec-05	Forecast qty	89	89	89	89	89	89	89	89	89	89	89	89	0.10
		Order qty	89	89	89	89	89	89	89	89	89	89	89	89	
25	Jan-06	Forecast qty	89	86	86	86	86	86	86	86	86	86	86	86	0.10
		Order qty	52	86	86	86	86	86	86	86	86	86	86	86	
26	Feb-06	Forecast qty	89	86	84	84	84	84	84	84	84	84	84	84	0.10
		Order qty	52	69	84	84	84	84	84	84	84	84	84	84	
27	Mar-06	Forecast qty	89	86	84	80	80	80	80	80	80	80	80	80	0.10
		Order qty	52	69	42	80	80	80	80	80	80	80	80	80	
28	Apr-06	Forecast qty	89	90	90	80	87	87	87	87	87	87	87	87	0.10
		Order qty	52	69	42	148	87	87	87	87	87	87	87	87	
29	May-06	Forecast qty	89	90	90	85	87	92	92	92	92	92	92	92	0.10
		Order qty	52	69	42	148	138	92	92	92	92	92	92	92	
30	Jun-06	Forecast qty	89	90	90	85	91	92	88	88	88	88	88	88	0.10
		Order qty	52	69	42	148	138	51	88	88	88	88	88	88	
31	Jul-06	Forecast qty	89	90	90	85	91	96	88	89	89	89	89	89	0.10
		Order qty	52	69	42	148	138	51	101	89	89	89	89	89	
32	Aug-06	Forecast qty	89	90	90	85	91	96	90	89	83	83	83	83	0.10
		Order qty	52	69	42	148	138	51	101	27	83	83	83	83	
33	Sep-06	Forecast qty	89	90	90	85	91	96	90	91	83	80	80	80	0.10
		Order qty	52	69	42	148	138	51	101	27	55	80	80	80	
34	Oct-06	Forecast qty	89	90	90	85	91	96	90	91	95	80	77	77	0.10
		Order qty	52	69	42	148	138	51	101	27	55	47	77	77	
35	Nov-06	Forecast qty	89	90	90	85	91	96	90	91	95	80	77	74	0.10
		Order qty	52	69	42	148	138	51	101	27	55	47	43	74	
36	Dec-06	Forecast qty	89	90	90	85	91	96	90	91	95	80	77	74	0.10
		Order qty	52	69	42	148	138	51	101	27	55	47	43	54	

Part no	Part name	Jan-04	Feb-04	Mar-04	Apr-04	May-04	Jun-04	Jul-04	Aug-04	Sep-04	Oct-04	Nov-04	Dec-04
AA00009	BELT,A/C	550	600	2130	160	1050	1689	695	1802	915	1446	2047	1602
		Jan-05	Feb-05	Mar-05	Apr-05	May-05	Jun-05	Jul-05	Aug-05	Sep-05	Oct-05	Nov-05	Dec-05
		1269	2486	2285	2080	1699	1718	2022	1181	1744	2950	1909	707
		Jan-06	Feb-06	Mar-06	Apr-06	May-06	Jun-06	Jul-06	Aug-06	Sep-06	Oct-06	Nov-06	Dec-06
		1335	2674	2078	1539	2721	1725	2996	1784	2014	1839	3751	2890

α = 0.26
MSE = 462462.11

	Month	Order qty (pcs)	Forecast qty	Forecast Error
1	Jan-04	550	550	0.00
2	Feb-04	600	550	2500.00
3	Mar-04	2130	563	2454910.19
4	Apr-04	160	976	666418.19
5	May-04	1050	761	83475.15
6	Jun-04	1689	837	725450.88
7	Jul-04	695	1062	134588.51
8	Aug-04	1802	965	700362.28
9	Sep-04	915	1186	73334.14
10	Oct-04	1446	1114	109962.73
11	Nov-04	2047	1202	714301.71
12	Dec-04	1602	1425	31434.99
13	Jan-05	1269	1471	40987.44
14	Feb-05	2486	1418	1140479.23
15	Mar-05	2285	1700	342605.31
16	Apr-05	2080	1854	51066.20
17	May-05	1699	1914	46057.79
18	Jun-05	1718	1857	19326.35
19	Jul-05	2022	1820	40658.41
20	Aug-05	1181	1874	479600.24
21	Sep-05	1744	1691	2817.98
22	Oct-05	2950	1705	1550240.55
23	Nov-05	1909	2033	15434.39
24	Dec-05	707	2000	1673077.96

AA00009	BELT,A/C	2006	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	α
24	Dec-05	Forecast qty	1659	1659	1659	1659	1659	1659	1659	1659	1659	1659	1659	1659	0.26
		Order qty	1659	1659	1659	1659	1659	1659	1659	1659	1659	1659	1659	1659	
25	Jan-06	Forecast qty	1659	1574	1574	1574	1574	1574	1574	1574	1574	1574	1574	1574	0.26
		Order qty	1335	1574	1574	1574	1574	1574	1574	1574	1574	1574	1574	1574	
26	Feb-06	Forecast qty	1659	1574	1864	1864	1864	1864	1864	1864	1864	1864	1864	1864	0.26
		Order qty	1335	2674	1864	1864	1864	1864	1864	1864	1864	1864	1864	1864	
27	Mar-06	Forecast qty	1659	1574	1864	1920	1920	1920	1920	1920	1920	1920	1920	1920	0.26
		Order qty	1335	2674	2078	1920	1920	1920	1920	1920	1920	1920	1920	1920	
28	Apr-06	Forecast qty	1659	1574	1864	1920	1820	1820	1820	1820	1820	1820	1820	1820	0.26
		Order qty	1335	2674	2078	1539	1820	1820	1820	1820	1820	1820	1820	1820	
29	May-06	Forecast qty	1659	1574	1864	1920	1820	2057	2057	2057	2057	2057	2057	2057	0.26
		Order qty	1335	2674	2078	1539	2721	2057	2057	2057	2057	2057	2057	2057	
30	Jun-06	Forecast qty	1659	1574	1864	1920	1820	2057	1970	1970	1970	1970	1970	1970	0.26
		Order qty	1335	2674	2078	1539	2721	1725	1970	1970	1970	1970	1970	1970	
31	Jul-06	Forecast qty	1659	1574	1864	1920	1820	2057	1970	2240	2240	2240	2240	2240	0.26
		Order qty	1335	2674	2078	1539	2721	1725	2996	2240	2240	2240	2240	2240	
32	Aug-06	Forecast qty	1659	1574	1864	1920	1820	2057	1970	2240	2120	2120	2120	2120	0.26
		Order qty	1335	2674	2078	1539	2721	1725	2996	1784	2120	2120	2120	2120	
33	Sep-06	Forecast qty	1659	1574	1864	1920	1820	2057	1970	2240	2120	2092	2092	2092	0.26
		Order qty	1335	2674	2078	1539	2721	1725	2996	1784	2014	2092	2092	2092	
34	Oct-06	Forecast qty	1659	1574	1864	1920	1820	2057	1970	2240	2120	2092	2025	2025	0.26
		Order qty	1335	2674	2078	1539	2721	1725	2996	1784	2014	1839	2025	2025	
35	Nov-06	Forecast qty	1659	1574	1864	1920	1820	2057	1970	2240	2120	2092	2025	2480	0.26
		Order qty	1335	2674	2078	1539	2721	1725	2996	1784	2014	1839	3751	2480	
36	Dec-06	Forecast qty	1659	1574	1864	1920	1820	2057	1970	2240	2120	2092	2025	2480	0.26
		Order qty	1335	2674	2078	1539	2721	1725	2996	1784	2014	1839	3751	2890	

Appendix B:
The Holt's Method

Part no	Part name	Jan-04	Feb-04	Mar-04	Apr-04	May-04	Jun-04	Jul-04	Aug-04	Sep-04	Oct-04	Nov-04	Dec-04
AA00001	OIL FILTER	20	300	11	22	30	218	250	37	689	747	708	234
		Jan-05	Feb-05	Mar-05	Apr-05	May-05	Jun-05	Jul-05	Aug-05	Sep-05	Oct-05	Nov-05	Dec-05
		1159	555	1093	400	860	1657	1660	1670	1958	850	1000	1000
		Jan-06	Feb-06	Mar-06	Apr-06	May-06	Jun-06	Jul-06	Aug-06	Sep-06	Oct-06	Nov-06	Dec-06
		1050	1360	1882	1440	1765	1115	553	2383	1390	1846	8012	4253

1. Find out the best alpha and beta value

				α =		0.37		
				β =		0.05		
				MSE =			172678.42	274973.14
Code	Month	Actual demand	Exp forecast (no trend)	Trend factor		Exp forecast (trend)	MSE (no trend)	MSE (trend)
1	Jan-04	20	20	0.00		20	0.00	78400.00
2	Feb-04	300	20	0.00		20	78400.00	81.00
3	Mar-04	11	123	5.67		129	12560.23	11392.89
4	Apr-04	22	82	3.09		85	3578.05	3014.34
5	May-04	30	60	1.71		62	887.88	24491.11
6	Jun-04	218	49	1.01		50	28619.02	40064.78
7	Jul-04	250	111	4.38		115	19292.33	6159.13
8	Aug-04	37	162	6.95		169	15683.38	270212.96
9	Sep-04	689	116	4.03		120	328176.68	392923.43
10	Oct-04	747	327	15.40		342	176387.90	133652.90
11	Nov-04	708	482	23.05		505	51248.91	73261.46
12	Dec-04	234	565	26.36		591	109529.67	322264.25
13	Jan-05	1159	443	18.22		461	512478.83	8771.66
14	Feb-05	555	707	31.70		738	22997.47	125776.06
15	Mar-05	1093	651	26.89		678	195519.00	77126.03
16	Apr-05	400	814	34.36		848	171062.02	145.06
17	May-05	860	661	24.10		685	39463.80	943913.59
18	Jun-05	1657	734	26.80		761	851055.92	807714.87
19	Jul-05	1660	1074	43.99		1118	343314.09	304638.58
20	Aug-05	1670	1290	53.43		1343	144582.40	377995.72
21	Sep-05	1958	1430	58.18		1488	279066.63	406936.21
22	Oct-05	850	1624	65.67		1690	599379.62	475919.84
23	Nov-05	1000	1339	46.40		1386	115058.15	148689.08
24	Dec-05	1000	1214	36.99		1251	45940.13	1565810.32

2. Explore demand forecasting underlying The Holt's Method

AA00001	OIL FILTER	2006	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	α	β
24	Dec-05	Forecast	1135	1086	1054	1034	1022	1014	1009	1005	1003	1002	1001	1001	0.37	0.05
		Trend	30.62	26.19	23.02	20.66	18.84	17.36	16.13	15.07	14.13	13.29	12.51	11.80		
		Forecast with T	1166	1138	1123	1117	1116	1118	1122	1126	1131	1135	1139	1142		
		Period	1	2	3	4	5	6	7	8	9	10	11	12		
25	Jan-06	Actual demand	1050													
		Forecast	1135	1104	1084	1072	1064	1059	1055	1053	1052	1051	1051	1051	0.37	0.05
		Trend	30.62	27.21	24.62	22.58	20.90	19.47	18.23	17.12	16.11	15.18	14.32	13.51		
		Forecast with T	1166	1131	1133	1139	1147	1156	1165	1173	1181	1188	1194	1199		
		Period		1	2	3	4	5	6	7	8	9	10	11		
26	Feb-06	Actual demand	1050	1360												
		Forecast	1135	1104	1198	1258	1295	1319	1334	1344	1350	1353	1356	1357	0.37	0.05
		Trend	30.62	27.21	30.89	32.47	32.75	32.26	31.31	30.11	28.79	27.41	26.04	24.69		
		Forecast with T	1166	1131	1229	1323	1394	1448	1491	1524	1551	1573	1590	1604		
		Period			1	2	3	4	5	6	7	8	9	10		
27	Mar-06	Actual demand	1050	1360	1882											
		Forecast	1135	1104	1198	1450	1609	1709	1773	1813	1838	1854	1865	1871	0.37	0.05
		Trend	30.62	27.21	30.89	30.89	30.89	30.89	30.89	30.89	30.89	30.89	30.89	30.89		
		Forecast with T	1166	1131	1229	1481	1671	1802	1897	1968	2024	2071	2112	2149		
		Period				1	2	3	4	5	6	7	8	9		
28	Apr-06	Actual demand	1050	1360	1882	1440										
		Forecast	1135	1104	1198	1450	1446	1444	1443	1442	1441	1441	1440	1440	0.37	0.05
		Trend	30.62	27.21	30.89	30.89	28.99	27.27	25.69	24.23	22.87	21.59	20.39	19.26		
		Forecast with T	1166	1131	1229	1481	1475	1499	1520	1539	1555	1570	1583	1594		
		Period					1	2	3	4	5	6	7	8		
29	May-06	Actual demand	1050	1360	1882	1440	1765									
		Forecast	1135	1104	1198	1450	1446	1564	1638	1685	1714	1733	1745	1752	0.37	0.05
		Trend	30.62	27.21	30.89	30.89	28.99	33.85	36.06	36.65	36.27	35.30	34.01	32.55		
		Forecast with T	1166	1131	1229	1481	1475	1597	1710	1795	1859	1909	1949	1980		
		Period						1	2	3	4	5	6	7		
30	Jun-06	Actual demand	1050	1360	1882	1440	1765	1115								
		Forecast	1135	1104	1198	1450	1446	1564	1398	1294	1228	1187	1160	1144	0.37	0.05
		Trend	30.62	27.21	30.89	30.89	28.99	33.85	22.91	15.92	11.42	8.50	6.59	5.31		
		Forecast with T	1166	1131	1229	1481	1475	1597	1421	1326	1262	1221	1193	1175		
		Period							1	2	3	4	5	6		
31	Jul-06	Actual demand	1050	1360	1882	1440	1765	1115	553							
		Forecast	1135	1104	1198	1450	1446	1564	1398	1087	891	766	688	638	0.37	0.05
		Trend	30.62	27.21	30.89	30.89	28.99	33.85	22.91	4.55	-6.51	-12.99	-16.59	-18.40		
		Forecast with T	1166	1131	1229	1481	1475	1597	1421	1092	878	727	621	546		
		Period								1	2	3	4	5		
32	Aug-06	Actual demand	1050	1360	1882	1440	1765	1115	553	2383						
		Forecast	1135	1104	1198	1450	1446	1564	1398	1087	1564	1866	2056	2176	0.37	0.05
		Trend	30.62	27.21	30.89	30.89	28.99	33.85	22.91	4.55	30.51	45.40	53.37	57.05		
		Forecast with T	1166	1131	1229	1481	1475	1597	1421	1092	1595	1956	2216	2405		
		Period									1	2	3	4		
33	Sep-06	Actual demand	1050	1360	1882	1440	1765	1115	553	2383	1390					
		Forecast	1135	1104	1198	1450	1446	1564	1398	1087	1564	1500	1460	1434	0.37	0.05
		Trend	30.62	27.21	30.89	30.89	28.99	33.85	22.91	4.55	30.51	25.31	21.69	19.09		
		Forecast with T	1166	1131	1229	1481	1475	1597	1421	1092	1595	1525	1503	1491		
		Period										1	2	3		
34	Oct-06	Actual demand	1050	1360	1882	1440	1765	1115	553	2383	1390	1846				
		Forecast	1135	1104	1198	1450	1446	1564	1398	1087	1564	1500	1627	1708	0.37	0.05
		Trend	30.62	27.21	30.89	30.89	28.99	33.85	22.91	4.55	30.51	25.31	30.92	33.64		
		Forecast with T	1166	1131	1229	1481	1475	1597	1421	1092	1595	1525	1658	1775		
		Period											1	2		
35	Nov-06	Actual demand	1050	1360	1882	1440	1765	1115	553	2383	1390	1846	8012			
		Forecast	1135	1104	1198	1450	1446	1564	1398	1087	1564	1500	1627	3978	0.37	0.05
		Trend	30.62	27.21	30.89	30.89	28.99	33.85	22.91	4.55	30.51	25.31	30.92	158.39		
		Forecast with T	1166	1131	1229	1481	1475	1597	1421	1092	1595	1525	1658	4136		
		Period												1		
36	Dec-06	Actual demand	1050	1360	1882	1440	1765	1115	553	2383	1390	1846	8012	4253		
		Forecast	1135	1104	1198	1450	1446	1564	1398	1087	1564	1500	1627	3978	0.37	0.05
		Trend	30.62	27.21	30.89	30.89	28.99	33.85	22.91	4.55	30.51	25.31	30.92	158.39		
		Forecast with T	1166	1131	1229	1481	1475	1597	1421	1092	1595	1525	1658	4136		
		Period												1		

Part no	Part name	Jan-04	Feb-04	Mar-04	Apr-04	May-04	Jun-04	Jul-04	Aug-04	Sep-04	Oct-04	Nov-04	Dec-04
AA00007	TIMING BELT	590	250	765	650	980	771	715	1339	700	1149	1187	1083
		Jan-05	Feb-05	Mar-05	Apr-05	May-05	Jun-05	Jul-05	Aug-05	Sep-05	Oct-05	Nov-05	Dec-05
		1288	174	1347	825	2023	1299	773	1124	868	1591	1193	680
		Jan-06	Feb-06	Mar-06	Apr-06	May-06	Jun-06	Jul-06	Aug-06	Sep-06	Oct-06	Nov-06	Dec-06
		1011	1404	1031	807	1568	1316	1181	901	1224	1452	1356	1418

1. Find out the best alpha and beta value

				α =	0.19		
				β =	0.06		
				MSE =		170295.97	169847.09
Code	Month	Actual demand	Exp forecast (no trend)	Trend factor	Exp forecast (trend)	MSE (no trend)	MSE (trend)
1	Jan-04	590	590	0.00	590.00	0.00	0.00
2	Feb-04	250	590	0.00	590.00	115600.00	115600.00
3	Mar-04	765	524	-4.03	520.41	57867.67	59825.10
4	Apr-04	650	571	-0.93	569.89	6268.53	6416.94
5	May-04	980	586	0.07	586.16	155163.63	155112.32
6	Jun-04	771	662	4.74	666.78	11871.60	10862.09
7	Jul-04	715	683	5.74	688.79	1020.70	687.03
8	Aug-04	1339	689	5.76	694.97	422224.79	414768.42
9	Sep-04	700	815	13.12	827.62	13110.36	16286.80
10	Oct-04	1149	792	10.95	803.38	127147.09	119455.81
11	Nov-04	1187	861	14.51	875.69	106161.04	96915.93
12	Dec-04	1083	924	17.48	941.48	25281.02	20026.84
13	Jan-05	1288	955	18.29	972.95	111117.23	99255.17
14	Feb-05	174	1019	21.12	1040.06	713908.10	750051.61
15	Mar-05	1347	856	9.80	865.81	241065.54	231540.51
16	Apr-05	825	951	15.02	965.71	15796.65	19798.12
17	May-05	2023	926	12.61	939.06	1202420.01	1174934.59
18	Jun-05	1299	1138	24.84	1162.72	25959.12	18571.29
19	Jul-05	773	1169	25.22	1194.17	156774.53	177386.31
20	Aug-05	1124	1093	18.97	1111.58	985.76	154.33
21	Sep-05	868	1099	18.18	1116.84	53202.60	61919.13
22	Oct-05	1591	1054	14.32	1068.51	288172.65	273000.43
23	Nov-05	1193	1158	19.81	1177.50	1246.86	240.23
24	Dec-05	680	1164	19.01	1183.51	234737.88	253521.09

2. Explore demand forecasting underlying The Holt's Method

AA00007	TIMING BELT	2006	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	α	β
24	Dec-05	Forecast	1071	996	935	886	846	814	788	767	750	737	726	717	0.19	0.06
		Trend	12.09	6.71	2.55	-0.63	-3.03	-4.82	-6.11	-7.02	-7.62	-7.99	-8.17	-8.22		
		Forecast with T	1083	1009	942	883	831	785	745	711	682	657	636	618		
		Period	1	2	3	4	5	6	7	8	9	10	11	12		
25	Jan-06	Actual demand	1011													
		Forecast	1071	1059	1050	1043	1037	1032	1028	1024	1022	1020	1018	1017	0.19	0.06
		Trend	12.09	10.63	9.40	8.36	7.47	6.71	6.05	5.48	4.99	4.55	4.17	3.83		
		Forecast with T	1083	1070	1069	1068	1066	1065	1064	1063	1062	1061	1060	1059		
		Period		1	2	3	4	5	6	7	8	9	10	11		
26	Feb-06	Actual demand	1011	1404												
		Forecast	1071	1059	1126	1180	1223	1258	1286	1309	1327	1342	1354	1364	0.19	0.06
		Trend	12.09	10.63	14.07	16.50	18.15	19.18	19.74	19.92	19.83	19.52	19.06	18.48		
		Forecast with T	1083	1070	1140	1213	1277	1334	1385	1428	1466	1498	1525	1548		
		Period			1	2	3	4	5	6	7	8	9	10		
27	Mar-06	Actual demand	1011	1404	1031											
		Forecast	1071	1059	1126	1108	1093	1081	1071	1064	1057	1052	1048	1045	0.19	0.06
		Trend	12.09	10.63	14.07	14.07	14.07	14.07	14.07	14.07	14.07	14.07	14.07	14.07		
		Forecast with T	1083	1070	1140	1122	1121	1123	1128	1134	1142	1151	1161	1171		
		Period				1	2	3	4	5	6	7	8	9		
28	Apr-06	Actual demand	1011	1404	1031	807										
		Forecast	1071	1059	1126	1108	1050	1003	965	935	910	890	874	861	0.19	0.06
		Trend	12.09	10.63	14.07	14.07	9.64	6.16	3.46	1.37	-0.23	-1.44	-2.34	-2.99		
		Forecast with T	1083	1070	1140	1122	1059	1015	975	940	909	882	858	837		
		Period					1	2	3	4	5	6	7	8		
29	May-06	Actual demand	1011	1404	1031	807	1568									
		Forecast	1071	1059	1126	1108	1050	1150	1230	1295	1348	1390	1425	1452	0.19	0.06
		Trend	12.09	10.63	14.07	14.07	9.64	15.19	19.22	22.05	23.93	25.06	25.63	25.75		
		Forecast with T	1083	1070	1140	1122	1059	1165	1269	1362	1444	1516	1578	1633		
		Period						1	2	3	4	5	6	7		
30	Jun-06	Actual demand	1011	1404	1031	807	1568	1316								
		Forecast	1071	1059	1126	1108	1050	1150	1182	1208	1228	1245	1259	1270	0.19	0.06
		Trend	12.09	10.63	14.07	14.07	9.64	15.19	16.23	16.83	17.08	17.07	16.85	16.49		
		Forecast with T	1083	1070	1140	1122	1059	1165	1198	1241	1280	1314	1343	1369		
		Period							1	2	3	4	5	6		
31	Jul-06	Actual demand	1011	1404	1031	807	1568	1316	1181							
		Forecast	1071	1059	1126	1108	1050	1150	1182	1182	1181	1181	1181	1181	0.19	0.06
		Trend	12.09	10.63	14.07	14.07	9.64	15.19	16.23	15.23	14.28	13.40	12.57	11.79		
		Forecast with T	1083	1070	1140	1122	1059	1165	1198	1197	1210	1222	1232	1240		
		Period								1	2	3	4	5		
32	Aug-06	Actual demand	1011	1404	1031	807	1568	1316	1181	901						
		Forecast	1071	1059	1126	1108	1050	1150	1182	1182	1127	1084	1049	1020	0.19	0.06
		Trend	12.09	10.63	14.07	14.07	9.64	15.19	16.23	15.23	10.96	7.60	4.96	2.90		
		Forecast with T	1083	1070	1140	1122	1059	1165	1198	1197	1138	1099	1063	1032		
		Period									1	2	3	4		
33	Sep-06	Actual demand	1011	1404	1031	807	1568	1316	1181	901	1224					
		Forecast	1071	1059	1126	1108	1050	1150	1182	1182	1127	1146	1161	1173	0.19	0.06
		Trend	12.09	10.63	14.07	14.07	9.64	15.19	16.23	15.23	10.96	11.43	11.65	11.68		
		Forecast with T	1083	1070	1140	1122	1059	1165	1198	1197	1138	1158	1184	1208		
		Period										1	2	3		
34	Oct-06	Actual demand	1011	1404	1031	807	1568	1316	1181	901	1224	1452				
		Forecast	1071	1059	1126	1108	1050	1150	1182	1182	1127	1146	1205	1253	0.19	0.06
		Trend	12.09	10.63	14.07	14.07	9.64	15.19	16.23	15.23	10.96	11.43	14.36	16.40		
		Forecast with T	1083	1070	1140	1122	1059	1165	1198	1197	1138	1158	1219	1285		
		Period											1	2		
35	Nov-06	Actual demand	1011	1404	1031	807	1568	1316	1181	901	1224	1452	1356			
		Forecast	1071	1059	1126	1108	1050	1150	1182	1182	1127	1146	1205	1234	0.19	0.06
		Trend	12.09	10.63	14.07	14.07	9.64	15.19	16.23	15.23	10.96	11.43	14.36	15.26		
		Forecast with T	1083	1070	1140	1122	1059	1165	1198	1197	1138	1158	1219	1249		
		Period												1		
36	Dec-06	Actual demand	1011	1404	1031	807	1568	1316	1181	901	1224	1452	1356	1418		
		Forecast	1071	1059	1126	1108	1050	1150	1182	1182	1127	1146	1205	1234	0.19	0.06
		Trend	12.09	10.63	14.07	14.07	9.64	15.19	16.23	15.23	10.96	11.43	14.36	15.26		
		Forecast with T	1083	1070	1140	1122	1059	1165	1198	1197	1138	1158	1219	1249		
		Period												1		

Appendix C:
Economic order quantity
And
Reorder Point

Inventory	EOQ Model
Part number	AA00001

Data

Demand rate, D	19508
Ordering cost, O	215
Holding cost rate	0.19
Unit Price, P	135

Results

Optimal Order Quantity, Q*	569
Maximum Inventory	569
Average Inventory	285
Number of Ordering	34

2006	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Forecast with T	1166	1131	1229	1481	1475	1597	1421	1092	1595	1525	1658	4136

Safety stock	
Fill Rate	90%
α	0.10
Q*	569
LT (month)	2
MSE Demand	353535.70
Mean demand	1626
STDV LT	0
σ_L	841
L(k)	0.0677
k	1.11
Safety stock	**933**

ROP	$\bar{d}$ x L+SS
Avr demand, $\bar{d}$	1626
Order Lead Time, L	2
SS	933
ROP	4185

Inventory	EOQ model
Part number	AA00002

Data

Demand rate, D	1466
Ordering cost, O	215
Holding cost, H	0.19
Unit Price, P	394

Results

Optimal Order Quantity, Q*	91
Maximum Inventory	91
Average Inventory	46
Number of Ordering	16

2006	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Forecast	131	115	93	137	141	143	127	139	123	104	102	109
Square Deviation	87	47	825	224	366	439	25	294	1	327	425	168
Sum of STDEV	3230											
STDEV	**16**											

Safety stock	
Fill Rate	90%
α	0.10
Q*	91
LT (month)	2
MSE Demand	8735.26
Mean demand	122
STDV LT	0
σ_L	132
L(Z)	0.0691
Z	1.09
Safety stock	**144**

ROP	$\bar{d}$ x L+SS
Avr demand, $\bar{d}$	122
Order Lead Time, L	2
SS	144
ROP	**388**

Inventory	EOQ Model
Part number	AA00003

Data

Demand rate, D	6696
Ordering cost, O	215
Holding cost, H	0.19
Unit Price, P	226

Results

Optimal Order Quantity, Q*	258
Maximum Inventory	258
Average Inventory	129
Number of Ordering	26

2006	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Forecast	545	421	478	537	510	422	576	710	683	776	557	482
Square Deviation	168	18844	6411	441	2323	18365	328	23009	15627	47453	1	5847
Sum of STDEV	138816											
STDEV	**112**											

Safety stock	
Fill Rate	90%
α	0.10
Q*	258
LT (month)	2
MSE Demand	26596.66
Mean demand	558
STDV LT	0
σ_L	231
L(Z)	0.1118
Z	0.84
Safety stock	**194**

ROP	$\bar{d}$ x L+SS
Avr demand, $\bar{d}$	558
Order Lead Time, L	2
SS	194
ROP	**1310**

Inventory	EOQ Model
Part number	AA00004

Data

Demand rate, D	2394
Ordering cost, O	215
Holding cost, H	0.19
Unit Price, P	132

Results

Optimal Order Quantity, Q*	202
Maximum Inventory	202
Average Inventory	101
Number of Ordering	12

2006	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Forecast	191	204	214	203	197	186	179	207	203	207	208	195
Square Deviation	68	17	203	10	8	172	417	60	15	57	69	20
Sum of STDEV	1115											
STDEV	**10**											

Safety stock	
Fill Rate	90%
α	0.10
Q*	202
LT (month)	2
MSE Demand	23493.71
Mean demand	200
STDV LT	0
σ_L	217
L(Z)	0.0930
Z	0.94
Safety stock	**204**

ROP	$\bar{d}$ x L+SS
Avr demand, $\bar{d}$	200
Order Lead Time, L	2
SS	204
ROP	**603**

Inventory	EOQ Model
Part number	AA00005

Data

Demand rate, D	1837
Ordering cost, O	215
Holding cost, H	0.19
Unit Price, P	530

Results

Optimal Order Quantity, Q*	88
Maximum Inventory	88
Average Inventory	44
Number of Ordering	21

2006	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Forecast	106	109	154	148	133	162	142	282	214	161	125	101
Square Deviation	2230	1942	2	28	391	85	119	16501	3712	61	816	2708
Sum of STDEV	28595											
STDEV	**51**											

Safety stock	
Fill Rate	90%
α	0.10
Q*	88
LT (month)	2
MSE Demand	1837.23
Mean demand	153
STDV LT	0
σ_L	61
L(Z)	0.1454
Z	0.69
Safety stock	**42**

ROP	$\bar{d}$ x L+SS
Avr demand, $\bar{d}$	153
Order Lead Time, L	2
SS	42
ROP	**348**

Inventory	EOQ Model
Part number	AA00006

Data

Demand rate, D	1330
Ordering cost, O	215
Holding cost, H	0.19
Unit Price, P	2396

Results

Optimal Order Quantity, Q*	35
Maximum Inventory	35
Average Inventory	18
Number of Ordering	38

2006	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Forecast	90	88	94	107	130	117	114	131	127	122	103	106
Square Deviation	433	520	282	14	369	38	10	408	263	126	55	21
Sum of STDEV	2539											
STDEV	**15**											

Safety stock	
Fill Rate	95%
α	0.05
Q*	35
LT (month)	2
MSE Demand	2085.20
Mean demand	111
STDV LT	0
σ_L	65
L(Z)	0.0273
Z	1.53
Safety stock	**99**

ROP	$\bar{d}$ x L+SS
Avr demand, $\bar{d}$	111
Order Lead Time, L	2
SS	99
ROP	**320**

Inventory	EOQ Model
Part number	AA00007

Data

Demand rate, D	13799
Ordering cost, O	215
Holding cost, H	0.19
Unit Price, P	201

Results

Optimal Order Quantity, Q*	392
Maximum Inventory	392
Average Inventory	196
Number of Ordering	35

2006	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Forecast	1083	1070	1140	1122	1059	1165	1198	1197	1138	1158	1219	1249
Square Deviation	4450	6360	98	795	8206	222	2308	2200	131	58	4836	9911
Sum of STDEV	39573											
STDEV	**60**											

Safety stock	
Fill Rate	95%
α	0.05
Q*	392
LT (month)	2
MSE Demand	169847.09
Mean demand	1150
STDV LT	0
σ_L	583
L(Z)	0.0337
Z	1.44
Safety stock	**839**

ROP	$\bar{d}$ x L+SS
Avr demand, $\bar{d}$	1150
Order Lead Time, L	2
SS	839
ROP	**3139**

Inventory	EOQ Model
Part number	AA00008

Data

Demand rate, D	1049
Ordering cost, O	215
Holding cost, H	0.19
Unit Price, P	45

Results

Optimal Order Quantity, Q*	229
Maximum Inventory	229
Average Inventory	114
Number of Ordering	5

2006	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Forecast	89	90	90	85	91	96	90	91	95	80	77	74
Square Deviation	4	7	7	4	16	73	7	13	57	52	108	188
Sum of STDEV	536											
STDEV	7											

Safety stock	
Fill Rate	95%
α	0.05
Q*	229
LT (month)	2
MSE Demand	586.68
Mean demand	87
STDV LT	0
σ_L	34
L(Z)	0.3337
Z	0.13
Safety stock	**4**

ROP	$\bar{d}$ x L+SS
Avr demand, $\bar{d}$	87
Order Lead Time, L	2
SS	4
ROP	**179**

Inventory	EOQ Model
Part number	AA00009

Data

Demand rate, D	23821
Ordering cost, O	215
Holding cost, H	0.19
Unit Price, P	66

Results

Optimal Order Quantity, Q*	900
Maximum Inventory	900
Average Inventory	450
Number of Ordering	26

2006	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Forecast	1659	1574	1864	1920	1820	2057	1970	2240	2120	2092	2025	2480
Square Deviation	106357	169382	14734	4210	27362	5220	237	65141	18195	11435	1616	245276
Sum of STDEV	669165											
STDEV	247											

Safety stock	
Fill Rate	90%
α	0.10
Q*	900
LT (month)	2
MSE Demand	462462.11
Mean demand	1985
STDV LT	0
σ_L	962
L(Z)	0.0935
Z	0.94
Safety stock	**904**

ROP	$\bar{d}$ x L+SS
Avr demand, $\bar{d}$	1985
Order Lead Time, L	2
SS	904
ROP	**4874**

Appendix D:
Ordering system
(The case study company)

ORDER QUANTITY SIMULATION: CURRENT SYSTEM

P/NO: AA00001

Wk	Month	Stock OHO	Dlry Qty	Order Qty	Stock OHC	Stock On order	OSD Stock	Forecast Qty	ROP	SS	Q*	PO Qty
1	1	4185			4185		4185	1166	2888	556	1166	
2		4185			4185	0	4185					
3		4185		500	3685	0	3685					
4		3685		500	3185	0	3185					
5		3185		50	3135	0	3135					
6	2	3135			3135	0	3135	1131	2802	540	1131	
7		3135		60	3075	0	3075					
8		3075		1300	1775	0	1775					
9		1775			1775	0	1775					
10	3	1775		844	931	0	931	1229	2948	490	1229	1229
11		931		38	893	1229	2122					
12		893		1000	-107	1229	1122					
13		-107			-107	1229	1122					
14	4	-107			-107	1229	1122	1481	3418	456	1481	1481
15		-107		68	-175	2710	2535					
16		-175		1338	-1513	2710	1197					
17		-1513		34	-1547	2710	1163					
18		-1547			-1547	2710	1163					
19	5	-1547	1229	295	-613	1481	868	1475	3369	419	1475	1475
20		-613		460	-1073	2956	1883					
21		-1073		1000	-2073	2956	883					
22		-2073		10	-2083	2956	873					
23	6	-2083	1481	55	-657	1475	818	1597	3628	434	1597	1597
24		-657			-657	3072	2415					
25		-657		60	-717	3072	2355					
26		-717		1000	-1717	3072	1355					
27	7	-1717			-1717	3072	1355	1421	3247	405	1421	1421
28		-1717	1475	300	-542	3018	2476					
29		-542		17	-559	3018	2459					
30		-559		154	-713	3018	2305					
31		-713		1302	-2015	3018	1003					
32	8	-2015	1597	150	-568	1421	853	1092	2763	579	1092	1092
33		-568			-568	2513	1945					
34		-568		1000	-1568	2513	945					
35		-1568		13	-1581	2513	932					
36	9	-1581	1421	360	-520	1092	572	1595	3960	770	1595	1595
37		-520		1000	-1520	2687	1167					
38		-1520		11	-1531	2687	1156					
39		-1531		19	-1550	2687	1137					
40	10	-1550			-1550	2687	1137	1525	3791	741	1525	1525
41		-1550	1092	1696	-2154	3120	966					
42		-2154		150	-2304	3120	816					
43		-2304		40	-2344	3120	776					
44	11	-2344			-2344	3120	776	1658	4083	767	1658	1658
45		-2344	1595		-749	3183	2434					
46		-749		7892	-8641	3183	-5458					
47		-8641		80	-8721	3183	-5538					
48	12	-8721		1450	-10171	3183	-6988	4136	11583	3311	4136	4136
49		-10171	1525	2283	-10929	5794	-5135					
50		-10929		520	-11449	5794	-5655					
51		-11449			-11449	5794	-5655					
52		-11449			-11449	5794	-5655					

	Jul-05	Aug-05	Sep-05	Oct-05	Nov-05	Dec-05	Jan-06	Feb-06	Mar-06	Apr-06	May-06	Jun-06	Jul-06	Aug-06	Sep-06	Oct-06	Nov-06	Dec-06
	1660	1670	1958	850	1000	1000	1050	1360	1882	1440	1765	1115	553	2383	1390	1846	8012	4253
AVERAGE							1356	1255	1203	1190	1289	1416	1435	1353	1523	1441	1509	2550
							1062923	1002533	825110	715163	603653	649681	564983	1153846	2041298	1889762	2026313	37749783
							177154	167089	137518	119194	100609	108280	94164	192308	340216	314960	337719	6291630
SD							420.90	408.77	370.83	345.24	317.19	329.06	306.86	438.53	583.28	561.21	581.14	2508.31

ORDER QUANTITY SIMULATION: CURRENT SYSTEM

P/NO: AA00002

Wk	Month	Stock OHO	Dlry Qty	Order Qty	Stock OHC	Stock On order	OSD Stock	Forecast Qty	ROP	SS	Q*	PO Qty
1	1	372			372		372	131	372	110	131	
2		372		40	332	0	332					
3		332		14	318	0	318					
4		318			318	0	318					
5		318			318	0	318					
6	2	318			318	0	318	115	340	110	115	115
7		318		11	307	115	422					
8		307			307	115	422					
9		307		72	235	115	350					
10	3	235		110	125	115	240	93	275	89	93	
11		125			125	115	240					
12		125		95	30	115	145					
13		30		25	5	115	120					
14	4	5			5	115	120	137	363	89	137	137
15		5	115	120	0	137	137					
16		0		24	-24	137	113					
17		-24		13	-37	137	100					
18		-37			-37	137	100					
19	5	-37		60	-97	137	40	141	340	58	141	141
20		-97		60	-157	278	121					
21		-157		14	-171	278	107					
22		-171		16	-187	278	91					
23	6	-187	137	43	-93	141	48	143	328	42	143	143
24		-93			-93	284	191					
25		-93		1	-94	284	190					
26		-94		23	-117	284	167					
27	7	-117			-117	284	167	127	273	19	127	127
28		-117	141	172	-148	270	122					
29		-148		6	-154	270	116					
30		-154		3	-157	270	113					
31		-157		35	-192	270	78					
32	8	-192	143	15	-64	127	63	139	293	15	139	139
33		-64			-64	266	202					
34		-64		15	-79	266	187					
35		-79		9	-88	266	178					
36	9	-88	127	10	29	139	168	123	256	10	123	123
37		29			29	262	291					
38		29			29	262	291					
39		29		14	15	262	277					
40	10	15		5	10	262	272	104	218	10	104	
41		10	139	3	146	123	269					
42		146		6	140	123	263					
43		140		78	62	123	185					
44	11	62		16	46	123	169	102	213	9	102	102
45		46	123	90	79	102	181					
46		79		6	73	102	175					
47		73		26	47	102	149					
48	12	47		12	35	102	137	109	223	5	109	109
49		35		68	-33	211	178					
50		-33		10	-43	211	168					
51		-43		5	-48	211	163					
52		-48			-48	211	163					

	Jul-05	Aug-05	Sep-05	Oct-05	Nov-05	Dec-05	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	171	257	135	243	40	55	150	147	128	127	108	119	130	127	123	122	122	124
AVERAGE							150	147	128	127	108	119	130	127	123	122	122	124
							41889	41382	27187	27135	11489	6111	1301	823	348	318	290	74
							6981	6897	4531	4523	1915	1019	217	137	58	53	48	12
SD							83.56	83.05	67.31	67.25	43.76	31.91	14.73	11.71	7.62	7.28	6.95	3.51

ORDER QUANTITY SIMULATION: CURRENT SYSTEM
P/NO: AA00003

Wk	Month	Stock OHO	Dlry Qty	Order Qty	Stock OHC	Stock On order	OSD Stock	Forecast Qty	ROP	SS	Q*	PO Qty
1	1	1210			1210		1210	545	1311	221	545	545
2		1210		101	1109	545	1654					
3		1109		40	1069	545	1614					
4		1069		60	1009	545	1554					
5		1009		46	963	545	1508					
6	2	963		59	904	545	1449	421	1116	274	421	
7		904		355	549	545	1094					
8		549		108	441	545	986					
9		441		24	417	545	962					
10	3	417	545	399	563	0	563	478	1205	249	478	478
11		563		114	449	478	927					
12		449		50	399	478	877					
13		399		67	332	478	810					
14	4	332			332	478	810	537	1292	218	537	537
15		332			332	1015	1347					
16		332		381	-49	1015	966					
17		-49		86	-135	1015	880					
18		-135		51	-186	1015	829					
19	5	-186	478	78	214	537	751	510	1223	203	510	510
20		214		132	82	1047	1129					
21		82			82	1047	1129					
22		82		24	58	1047	1105					
23	6	58	537	740	-145	510	365	422	1037	193	422	422
24		-145			-145	932	787					
25		-145		54	-199	932	733					
26		-199		24	-223	932	709					
27	7	-223		520	-743	932	189	576	1419	267	576	576
28		-743	510	149	-382	998	616					
29		-382		77	-459	998	539					
30		-459		132	-591	998	407					
31		-591		583	-1174	998	-176					
32	8	-1174	422	60	-812	576	-236	710	1699	279	710	710
33		-812			-812	1286	474					
34		-812		40	-852	1286	434					
35		-852		661	-1513	1286	-227					
36	9	-1513	576	36	-973	710	-263	683	1643	277	683	683
37		-973			-973	1393	420					
38		-973		211	-1184	1393	209					
39		-1184		14	-1198	1393	195					
40	10	-1198		70	-1268	1393	125	776	1865	313	776	776
41		-1268	710	55	-613	1459	846					
42		-613		55	-668	1459	791					
43		-668		32	-700	1459	759					
44	11	-700			-700	1459	759	557	1494	380	557	557
45		-700	683	178	-195	1333	1138					
46		-195		81	-276	1333	1057					
47		-276		104	-380	1333	953					
48	12	-380		43	-423	1333	910	482	1325	361	482	482
49		-423	776	337	16	1039	1055					
50		16			16	1039	1055					
51		16			16	1039	1055					
52		16			16	1039	1055					

	Jul-05	Aug-05	Sep-05	Oct-05	Nov-05	Dec-05	Jan-06	Feb-06	Mar-06	Apr-06	May-06	Jun-06	Jul-06	Aug-06	Sep-06	Oct-06	Nov-06	Dec-06
DEMAND	385	770	774	650	662	363	225	568	630	467	285	818	920	641	922	212	363	380
AVERAGE							601	574	540	516	486	423	499	615	627	676	633	646
							167911	258258	213077	163061	142047	127658	245579	267471	265099	338002	498524	449306
							27985	43043	35513	27177	23674	21276	40930	44579	44183	56334	83087	74884
SD							167.29	207.47	188.45	164.85	153.87	145.86	202.31	211.14	210.20	237.35	288.25	273.65

ORDER QUANTITY SIMULATION: CURRENT SYSTEM
P/NO: AA00004

Wk	Month	Stock OHO	Dlry Qty	Order Qty	Stock OHC	Stock On order	OSD Stock	Forecast Qty	ROP	SS	Q*	PO Qty
1	1	603		100	503		503	191	503	121	191	
2		503		190	313	0	313					
3		313		35	278	0	278					
4		278		5	273	0	273					
5		273		85	188	0	188					
6	2	188		97	91	0	91	204	544	136	204	204
7		91		38	53	204	257					
8		53		5	48	204	252					
9		48		117	-69	204	135					
10	3	-69	0		-69	204	135	214	551	123	214	214
11		-69	0		-69	418	349					
12		-69	0	65	-134	418	284					
13		-134	0		-134	418	284					
14	4	-134	0	6	-140	418	278	203	531	125	203	203
15		-140	204		64	417	481					
16		64	0	64	0	417	417					
17		0	0	65	-65	417	352					
18		-65	0	16	-81	417	336					
19	5	-81	214	26	107	203	310	197	523	129	197	197
20		107	0	23	84	400	484					
21		84	0	5	79	400	479					
22		79	0	33	46	400	446					
23	6	46	203	38	211	197	408	186	504	132	186	186
24		211	0		211	383	594					
25		211	0	14	197	383	580					
26		197	0	32	165	383	548					
27	7	165	0	40	125	383	508	179	497	139	179	
28		125	197	220	102	186	288					
29		102	0	233	-131	186	55					
30		-131	0		-131	186	55					
31		-131	0	35	-166	186	20					
32	8	-166	186	85	-65	0	-65	207	614	200	207	207
33		-65	0	11	-76	207	131					
34		-76	0	33	-109	207	98					
35		-109	0	100	-209	207	-2					
36	9	-209	0	37	-246	207	-39	203	595	189	203	203
37		-246	0		-246	410	164					
38		-246	0	88	-334	410	76					
39		-334	0	20	-354	410	56					
40	10	-354	0		-354	410	56	207	598	184	207	207
41		-354	207	75	-222	410	188					
42		-222	0	49	-271	410	139					
43		-271	0	91	-362	410	48					
44	11	-362	0		-362	410	48	208	595	179	208	208
45		-362	203	50	-209	415	206					
46		-209	0	10	-219	415	196					
47		-219	0	6	-225	415	190					
48	12	-225	0	23	-248	415	167	195	573	183	195	195
49		-248	207	20	-61	403	342					
50		-61	0	39	-100	403	303					
51		-100	0	49	-149	403	254					
52		-149	0		-149	403	254					

	Jul-05	Aug-05	Sep-05	Oct-05	Nov-05	Dec-05	Jan-06	Feb-06	Mar-06	Apr-06	May-06	Jun-06	Jul-06	Aug-06	Sep-06	Oct-06	Nov-06	Dec-06
DEMAND	110	88	351	184	94	201	330	316	91	135	82	105	493	164	245	215	66	120
AVERAGE							171	208	246	203	195	193	177	204	178	204	217	215
							50007	63354	51954	53687	57518	60050	66098	138279	123383	116248	110541	115085
							8335	10559	8659	8948	9586	10008	11016	23047	20564	19375	18424	19181
SD							91.29	102.76	93.05	94.59	97.91	100.04	104.96	151.81	143.40	139.19	135.73	138.50

ORDER QUANTITY SIMULATION: CURRENT SYSTEM
P/NO: AA00005

Wk	Month	Stock OHO	Dlry Qty	Order Qty	Stock OHC	Stock On order	OSD Stock	Forecast Qty	ROP	SS	Q*	PO Qty
1	1	241		45	196		196	106	241	29	106	106
2		196		40	156	106	262					
3		156		28	128	106	234					
4		128		5	123	106	229					
5		123		46	77	106	183					
6	2	77		23	54	106	160	109	246	28	109	109
7		54		31	23	215	238					
8		23		122	-99	215	116					
9		-99		38	-137	215	78					
10	3	-137	106	70	-101	109	8	154	372	64	154	154
11		-101	0	10	-111	263	152					
12		-111	0	30	-141	263	122					
13		-141	0		-141	263	122					
14	4	-141	0		-141	263	122	148	359	63	148	148
15		-141	109	40	-72	302	230					
16		-72	0	8	-80	302	222					
17		-80	0	60	-140	302	162					
18		-140	0	7	-147	302	155					
19	5	-147	154	67	-60	148	88	133	331	65	133	133
20		-60	0	61	-121	281	160					
21		-121	0	67	-188	281	93					
22		-188	0	11	-199	281	82					
23	6	-199	148	55	-106	133	27	162	399	75	162	162
24		-106	0		-106	295	189					
25		-106	0	45	-151	295	144					
26		-151	0	7	-158	295	137					
27	7	-158	0	57	-215	295	80	142	352	68	142	142
28		-215	133	366	-448	304	-144					
29		-448	0	66	-514	304	-210					
30		-514	0	13	-527	304	-223					
31		-527	0	38	-565	304	-261					
32	8	-565	162	51	-454	142	-312	282	755	191	282	282
33		-454	0		-454	424	-30					
34		-454	0	30	-484	424	-60					
35		-484	0		-484	424	-60					
36	9	-484	142	15	-357	282	-75	214	628	200	214	214
37		-357	0		-357	496	139					
38		-357	0	50	-407	496	89					
39		-407	0	14	-421	496	75					
40	10	-421	0		-421	496	75	161	531	209	161	161
41		-421	282	8	-147	375	228					
42		-147	0	5	-152	375	223					
43		-152	0	37	-189	375	186					
44	11	-189	0		-189	375	186	125	465	215	125	125
45		-189	214		25	286	311					
46		25	0	54	-29	286	257					
47		-29	0	6	-35	286	251					
48	12	-35	0	15	-50	286	236	101	423	221	101	101
49		-50	161	37	74	226	300					
50		74	0		74	226	300					
51		74	0		74	226	300					
52		74	0		74	226	300					

	Jul-05	Aug-05	Sep-05	Oct-05	Nov-05	Dec-05	Jan-06	Feb-06	Mar-06	Apr-06	May-06	Jun-06	Jul-06	Aug-06	Sep-06	Oct-06	Nov-06	Dec-06
DEMAND	131	145	112	129	121	76	118	234	136	108	213	107	525	96	68	61	60	52
AVERAGE							119	117	132	136	132	148	153	221	198	186	178	153
							2822	2651	14265	13801	14449	19448	15815	125638	137782	149999	159187	168087
							470	442	2378	2300	2408	3241	2636	20940	22964	25000	26531	28014
SD							21.69	21.02	48.76	47.96	49.07	56.93	51.34	144.71	151.54	158.11	162.88	167.38

ORDER QUANTITY SIMULATION: CURRENT SYSTEM
P/NO: AA00006

Wk	Month	Stock OHO	Dlry Qty	Order Qty	Stock OHC	Stock On order	OSD Stock	Forecast Qty	ROP	SS	Q*	PO Qty
1	1	209		30	179		179	90	209	29	90	90
2		179		20	159	90	249					
3		159			159	90	249					
4		159		30	129	90	219					
5		129			129	90	219					
6	2	129		50	79	90	169	88	204	28	88	88
7		79			79	178	257					
8		79		30	49	178	227					
9		49		40	9	178	187					
10	3	9	90	30	69	88	157	94	252	64	94	94
11		69	0	31	38	182	220					
12		38	0	38	-0	182	182					
13		-0	0	70	-70	182	112					
14	4	-70	0	100	-170	182	12	107	277	63	107	107
15		-170	88	44	-126	201	75					
16		-126	0	40	-166	201	35					
17		-166	0	50	-216	201	-15					
18		-216	0	40	-256	201	-55					
19	5	-256	94	8	-170	107	-63	130	325	65	130	130
20		-170	0	8	-178	237	59					
21		-178	0		-178	237	59					
22		-178	0		-178	237	59					
23	6	-178	107	100	-171	130	-41	117	309	75	117	117
24		-171	0		-171	247	76					
25		-171	0		-171	247	76					
26		-171	0		-171	247	76					
27	7	-171	0	201	-372	247	-125	114	296	68	114	114
28		-372	130	9	-251	231	-20					
29		-251	0		-251	231	-20					
30		-251	0		-251	231	-20					
31		-251	0	101	-352	231	-121					
32	8	-352	117	6	-241	114	-127	131	453	191	131	131
33		-241	0		-241	245	4					
34		-241	0		-241	245	4					
35		-241	0	100	-341	245	-96					
36	9	-341	114		-227	131	-96	127	454	200	127	127
37		-227	0		-227	258	31					
38		-227	0		-227	258	31					
39		-227	0		-227	258	31					
40	10	-227	0		-227	258	31	122	453	209	122	122
41		-227	131		-96	249	153					
42		-96	0		-96	249	153					
43		-96	0	11	-107	249	142					
44	11	-107	0		-107	249	142	103	421	215	103	103
45		-107	127	60	-40	225	185					
46		-40	0	1	-41	225	184					
47		-41	0	59	-100	225	125					
48	12	-100	0	12	-112	225	113	106	433	221	106	106
49		-112	122	51	-41	209	168					
50		-41	0		-41	209	168					
51		-41	0	23	-64	209	145					
52		-64	0		-64	209	145					

	Jul-05	Aug-05	Sep-05	Oct-05	Nov-05	Dec-05	Jan-06	Feb-06	Mar-06	Apr-06	May-06	Jun-06	Jul-06	Aug-06	Sep-06	Oct-06	Nov-06	Dec-06
DEMAND	131	145	112	129	121	76	118	234	136	108	213	107	525	96	68	61	60	52
AVERAGE							119	117	132	136	132	148	153	221	198	186	178	153
							2822	2651	14265	13801	14449	19448	15815	125638	137782	149999	159187	168087
							470	442	2378	2300	2408	3241	2636	20940	22964	25000	26531	28014
SD							21.69	21.02	48.76	47.96	49.07	56.93	51.34	144.71	151.54	158.11	162.88	167.38

ORDER QUANTITY SIMULATION: CURRENT SYSTEM
P/NO: AA00007

Wk	Month	Stock OHO	Dlry Qty	Order Qty	Stock OHC	Stock On order	OSD Stock	Forecast Qty	ROP	SS	Q*	PO Qty
1	1	3011		376	2635		2635	1083	2571	405	1083	
2		2635			2635	0	2635					
3		2635		335	2300	0	2300					
4		2300			2300	0	2300					
5		2300		300	2000	0	2000					
6	2	2000		412	1588	0	1588	1070	2515	375	1070	1070
7		1588		55	1533	1070	2603					
8		1533		300	1233	1070	2303					
9		1233		702	531	1070	1601					
10	3	531	0	508	23	1070	1093	1140	2689	409	1140	1140
11		23	0	333	-310	2210	1900					
12		-310	0	79	-389	2210	1821					
13		-389	0	46	-435	2210	1775					
14	4	-435	0	371	-806	2210	1404	1122	2631	387	1122	1122
15		-806	1070		264	2262	2526					
16		264	0	402	-138	2262	2124					
17		-138	0	34	-172	2262	2090					
18		-172	0	398	-570	2262	1692					
19	5	-570	1140	60	510	1122	1632	1059	2432	314	1059	1059
20		510	0	582	-72	2181	2109					
21		-72	0	2	-74	2181	2107					
22		-74	0	526	-600	2181	1581					
23	6	-600	1122	595	-73	1059	986	1165	2742	412	1165	1165
24		-73	0	30	-103	2224	2121					
25		-103	0	345	-448	2224	1776					
26		-448	0	346	-794	2224	1430					
27	7	-794	0	300	-1094	2224	1130	1198	2740	344	1198	1198
28		-1094	1059	50	-85	2363	2278					
29		-85	0	444	-529	2363	1834					
30		-529	0	300	-829	2363	1534					
31		-829	0	207	-1036	2363	1327					
32	8	-1036	1165	300	-171	1198	1027	1197	2723	329	1197	1197
33		-171	0	64	-235	2395	2160					
34		-235	0	417	-652	2395	1743					
35		-652	0	478	-1130	2395	1265					
36	9	-1130	1198	20	48	1197	1245	1138	2615	339	1138	1138
37		48	0	305	-257	2335	2078					
38		-257	0	261	-518	2335	1817					
39		-518	0	460	-978	2335	1357					
40	10	-978	0	37	-1015	2335	1320	1158	2651	335	1158	1158
41		-1015	1197	930	-748	2296	1548					
42		-748	0	166	-914	2296	1382					
43		-914	0	22	-936	2296	1360					
44	11	-936	0	539	-1475	2296	821	1219	2718	280	1219	1219
45		-1475	1138	600	-937	2377	1440					
46		-937	0	90	-1027	2377	1350					
47		-1027	0	124	-1151	2377	1226					
48	12	-1151	0	500	-1651	2377	726	1249	2728	230	1249	1249
49		-1651	1158	256	-749	2468	1719					
50		-749	0	662	-1411	2468	1057					
51		-1411	0		-1411	2468	1057					
52		-1411	0		-1411	2468	1057					

	Jul-05	Aug-05	Sep-05	Oct-05	Nov-05	Dec-05	Jan-06	Feb-06	Mar-06	Apr-06	May-06	Jun-06	Jul-06	Aug-06	Sep-06	Oct-06	Nov-06	Dec-06
DEMAND	773	1124	868	1591	1193	680	1011	1404	1031	807	1568	1316	1181	901	1224	1452	1356	1418
AVERAGE							1038	1078	1125	1152	1021	1084	1190	1218	1134	1166	1274	1238
							564519	485503	576690	515211	338550	584738	408566	371959	395516	386799	270161	182817
							94086	80917	96115	85869	56425	97456	68094	61993	65919	64466	45027	30470
SD							306.74	284.46	310.02	293.03	237.54	312.18	260.95	248.98	256.75	253.90	212.20	174.56

ORDER QUANTITY SIMULATION: CURRENT SYSTEM
P/NO: AA00008

Wk	Month	Stock OHO	Dlry Qty	Order Qty	Stock OHC	Stock On order	OSD Stock	Forecast Qty	ROP	SS	Q*	PO Qty
1	1	188			188		188	89	205	27	89	89
2		188		11	177	89	266					
3		177			177	89	266					
4		177			177	89	266					
5		177		25	152	89	241					
6	2	152			152	89	241	90	213	33	90	
7		152		4	148	89	237					
8		148		19	129	89	218					
9		129		21	108	89	197					
10	3	108	89	11	186	0	186	90	211	31	90	90
11		186	0	2	184	90	274					
12		184	0		184	90	274					
13		184	0	29	155	90	245					
14	4	155	0	25	130	90	220	85	205	35	85	
15		130	0	50	80	90	170					
16		80	0	40	40	90	130					
17		40	0	33	7	90	97					
18		7	0	30	-23	90	67					
19	5	-23	90	10	57	0	57	91	228	46	91	91
20		57	0	53	4	91	95					
21		4	0	20	-16	91	75					
22		-16	0	25	-41	91	50					
23	6	-41	0	7	-48	91	43	96	246	54	96	96
24		-48	0	20	-68	187	119					
25		-68	0	9	-77	187	110					
26		-77	0	15	-92	187	95					
27	7	-92	0	29	-121	187	66	90	237	57	90	90
28		-121	91	3	-33	186	153					
29		-33	0		-33	186	153					
30		-33	0	58	-91	186	95					
31		-91	0	11	-102	186	84					
32	8	-102	96	10	-16	90	74	91	236	54	91	91
33		-16	0		-16	181	165					
34		-16	0	7	-23	181	158					
35		-23	0	6	-29	181	152					
36	9	-29	90	41	20	91	111	95	252	62	95	95
37		20	0	4	16	186	202					
38		16	0		16	186	202					
39		16	0	5	11	186	197					
40	10	11	0	15	-4	186	182	80	220	60	80	80
41		-4	91		87	175	262					
42		87	0	29	58	175	233					
43		58	0	3	55	175	230					
44	11	55	0	5	50	175	225	77	204	50	77	0
45		50	95		145	80	225					
46		145	0	30	115	80	195					
47		115	0	8	107	80	187					
48	12	107	0		107	80	187	74	178	30	74	0
49		107	80	54	133	0	133					
50		133	0		133	0	133					
51		133	0		133	0	133					
52		133	0		133	0	133					

	Jul-05	Aug-05	Sep-05	Oct-05	Nov-05	Dec-05	Jan-06	Feb-06	Mar-06	Apr-06	May-06	Jun-06	Jul-06	Aug-06	Sep-06	Oct-06	Nov-06	Dec-06
DEMAND	75	113	92	123	63	87	52	69	42	148	138	51	101	27	55	47	43	54
AVERAGE							92	88	81	73	77	89	83	92	85	87	70	54
							2557	3787	3230	4213	7251	9863	11111	10042	13402	12437	8549	3118
							426	631	538	702	1208	1644	1852	1674	2234	2073	1425	520
SD							20.64	25.12	23.20	26.50	34.76	40.54	43.03	40.91	47.26	45.53	37.75	22.80

ORDER QUANTITY SIMULATION: CURRENT SYSTEM
P/NO: AA00009

Wk	Month	Stock OHO	Dlry Qty	Order Qty	Stock OHC	Stock On order	OSD Stock	Forecast Qty	ROP	SS	Q*	PO Qty
1	1	4991		1	4990		4990	1659	4244	926	1659	
2		4990		343	4647	0	4647					
3		4647		800	3847	0	3847					
4		3847		101	3746	0	3746					
5		3746		290	3456	0	3456					
6	2	3456		220	3236	0	3236	1574	4077	929	1574	1574
7		3236		895	2341	1574	3915					
8		2341		104	2237	1574	3811					
9		2237		1340	897	1574	2471					
10	3	897	0	244	653	1574	2227	1864	4731	1003	1864	1864
11		653	0	1419	-766	3438	2672					
12		-766	0	200	-966	3438	2472					
13		-966	0	130	-1096	3438	2342					
14	4	-1096	0	100	-1196	3438	2242	1920	4843	1003	1920	1920
15		-1196	1574	101	277	3784	4061					
16		277	0	1232	-955	3784	2829					
17		-955	0	106	-1061	3784	2723					
18		-1061	0	330	-1391	3784	2393					
19	5	-1391	1864	519	-46	1920	1874	1820	4454	814	1820	1820
20		-46	0	450	-496	3740	3244					
21		-496	0	1125	-1621	3740	2119					
22		-1621	0	297	-1918	3740	1822					
23	6	-1918	1920	701	-699	1820	1121	2057	5072	958	2057	2057
24		-699	0		-699	3877	3178					
25		-699	0	206	-905	3877	2972					
26		-905	0	818	-1723	3877	2154					
27	7	-1723	0	137	-1860	3877	2017	1970	4645	705	1970	1970
28		-1860	1820	632	-672	4027	3355					
29		-672	0	**1392**	-2064	4027	1963					
30		-2064	0	447	-2511	4027	1516					
31		-2511	0	874	-3385	4027	642					
32	8	-3385	2057	131	-1459	1970	511	2240	5195	715	2240	2240
33		-1459	0		-1459	4210	2751					
34		-1459	0	**1134**	-2593	4210	1617					
35		-2593	0	740	-3333	4210	877					
36	9	-3333	1970	90	-1453	2240	787	2120	4950	710	2120	2120
37		-1453	0	1005	-2458	4360	1902					
38		-2458	0	137	-2595	4360	1765					
39		-2595	0	201	-2796	4360	1564					
40	10	-2796	0	15	-2811	4360	1549	2092	4896	712	2092	2092
41		-2811	2240	1010	-1581	4212	2631					
42		-1581	0	135	-1716	4212	2496					
43		-1716	0	553	-2269	4212	1943					
44	11	-2269	0	1300	-3569	4212	643	2025	4703	653	2025	2025
45		-3569	2120	514	-1963	4117	2154					
46		-1963	0	697	-2660	4117	1457					
47		-2660	0	1230	-3890	4117	227					
48	12	-3890	0	330	-4220	4117	-103	2480	5963	1003	2480	2480
49		-4220	2092	2570	-4698	4505	-193					
50		-4698	0		-4698	4505	-193					
51		-4698	0		-4698	4505	-193					
52		-4698	0		-4698	4505	-193					

	Jul-05	Aug-05	Sep-05	Oct-05	Nov-05	Dec-05	Jan-06	Feb-06	Mar-06	Apr-06	May-06	Jun-06	Jul-06	Aug-06	Sep-06	Oct-06	Nov-06	Dec-06
DEMAND	2022	1181	1744	2950	1909	707	1335	2674	2078	1539	2721	1725	2996	1784	2014	1839	3751	2890
AVERAGE							1752	1638	1887	1942	1707	1842	2012	2289	2141	2130	2180	2352
							2950883	2973439	3467374	3465147	2280142	3157643	1709708	1759815	1734302	1745715	1466215	3465102
							491814	495573	577896	577524	380024	526274	284951	293302	289050	290952	244369	577517
SD							701.29	703.97	760.19	759.95	616.46	725.45	533.81	541.57	537.63	539.40	494.34	759.95

Appendix E:
Ordering system
(Reorder Point Model)

ORDER QUANTITY SIMULATION: REORDER POINT (Q*)
P/NO: AA00001

Wk	Month	Stock OHO	Dlry Qty	Order Qty	Stock OHC	Stock On order	OSD Stock	ROP	Q*	PO Qty
1	1	4185			4185		4185	4185	569	0
2	1	4185			4185	0	4185	4185	569	0
3	1	4185		500	3685	0	3685	4185	569	569
4	1	3685		500	3185	569	3754	4185	569	569
5	1	3185		50	3135	1138	4273	4185	569	0
6	2	3135			3135	1138	4273	4185	569	0
7	2	3135		60	3075	1138	4213	4185	569	0
8	2	3075		1300	1775	1138	2913	4185	569	569
9	2	1775			1775	1707	3482	4185	569	569
10	3	1775	0	844	931	2276	3207	4185	569	569
11	3	931	0	38	893	2845	3738	4185	569	569
12	3	893	569	1000	462	2845	3307	4185	569	569
13	3	462	569		1031	2845	3876	4185	569	569
14	4	1031	0		1031	3414	4445	4185	569	0
15	4	1031	0	68	963	3414	4377	4185	569	0
16	4	963	0	1338	-375	3414	3039	4185	569	569
17	4	-375	569	34	160	3414	3574	4185	569	569
18	4	160	569		729	3414	4143	4185	569	569
19	5	729	569	295	1003	3414	4417	4185	569	0
20	5	1003	569	460	1112	2845	3957	4185	569	569
21	5	1112	569	1000	681	2845	3526	4185	569	569
22	5	681	569	10	1240	2845	4085	4185	569	569
23	6	1240	0	55	1185	3414	4599	4185	569	0
24	6	1185	0		1185	3414	4599	4185	569	0
25	6	1185	569	60	1694	2845	4539	4185	569	0
26	6	1694	569	1000	1263	2276	3539	4185	569	569
27	7	1263	569		1832	2276	4108	4185	569	569
28	7	1832	0	300	1532	2845	4377	4185	569	0
29	7	1532	569	17	2084	2276	4360	4185	569	0
30	7	2084	569	154	2499	1707	4206	4185	569	0
31	7	2499	569	1302	1766	1138	2904	4185	569	569
32	8	1766	0	150	1616	1707	3323	4185	569	569
33	8	1616	0		1616	2276	3892	4185	569	569
34	8	1616	0	1000	616	2845	3461	4185	569	569
35	8	616	569	13	1172	2845	4017	4185	569	569
36	9	1172	569	360	1381	2845	4226	4185	569	0
37	9	1381	0	1000	381	2845	3226	4185	569	569
38	9	381	0	11	370	3414	3784	4185	569	569
39	9	370	0	19	351	3983	4334	4185	569	0
40	10	351	569		920	3414	4334	4185	569	0
41	10	920	569	1696	-207	2845	2638	4185	569	569
42	10	-207	569	150	212	2845	3057	4185	569	569
43	10	212	569	40	741	2845	3586	4185	569	569
44	11	741	569		1310	2845	4155	4185	569	569
45	11	1310	0		1310	3414	4724	4185	569	0
46	11	1310	569	7892	-6013	2845	-3168	4185	569	569
47	11	-6013	569	80	-5524	2845	-2679	4185	569	569
48	12	-5524	0	1450	-6974	3414	-3560	4185	569	569
49	12	-6974	0	2283	-9257	3983	-5274	4185	569	569
50	12	-9257	569	520	-9208	3983	-5225	4185	569	569
51	12	-9208	569		-8639	3983	-4656	4185	569	569
52	12	-8639	569		-8070	3983	-4087	4185	569	569

ORDER QUANTITY SIMULATION: REORDER POINT (Q*)

P/NO: AA00002

Wk	Month	Stock OHO	Dlry Qty	Order Qty	Stock OHC	Stock On order	OSD Stock	ROP	Q*	PO Qty
1	1	338			338		338	338	91	0
2	1	338		40	298	0	298	338	91	91
3	1	298		14	284	91	375	338	91	0
4	1	284			284	91	375	338	91	0
5	1	284			284	91	375	338	91	0
6	2	284			284	91	375	338	91	0
7	2	284		11	273	91	364	338	91	0
8	2	273			273	91	364	338	91	0
9	2	273		72	201	91	292	338	91	91
10	3	201	0	110	91	182	273	338	91	91
11	3	91	91		182	182	364	338	91	0
12	3	182	0	95	87	182	269	338	91	91
13	3	87	0	25	62	273	335	338	91	91
14	4	62	0		62	364	426	338	91	0
15	4	62	0	120	-58	364	306	338	91	91
16	4	-58	0	24	-82	455	373	338	91	0
17	4	-82	0	13	-95	455	360	338	91	0
18	4	-95	91		-4	364	360	338	91	0
19	5	-4	91	60	27	273	300	338	91	91
20	5	27	0	60	-33	364	331	338	91	91
21	5	-33	91	14	44	364	408	338	91	0
22	5	44	91	16	119	273	392	338	91	0
23	6	119	0	43	76	273	349	338	91	0
24	6	76	91		167	182	349	338	91	0
25	6	167	0	1	166	182	348	338	91	0
26	6	166	0	23	143	182	325	338	91	91
27	7	143	0		143	273	416	338	91	0
28	7	143	91	172	62	182	244	338	91	91
29	7	62	91	6	147	182	329	338	91	91
30	7	147	0	3	144	273	417	338	91	0
31	7	144	0	35	109	273	382	338	91	0
32	8	109	0	15	94	273	367	338	91	0
33	8	94	0		94	273	367	338	91	0
34	8	94	0	15	79	273	352	338	91	0
35	8	79	91	9	161	182	343	338	91	0
36	9	161	0	10	151	182	333	338	91	91
37	9	151	91		242	182	424	338	91	0
38	9	242	91		333	91	424	338	91	0
39	9	333	0	14	319	91	410	338	91	0
40	10	319	0	5	314	91	405	338	91	0
41	10	314	0	3	311	91	402	338	91	0
42	10	311	0	6	305	91	396	338	91	0
43	10	305	0	78	227	91	318	338	91	91
44	11	227	0	16	211	182	393	338	91	0
45	11	211	91	90	212	91	303	338	91	91
46	11	212	0	6	206	182	388	338	91	0
47	11	206	0	26	180	182	362	338	91	0
48	12	180	0	12	168	182	350	338	91	0
49	12	168	0	68	100	182	282	338	91	91
50	12	100	0	10	90	273	363	338	91	0
51	12	90	0	5	85	273	358	338	91	0
52	12	85	91		176	182	358	338	91	0

ORDER QUANTITY SIMULATION: REORDER POINT (Q*)

P/NO: AA00003

Wk	Month	Stock OHO	Dlry Qty	Order Qty	Stock OHC	Stock On order	OSD Stock	ROP	Q*	PO Qty
1	1	1210			1210		1210	1210	258	0
2	1	1210		101	1109	0	1109	1210	258	258
3	1	1109		40	1069	258	1327	1210	258	0
4	1	1069		60	1009	258	1267	1210	258	0
5	1	1009		46	963	258	1221	1210	258	0
6	2	963		59	904	258	1162	1210	258	258
7	2	904		355	549	516	1065	1210	258	258
8	2	549		108	441	774	1215	1210	258	0
9	2	441		24	417	774	1191	1210	258	258
10	3	417	0	399	18	1032	1050	1210	258	258
11	3	18	258	114	162	1032	1194	1210	258	258
12	3	162	0	50	112	1290	1402	1210	258	0
13	3	112	0	67	45	1290	1335	1210	258	0
14	4	45	0		45	1290	1335	1210	258	0
15	4	45	258		303	1032	1335	1210	258	0
16	4	303	258	381	180	774	954	1210	258	258
17	4	180	0	86	94	1032	1126	1210	258	258
18	4	94	258	51	301	1032	1333	1210	258	0
19	5	301	258	78	481	774	1255	1210	258	0
20	5	481	258	132	607	516	1123	1210	258	258
21	5	607	0		607	774	1381	1210	258	0
22	5	607	0	24	583	774	1357	1210	258	0
23	6	583	0	740	-157	774	617	1210	258	258
24	6	-157	0		-157	1032	875	1210	258	258
25	6	-157	258	54	47	1032	1079	1210	258	258
26	6	47	258	24	281	1032	1313	1210	258	0
27	7	281	0	520	-239	1032	793	1210	258	258
28	7	-239	0	149	-388	1290	902	1210	258	258
29	7	-388	258	77	-207	1290	1083	1210	258	258
30	7	-207	0	132	-339	1548	1209	1210	258	258
31	7	-339	0	583	-922	1806	884	1210	258	258
32	8	-922	258	60	-724	1806	1082	1210	258	258
33	8	-724	258		-466	1806	1340	1210	258	0
34	8	-466	258	40	-248	1548	1300	1210	258	0
35	8	-248	0	661	-909	1548	639	1210	258	258
36	9	-909	258	36	-687	1548	861	1210	258	258
37	9	-687	258		-429	1548	1119	1210	258	258
38	9	-429	258	211	-382	1548	1166	1210	258	258
39	9	-382	258	14	-138	1548	1410	1210	258	0
40	10	-138	258	70	50	1290	1340	1210	258	0
41	10	50	258	55	253	1032	1285	1210	258	0
42	10	253	0	55	198	1032	1230	1210	258	0
43	10	198	0	32	166	1032	1198	1210	258	258
44	11	166	258		424	1032	1456	1210	258	0
45	11	424	258	178	504	774	1278	1210	258	0
46	11	504	258	81	681	516	1197	1210	258	258
47	11	681	258	104	835	516	1351	1210	258	0
48	12	835	0	43	792	516	1308	1210	258	0
49	12	792	0	337	455	516	971	1210	258	258
50	12	455	0		455	774	1229	1210	258	0
51	12	455	0		455	774	1229	1210	258	0
52	12	455	258		713	516	1229	1210	258	0

ORDER QUANTITY SIMULATION: REORDER POINT (Q*)

P/NO: AA00004

Wk	Month	Stock OHO	Dlry Qty	Order Qty	Stock OHC	Stock On order	OSD Stock	ROP	Q*	PO Qty
1	1	603		100	503		503	603	202	202
2	1	503		190	313	202	515	603	202	202
3	1	313		35	278	404	682	603	202	0
4	1	278		5	273	404	677	603	202	0
5	1	273		85	188	404	592	603	202	202
6	2	188		97	91	606	697	603	202	0
7	2	91		38	53	606	659	603	202	0
8	2	53		5	48	606	654	603	202	0
9	2	48		117	-69	606	537	603	202	202
10	3	-69	202		133	606	739	603	202	0
11	3	133	202		335	404	739	603	202	0
12	3	335	0	65	270	404	674	603	202	0
13	3	270	0		270	404	674	603	202	0
14	4	270	202	6	466	202	668	603	202	0
15	4	466	0		466	202	668	603	202	0
16	4	466	0	64	402	202	604	603	202	0
17	4	402	0	65	337	202	539	603	202	202
18	4	337	202	16	523	202	725	603	202	0
19	5	523	0	26	497	202	699	603	202	0
20	5	497	0	23	474	202	676	603	202	0
21	5	474	0	5	469	202	671	603	202	0
22	5	469	0	33	436	202	638	603	202	0
23	6	436	0	38	398	202	600	603	202	202
24	6	398	0		398	404	802	603	202	0
25	6	398	0	14	384	404	788	603	202	0
26	6	384	202	32	554	202	756	603	202	0
27	7	554	0	40	514	202	716	603	202	0
28	7	514	0	220	294	202	496	603	202	202
29	7	294	0	233	61	404	465	603	202	202
30	7	61	0		61	606	667	603	202	0
31	7	61	0	35	26	606	632	603	202	0
32	8	26	202	85	143	404	547	603	202	202
33	8	143	0	11	132	606	738	603	202	0
34	8	132	0	33	99	606	705	603	202	0
35	8	99	0	100	-1	606	605	603	202	0
36	9	-1	0	37	-38	606	568	603	202	202
37	9	-38	202		164	606	770	603	202	0
38	9	164	202	88	278	404	682	603	202	0
39	9	278	0	20	258	404	662	603	202	0
40	10	258	0		258	404	662	603	202	0
41	10	258	202	75	385	202	587	603	202	202
42	10	385	0	49	336	404	740	603	202	0
43	10	336	0	91	245	404	649	603	202	0
44	11	245	0		245	404	649	603	202	0
45	11	245	202	50	397	202	599	603	202	202
46	11	397	0	10	387	404	791	603	202	0
47	11	387	0	6	381	404	785	603	202	0
48	12	381	0	23	358	404	762	603	202	0
49	12	358	0	20	338	404	742	603	202	0
50	12	338	202	39	501	202	703	603	202	0
51	12	501	0	49	452	202	654	603	202	0
52	12	452	0		452	202	654	603	202	0

ORDER QUANTITY SIMULATION: REORDER POINT (Q*)

P/NO: AA00005

Wk	Month	Stock OHO	Dlry Qty	Order Qty	Stock OHC	Stock On order	OSD Stock	ROP	Q*	PO Qty
1	1	348		45	303		303	348	88	88
2	1	303		40	263	88	351	348	88	0
3	1	263		28	235	88	323	348	88	88
4	1	235		5	230	176	406	348	88	0
5	1	230		46	184	176	360	348	88	0
6	2	184		23	161	176	337	348	88	88
7	2	161		31	130	264	394	348	88	0
8	2	130		122	8	264	272	348	88	88
9	2	8		38	-30	352	322	348	88	88
10	3	-30	88	70	-12	352	340	348	88	88
11	3	-12	0	10	-22	440	418	348	88	0
12	3	-22	88	30	36	352	388	348	88	0
13	3	36	0		36	352	388	348	88	0
14	4	36	0		36	352	388	348	88	0
15	4	36	88	40	84	264	348	348	88	0
16	4	84	0	8	76	264	340	348	88	88
17	4	76	88	60	104	264	368	348	88	0
18	4	104	88	7	185	176	361	348	88	0
19	5	185	88	67	206	88	294	348	88	88
20	5	206	0	61	145	176	321	348	88	88
21	5	145	0	67	78	264	342	348	88	88
22	5	78	0	11	67	352	419	348	88	0
23	6	67	0	55	12	352	364	348	88	0
24	6	12	0		12	352	364	348	88	0
25	6	12	88	45	55	264	319	348	88	88
26	6	55	0	7	48	352	400	348	88	0
27	7	48	0	57	-9	352	343	348	88	88
28	7	-9	88	366	-287	352	65	348	88	88
29	7	-287	88	66	-265	352	87	348	88	88
30	7	-265	88	13	-190	352	162	348	88	88
31	7	-190	0	38	-228	440	212	348	88	88
32	8	-228	0	51	-279	528	249	348	88	88
33	8	-279	0		-279	616	337	348	88	88
34	8	-279	88	30	-221	616	395	348	88	0
35	8	-221	0		-221	616	395	348	88	0
36	9	-221	88	15	-148	528	380	348	88	0
37	9	-148	88		-60	440	380	348	88	0
38	9	-60	88	50	-22	352	330	348	88	88
39	9	-22	88	14	52	352	404	348	88	0
40	10	52	88		140	264	404	348	88	0
41	10	140	88	8	220	176	396	348	88	0
42	10	220	88	5	303	88	391	348	88	0
43	10	303	0	37	266	88	354	348	88	0
44	11	266	0		266	88	354	348	88	0
45	11	266	0		266	88	354	348	88	0
46	11	266	0	54	212	88	300	348	88	88
47	11	212	88	6	294	88	382	348	88	0
48	12	294	0	15	279	88	367	348	88	0
49	12	279	0	37	242	88	330	348	88	88
50	12	242	0		242	176	418	348	88	0
51	12	242	0		242	176	418	348	88	0
52	12	242	0		242	176	418	348	88	0

ORDER QUANTITY SIMULATION: REORDER POINT (Q*)

P/NO: AA00006

Wk	Month	Stock OHO	Dlry Qty	Order Qty	Stock OHC	Stock On order	OSD STOCK	ROP	Q*	PO Qty
1	1	320		30	290		290	320	35	35
2	1	290		20	270	35	305	320	35	35
3	1	270			270	70	340	320	35	0
4	1	270		30	240	70	310	320	35	35
5	1	240			240	105	345	320	35	0
6	2	240		50	190	105	295	320	35	35
7	2	190			190	140	330	320	35	0
8	2	190		30	160	140	300	320	35	35
9	2	160		40	120	175	295	320	35	35
10	3	120	35	30	125	175	300	320	35	35
11	3	125	35	31	129	175	304	320	35	35
12	3	129	0	38	91	210	301	320	35	35
13	3	91	35	70	56	210	266	320	35	35
14	4	56	0	100	-44	245	201	320	35	35
15	4	-44	35	44	-53	245	192	320	35	35
16	4	-53	0	40	-93	280	187	320	35	35
17	4	-93	35	50	-108	280	172	320	35	35
18	4	-108	35	40	-113	280	167	320	35	35
19	5	-113	35	8	-86	280	194	320	35	35
20	5	-86	35	8	-59	280	221	320	35	35
21	5	-59	35		-24	280	256	320	35	35
22	5	-24	35		11	280	291	320	35	35
23	6	11	35	100	-54	280	226	320	35	35
24	6	-54	35		-19	280	261	320	35	35
25	6	-19	35		16	280	296	320	35	35
26	6	16	35		51	280	331	320	35	0
27	7	51	35	201	-115	245	130	320	35	35
28	7	-115	35	9	-89	245	156	320	35	35
29	7	-89	35		-54	245	191	320	35	35
30	7	-54	35		-19	245	226	320	35	35
31	7	-19	35	101	-85	245	160	320	35	35
32	8	-85	35	6	-56	245	189	320	35	35
33	8	-56	35		-21	245	224	320	35	35
34	8	-21	35		14	245	259	320	35	35
35	8	14	0	100	-86	280	194	320	35	35
36	9	-86	35		-51	280	229	320	35	35
37	9	-51	35		-16	280	264	320	35	35
38	9	-16	35		19	280	299	320	35	35
39	9	19	35		54	280	334	320	35	0
40	10	54	35		89	245	334	320	35	0
41	10	89	35		124	210	334	320	35	0
42	10	124	35		159	175	334	320	35	0
43	10	159	35	11	183	140	323	320	35	0
44	11	183	35		218	105	323	320	35	0
45	11	218	35	60	193	70	263	320	35	35
46	11	193	35	1	227	70	297	320	35	35
47	11	227	35	59	203	70	273	320	35	35
48	12	203	0	12	191	105	296	320	35	35
49	12	191	0	51	140	140	280	320	35	35
50	12	140	0		140	175	315	320	35	35
51	12	140	0	23	117	210	327	320	35	0
52	12	117	0		117	210	327	320	35	0

ORDER QUANTITY SIMULATION: REORDER POINT (Q*)
P/NO: AA00007

Wk	Month	Stock OHO	Dlry Qty	Order Qty	Stock OHC	Stock On order	OSD Stock	ROP	Q*	PO Qty
1	1	3011		376	2635		2635	3139	392	392
2	1	2635			2635	392	3027	3139	392	392
3	1	2635		335	2300	784	3084	3139	392	392
4	1	2300			2300	1176	3476	3139	392	0
5	1	2300		300	2000	1176	3176	3139	392	0
6	2	2000		412	1588	1176	2764	3139	392	392
7	2	1588		55	1533	1568	3101	3139	392	392
8	2	1533		300	1233	1960	3193	3139	392	0
9	2	1233		702	531	1960	2491	3139	392	392
10	3	531	392	508	415	1960	2375	3139	392	392
11	3	415	392	333	474	1960	2434	3139	392	392
12	3	474	392	79	787	1960	2747	3139	392	392
13	3	787	0	46	741	2352	3093	3139	392	392
14	4	741	0	371	370	2744	3114	3139	392	392
15	4	370	392		762	2744	3506	3139	392	0
16	4	762	392	402	752	2352	3104	3139	392	392
17	4	752	0	34	718	2744	3462	3139	392	0
18	4	718	392	398	712	2352	3064	3139	392	392
19	5	712	392	60	1044	2352	3396	3139	392	0
20	5	1044	392	582	854	1960	2814	3139	392	392
21	5	854	392	2	1244	1960	3204	3139	392	0
22	5	1244	392	526	1110	1568	2678	3139	392	392
23	6	1110	392	595	907	1568	2475	3139	392	392
24	6	907	0	30	877	1960	2837	3139	392	392
25	6	877	392	345	924	1960	2884	3139	392	392
26	6	924	0	346	578	2352	2930	3139	392	392
27	7	578	392	300	670	2352	3022	3139	392	392
28	7	670	0	50	620	2744	3364	3139	392	0
29	7	620	392	444	568	2352	2920	3139	392	392
30	7	568	0	300	268	2744	3012	3139	392	392
31	7	268	392	207	453	2744	3197	3139	392	0
32	8	453	392	300	545	2352	2897	3139	392	392
33	8	545	392	64	873	2352	3225	3139	392	0
34	8	873	392	417	848	1960	2808	3139	392	392
35	8	848	392	478	762	1960	2722	3139	392	392
36	9	762	392	20	1134	1960	3094	3139	392	392
37	9	1134	0	305	829	2352	3181	3139	392	0
38	9	829	392	261	960	1960	2920	3139	392	392
39	9	960	392	460	892	1960	2852	3139	392	392
40	10	892	0	37	855	2352	3207	3139	392	0
41	10	855	392	930	317	1960	2277	3139	392	392
42	10	317	0	166	151	2352	2503	3139	392	392
43	10	151	392	22	521	2352	2873	3139	392	392
44	11	521	392	539	374	2352	2726	3139	392	392
45	11	374	392	600	166	2352	2518	3139	392	392
46	11	166	0	90	76	2744	2820	3139	392	392
47	11	76	392	124	344	2744	3088	3139	392	392
48	12	344	392	500	236	2744	2980	3139	392	392
49	12	236	0	256	-20	3136	3116	3139	392	392
50	12	-20	392	662	-290	3136	2846	3139	392	392
51	12	-290	392		102	3136	3238	3139	392	0
52	12	102	392		494	2744	3238	3139	392	0

ORDER QUANTITY SIMULATION: REORDER POINT (Q*)
P/NO: AA00008

Wk	Month	Stock OHO	Dlry Qty	Order Qty	Stock OHC	Stock On order	OSD Stock	ROP	Q*	PO Qty
1	1	188			188		188	179	229	0
2	1	188		52	136	0	136	179	229	229
3	1	136			136	229	365	179	229	0
4	1	136			136	229	365	179	229	0
5	1	136		25	111	229	340	179	229	0
6	2	111			111	229	340	179	229	0
7	2	111		4	107	229	336	179	229	0
8	2	107		19	88	229	317	179	229	0
9	2	88		21	67	229	296	179	229	0
10	3	67	0	11	56	229	285	179	229	0
11	3	56	229	2	283	0	283	179	229	0
12	3	283	0		283	0	283	179	229	0
13	3	283	0	29	254	0	254	179	229	0
14	4	254	0	25	229	0	229	179	229	0
15	4	229	0	50	179	0	179	179	229	0
16	4	179	0	40	139	0	139	179	229	229
17	4	139	0	33	106	229	335	179	229	0
18	4	106	0	30	76	229	305	179	229	0
19	5	76	0	10	66	229	295	179	229	0
20	5	66	0	53	13	229	242	179	229	0
21	5	13	0	20	-7	229	222	179	229	0
22	5	-7	0	25	-32	229	197	179	229	0
23	6	-32	0	7	-39	229	190	179	229	0
24	6	-39	0	20	-59	229	170	179	229	229
25	6	-59	229	9	161	229	390	179	229	0
26	6	161	0	15	146	229	375	179	229	0
27	7	146	0	29	117	229	346	179	229	0
28	7	117	0	3	114	229	343	179	229	0
29	7	114	0		114	229	343	179	229	0
30	7	114	0	58	56	229	285	179	229	0
31	7	56	0	11	45	229	274	179	229	0
32	8	45	0	10	35	229	264	179	229	0
33	8	35	229		264	0	264	179	229	0
34	8	264	0	7	257	0	257	179	229	0
35	8	257	0	6	251	0	251	179	229	0
36	9	251	0	41	210	0	210	179	229	0
37	9	210	0	4	206	0	206	179	229	0
38	9	206	0		206	0	206	179	229	0
39	9	206	0	5	201	0	201	179	229	0
40	10	201	0	15	186	0	186	179	229	0
41	10	186	0		186	0	186	179	229	0
42	10	186	0	29	157	0	157	179	229	229
43	10	157	0	3	154	229	383	179	229	0
44	11	154	0	5	149	229	378	179	229	0
45	11	149	0		149	229	378	179	229	0
46	11	149	0	30	119	229	348	179	229	0
47	11	119	0	8	111	229	340	179	229	0
48	12	111	0		111	229	340	179	229	0
49	12	111	0	54	57	229	286	179	229	0
50	12	57	0		57	229	286	179	229	0
51	12	57	229		286	0	286	179	229	0
52	12	286	0		286	0	286	179	229	0

ORDER QUANTITY SIMULATION: REORDER POINT (Q*)
P/NO: AA00009

Wk	Month	Stock OHO	Dlry Qty	Order Qty	Stock OHC	Stock On order	OSD Stock	ROP	Q*	PO Qty
1	1	4991		1	4990		4990	4874	900	0
2	1	4990		343	4647	0	4647	4874	900	900
3	1	4647		800	3847	900	4747	4874	900	900
4	1	3847		101	3746	1800	5546	4874	900	0
5	1	3746		290	3456	1800	5256	4874	900	0
6	2	3456		220	3236	1800	5036	4874	900	0
7	2	3236		895	2341	1800	4141	4874	900	900
8	2	2341		104	2237	2700	4937	4874	900	0
9	2	2237		1340	897	2700	3597	4874	900	900
10	3	897	0	244	653	3600	4253	4874	900	900
11	3	653	900	1419	134	3600	3734	4874	900	900
12	3	134	900	200	834	3600	4434	4874	900	900
13	3	834	0	130	704	4500	5204	4874	900	0
14	4	704	0	100	604	4500	5104	4874	900	0
15	4	604	0	101	503	4500	5003	4874	900	0
16	4	503	900	1232	171	3600	3771	4874	900	900
17	4	171	0	106	65	4500	4565	4874	900	900
18	4	65	900	330	635	4500	5135	4874	900	0
19	5	635	900	519	1016	3600	4616	4874	900	900
20	5	1016	900	450	1466	3600	5066	4874	900	0
21	5	1466	900	1125	1241	2700	3941	4874	900	900
22	5	1241	0	297	944	3600	4544	4874	900	900
23	6	944	0	701	243	4500	4743	4874	900	900
24	6	243	0		243	5400	5643	4874	900	0
25	6	243	900	206	937	4500	5437	4874	900	0
26	6	937	900	818	1019	3600	4619	4874	900	900
27	7	1019	0	137	882	4500	5382	4874	900	0
28	7	882	900	632	1150	3600	4750	4874	900	900
29	7	1150	0	1392	-242	4500	4258	4874	900	900
30	7	-242	900	447	211	4500	4711	4874	900	900
31	7	211	900	874	237	4500	4737	4874	900	900
32	8	237	900	131	1006	4500	5506	4874	900	0
33	8	1006	0		1006	4500	5506	4874	900	0
34	8	1006	0	1134	-128	4500	4372	4874	900	900
35	8	-128	900	740	32	4500	4532	4874	900	900
36	9	32	0	90	-58	5400	5342	4874	900	0
37	9	-58	900	1005	-163	4500	4337	4874	900	900
38	9	-163	900	137	600	4500	5100	4874	900	0
39	9	600	900	201	1299	3600	4899	4874	900	0
40	10	1299	900	15	2184	2700	4884	4874	900	0
41	10	2184	0	1010	1174	2700	3874	4874	900	900
42	10	1174	0	135	1039	3600	4639	4874	900	900
43	10	1039	900	553	1386	3600	4986	4874	900	0
44	11	1386	900	1300	986	2700	3686	4874	900	900
45	11	986	0	514	472	3600	4072	4874	900	900
46	11	472	900	697	675	3600	4275	4874	900	900
47	11	675	0	1230	-555	4500	3945	4874	900	900
48	12	-555	0	330	-885	5400	4515	4874	900	900
49	12	-885	0	2570	-3455	6300	2845	4874	900	900
50	12	-3455	900		-2555	6300	3745	4874	900	900
51	12	-2555	900		-1655	6300	4645	4874	900	900
52	12	-1655	0		-1655	7200	5545	4874	900	0

Appendix F:
Ordering system
(A Min-Max Model)

ORDER QUANTITY SIMULATION: A MIN-MAX POLICY (M*)

P/NO: AA00001

Wk	Month	Stock OHO	Dlry Qty	Order Qty	Stock OHC	Stock On order	OSD Stock	ROP	Q*	PO Qty	M*
1	1	4185			4185		4185	4185	569		4754
2	1	4185			4185	0	4185	4185	569		4754
3	1	4185		500	3685	0	3685	4185	569	1069	4754
4	1	3685		500	3185	1069	4254	4185	569		4754
5	1	3185		50	3135	1069	4204	4185	569		4754
6	2	3135			3135	1069	4204	4185	569		4754
7	2	3135		60	3075	1069	4144	4185	569	610	4754
8	2	3075		1300	1775	1679	3454	4185	569	1300	4754
9	2	1775			1775	2979	4754	4185	569		4754
10	3	1775	0	844	931	2979	3910	4185	569	844	4754
11	3	931	0	38	893	3823	4716	4185	569		4754
12	3	893	1069	1000	962	2754	3716	4185	569	1038	4754
13	3	962	0		962	3792	4754	4185	569		4754
14	4	962	0		962	3792	4754	4185	569		4754
15	4	962	0	68	894	3792	4686	4185	569		4754
16	4	894	610	1338	166	3182	3348	4185	569	1406	4754
17	4	166	1300	34	1432	3288	4720	4185	569		4754
18	4	1432	0		1432	3288	4720	4185	569		4754
19	5	1432	844	295	1981	2444	4425	4185	569		4754
20	5	1981	0	460	1521	2444	3965	4185	569	789	4754
21	5	1521	1038	1000	1559	2195	3754	4185	569	1000	4754
22	5	1559	0	10	1549	3195	4744	4185	569		4754
23	6	1549	0	55	1494	3195	4689	4185	569		4754
24	6	1494	0		1494	3195	4689	4185	569		4754
25	6	1494	1406	60	2840	1789	4629	4185	569		4754
26	6	2840	0	1000	1840	1789	3629	4185	569	1125	4754
27	7	1840	0		1840	2914	4754	4185	569		4754
28	7	1840	0	300	1540	2914	4454	4185	569		4754
29	7	1540	789	17	2312	2125	4437	4185	569		4754
30	7	2312	1000	154	3158	1125	4283	4185	569		4754
31	7	3158	0	1302	1856	1125	2981	4185	569	1773	4754
32	8	1856	0	150	1706	2898	4604	4185	569		4754
33	8	1706	0		1706	2898	4604	4185	569		4754
34	8	1706	0	1000	706	2898	3604	4185	569	1150	4754
35	8	706	1125	13	1818	2923	4741	4185	569		4754
36	9	1818	0	360	1458	2923	4381	4185	569		4754
37	9	1458	0	1000	458	2923	3381	4185	569	1373	4754
38	9	458	0	11	447	4296	4743	4185	569		4754
39	9	447	0	19	428	4296	4724	4185	569		4754
40	10	428	1773		2201	2523	4724	4185	569		4754
41	10	2201	0	1696	505	2523	3028	4185	569	1726	4754
42	10	505	0	150	355	4249	4604	4185	569		4754
43	10	355	1150	40	1465	3099	4564	4185	569		4754
44	11	1465	0		1465	3099	4564	4185	569		4754
45	11	1465	0		1465	3099	4564	4185	569		4754
46	11	1465	1373	7892	-5054	1726	-3328	4185	569	8082	4754
47	11	-5054	0	80	-5134	9808	4674	4185	569		4754
48	12	-5134	0	1450	-6584	9808	3224	4185	569	1530	4754
49	12	-6584	0	2283	-8867	11338	2471	4185	569	2283	4754
50	12	-8867	1726	520	-7661	11895	4234	4185	569		4754
51	12	-7661	0		-7661	11895	4234	4185	569		4754
52	12	-7661	0		-7661	11895	4234	4185	569		4754

ORDER QUANTITY SIMULATION: A MIN-MAX POLICY (M*)
P/NO: AA00002

Wk	Month	Stock OHO	Dlry Qty	Order Qty	Stock OHC	Stock On order	OSD Stock	ROP	Q*	PO Qty	M*
1	1	338			338		338	338	91	0	429
2	1	338		40	298	0	298	338	91	131	429
3	1	298		14	284	131	415	338	91	0	429
4	1	284			284	131	415	338	91	0	429
5	1	284			284	131	415	338	91	0	429
6	2	284			284	131	415	338	91	0	429
7	2	284		11	273	131	404	338	91	0	429
8	2	273			273	131	404	338	91	0	429
9	2	273		72	201	131	332	338	91	97	429
10	3	201	0	110	91	228	319	338	91	110	429
11	3	91	131		222	207	429	338	91	0	429
12	3	222	0	95	127	207	334	338	91	95	429
13	3	127	0	25	102	302	404	338	91		429
14	4	102	0		102	302	404	338	91		429
15	4	102	0	120	-18	302	284	338	91	145	429
16	4	-18	0	24	-42	447	405	338	91		429
17	4	-42	0	13	-55	447	392	338	91		429
18	4	-55	97		42	350	392	338	91		429
19	5	42	110	60	92	240	332	338	91	97	429
20	5	92	0	60	32	337	369	338	91		429
21	5	32	95	14	113	242	355	338	91		429
22	5	113	0	16	97	242	339	338	91		429
23	6	97	0	43	54	242	296	338	91	133	429
24	6	54	145		199	230	429	338	91		429
25	6	199	0	1	198	230	428	338	91		429
26	6	198	0	23	175	230	405	338	91		429
27	7	175	0		175	230	405	338	91		429
28	7	175	97	172	100	133	233	338	91	196	429
29	7	100	0	6	94	329	423	338	91		429
30	7	94	0	3	91	329	420	338	91		429
31	7	91	0	35	56	329	385	338	91		429
32	8	56	133	15	174	196	370	338	91		429
33	8	174	0		174	196	370	338	91		429
34	8	174	0	15	159	196	355	338	91		429
35	8	159	0	9	150	196	346	338	91		429
36	9	150	0	10	140	196	336	338	91	93	429
37	9	140	196		336	93	429	338	91		429
38	9	336	0		336	93	429	338	91		429
39	9	336	0	14	322	93	415	338	91		429
40	10	322	0	5	317	93	410	338	91		429
41	10	317	0	3	314	93	407	338	91		429
42	10	314	0	6	308	93	401	338	91		429
43	10	308	0	78	230	93	323	338	91	106	429
44	11	230	0	16	214	199	413	338	91		429
45	11	214	93	90	217	106	323	338	91	106	429
46	11	217	0	6	211	212	423	338	91		429
47	11	211	0	26	185	212	397	338	91		429
48	12	185	0	12	173	212	385	338	91		429
49	12	173	0	68	105	212	317	338	91	112	429
50	12	105	0	10	95	324	419	338	91		429
51	12	95	0	5	90	324	414	338	91		429
52	12	90	106		196	218	414	338	91		429

ORDER QUANTITY SIMULATION: A MIN-MAX POLICY (M*)
P/NO: AA00003

Wk	Month	Stock OHO	Dlry Qty	Order Qty	Stock OHC	Stock On order	OSD Stock	ROP	Q*	PO Qty	M*
1	1	1210			1210		1210	1210	258		1468
2	1	1210		101	1109	0	1109	1210	258	359	1468
3	1	1109		40	1069	359	1428	1210	258		1468
4	1	1069		60	1009	359	1368	1210	258		1468
5	1	1009		46	963	359	1322	1210	258		1468
6	2	963		59	904	359	1263	1210	258		1468
7	2	904		355	549	359	908	1210	258	560	1468
8	2	549		108	441	919	1360	1210	258		1468
9	2	441		24	417	919	1336	1210	258		1468
10	3	417	0	399	18	919	937	1210	258	531	1468
11	3	18	359	114	263	1091	1354	1210	258		1468
12	3	263	0	50	213	1091	1304	1210	258		1468
13	3	213	0	67	146	1091	1237	1210	258		1468
14	4	146	0		146	1091	1237	1210	258		1468
15	4	146	0		146	1091	1237	1210	258		1468
16	4	146	560	381	325	531	856	1210	258	612	1468
17	4	325	0	86	239	1143	1382	1210	258		1468
18	4	239	0	51	188	1143	1331	1210	258		1468
19	5	188	531	78	641	612	1253	1210	258		1468
20	5	641	0	132	509	612	1121	1210	258	347	1468
21	5	509	0		509	959	1468	1210	258		1468
22	5	509	0	24	485	959	1444	1210	258		1468
23	6	485	0	740	-255	959	704	1210	258	764	1468
24	6	-255	0		-255	1723	1468	1210	258		1468
25	6	-255	612	54	303	1111	1414	1210	258		1468
26	6	303	0	24	279	1111	1390	1210	258		1468
27	7	279	0	520	-241	1111	870	1210	258	598	1468
28	7	-241	0	149	-390	1709	1319	1210	258		1468
29	7	-390	347	77	-120	1362	1242	1210	258		1468
30	7	-120	0	132	-252	1362	1110	1210	258	358	1468
31	7	-252	0	583	-835	1720	885	1210	258	583	1468
32	8	-835	764	60	-131	1539	1408	1210	258		1468
33	8	-131	0		-131	1539	1408	1210	258		1468
34	8	-131	0	40	-171	1539	1368	1210	258		1468
35	8	-171	0	661	-832	1539	707	1210	258	761	1468
36	9	-832	598	36	-270	1702	1432	1210	258		1468
37	9	-270	0		-270	1702	1432	1210	258		1468
38	9	-270	0	211	-481	1702	1221	1210	258		1468
39	9	-481	358	14	-137	1344	1207	1210	258	261	1468
40	10	-137	583	70	376	1022	1398	1210	258		1468
41	10	376	0	55	321	1022	1343	1210	258		1468
42	10	321	0	55	266	1022	1288	1210	258		1468
43	10	266	0	32	234	1022	1256	1210	258		1468
44	11	234	761		995	261	1256	1210	258		1468
45	11	995	0	178	817	261	1078	1210	258	390	1468
46	11	817	0	81	736	651	1387	1210	258		1468
47	11	736	0	104	632	651	1283	1210	258		1468
48	12	632	261	43	850	390	1240	1210	258		1468
49	12	850	0	337	513	390	903	1210	258	565	1468
50	12	513	0		513	955	1468	1210	258		1468
51	12	513	0		513	955	1468	1210	258		1468
52	12	513	0		513	955	1468	1210	258		1468

ORDER QUANTITY SIMULATION: A MIN-MAX POLICY (M*)
P/NO: AA00004

Wk	Month	Stock OHO	Dlry Qty	Order Qty	Stock OHC	Stock On order	OSD Stock	ROP	Q*	PO Qty	M*
1	1	603		100	503	0	503	603	202	302	805
2	1	503		190	313	302	615	603	202		805
3	1	313		35	278	302	580	603	202	225	805
4	1	278		5	273	527	800	603	202		805
5	1	273		85	188	527	715	603	202		805
6	2	188		97	91	527	618	603	202		805
7	2	91		38	53	527	580	603	202	225	805
8	2	53		5	48	752	800	603	202		805
9	2	48		117	-69	752	683	603	202		805
10	3	-69	302		233	450	683	603	202		805
11	3	233	0		233	450	683	603	202		805
12	3	233	225	65	393	225	618	603	202		805
13	3	393	0		393	225	618	603	202		805
14	4	393	0	6	387	225	612	603	202		805
15	4	387	0		387	225	612	603	202		805
16	4	387	225	64	548	0	548	603	202	257	805
17	4	548	0	65	483	257	740	603	202		805
18	4	483	0	16	467	257	724	603	202		805
19	5	467	0	26	441	257	698	603	202		805
20	5	441	0	23	418	257	675	603	202		805
21	5	418	0	5	413	257	670	603	202		805
22	5	413	0	33	380	257	637	603	202		805
23	6	380	0	38	342	257	599	603	202	206	805
24	6	342	0		342	463	805	603	202		805
25	6	342	257	14	585	206	791	603	202		805
26	6	585	0	32	553	206	759	603	202		805
27	7	553	0	40	513	206	719	603	202		805
28	7	513	0	220	293	206	499	603	202	306	805
29	7	293	0	233	60	512	572	603	202	233	805
30	7	60	0		60	745	805	603	202		805
31	7	60	0	35	25	745	770	603	202		805
32	8	25	206	85	146	539	685	603	202		805
33	8	146	0	11	135	539	674	603	202		805
34	8	135	0	33	102	539	641	603	202		805
35	8	102	0	100	2	539	541	603	202	264	805
36	9	2	0	37	-35	803	768	603	202		805
37	9	-35	306		271	497	768	603	202		805
38	9	271	233	88	416	264	680	603	202		805
39	9	416	0	20	396	264	660	603	202		805
40	10	396	0		396	264	660	603	202		805
41	10	396	0	75	321	264	585	603	202	220	805
42	10	321	0	49	272	484	756	603	202		805
43	10	272	0	91	181	484	665	603	202		805
44	11	181	264		445	220	665	603	202		805
45	11	445	0	50	395	220	615	603	202		805
46	11	395	0	10	385	220	605	603	202		805
47	11	385	0	6	379	220	599	603	202	206	805
48	12	379	0	23	356	426	782	603	202		805
49	12	356	0	20	336	426	762	603	202		805
50	12	336	220	39	517	206	723	603	202		805
51	12	517	0	49	468	206	674	603	202		805
52	12	468	0		468	206	674	603	202		805

ORDER QUANTITY SIMULATION: A MIN-MAX POLICY (M*)
P/NO: AA00005

Wk	Month	Stock OHO	Dlry Qty	Order Qty	Stock OHC	Stock On order	OSD Stock	ROP	Q*	PO Qty	M*
1	1	348		45	303		303	348	88	133	436
2	1	303		40	263	133	396	348	88		436
3	1	263		28	235	133	368	348	88		436
4	1	235		5	230	133	363	348	88		436
5	1	230		46	184	133	317	348	88	119	436
6	2	184		23	161	252	413	348	88		436
7	2	161		31	130	252	382	348	88		436
8	2	130		122	8	252	260	348	88	176	436
9	2	8		38	-30	428	398	348	88		436
10	3	-30	133	70	33	295	328	348	88	108	436
11	3	33	0	10	23	403	426	348	88		436
12	3	23	0	30	-7	403	396	348	88		436
13	3	-7	0		-7	403	396	348	88		436
14	4	-7	119		112	284	396	348	88		436
15	4	112	0	40	72	284	356	348	88		436
16	4	72	0	8	64	284	348	348	88		436
17	4	64	176	60	180	108	288	348	88	148	436
18	4	180	0	7	173	256	429	348	88		436
19	5	173	108	67	214	148	362	348	88		436
20	5	214	0	61	153	148	301	348	88	135	436
21	5	153	0	67	86	283	369	348	88		436
22	5	86	0	11	75	283	358	348	88		436
23	6	75	0	55	20	283	303	348	88	133	436
24	6	20	0		20	416	436	348	88		436
25	6	20	0	45	-25	416	391	348	88		436
26	6	-25	148	7	116	268	384	348	88		436
27	7	116	0	57	59	268	327	348	88	109	436
28	7	59	0	366	-307	377	70	348	88	366	436
29	7	-307	135	66	-238	608	370	348	88		436
30	7	-238	0	13	-251	608	357	348	88		436
31	7	-251	0	38	-289	608	319	348	88	117	436
32	8	-289	133	51	-207	592	385	348	88		436
33	8	-207	0		-207	592	385	348	88		436
34	8	-207	0	30	-237	592	355	348	88		436
35	8	-237	0		-237	592	355	348	88		436
36	9	-237	109	15	-143	483	340	348	88	96	436
37	9	-143	366		223	213	436	348	88		436
38	9	223	0	50	173	213	386	348	88		436
39	9	173	0	14	159	213	372	348	88		436
40	10	159	117		276	96	372	348	88		436
41	10	276	0	8	268	96	364	348	88		436
42	10	268	0	5	263	96	359	348	88		436
43	10	263	0	37	226	96	322	348	88	114	436
44	11	226	0		226	210	436	348	88		436
45	11	226	96		322	114	436	348	88		436
46	11	322	0	54	268	114	382	348	88		436
47	11	268	0	6	262	114	376	348	88		436
48	12	262	0	15	247	114	361	348	88		436
49	12	247	0	37	210	114	324	348	88	112	436
50	12	210	0		210	226	436	348	88		436
51	12	210	0		210	226	436	348	88		436
52	12	210	114		324	112	436	348	88		436

ORDER QUANTITY SIMULATION: A MIN-MAX POLICY (M*)
P/NO: AA00006

Wk	Month	Stock OHO	Dlry Qty	Order Qty	Stock OHC	Stock On order	OSD Stock	ROP	Q*	PO Qty	M*
1	1	320		30	290		290	320	35	65	355
2	1	290		20	270	65	335	320	35		355
3	1	270			270	65	335	320	35		355
4	1	270		30	240	65	305	320	35	50	355
5	1	240			240	115	355	320	35		355
6	2	240		50	190	115	305	320	35	50	355
7	2	190			190	165	355	320	35		355
8	2	190		30	160	165	325	320	35		355
9	2	160		40	120	165	285	320	35	70	355
10	3	120	65	30	155	170	325	320	35		355
11	3	155	0	31	124	170	294	320	35	61	355
12	3	124	0	38	86	231	317	320	35	38	355
13	3	86	50	70	66	219	285	320	35	70	355
14	4	66	0	100	-34	289	255	320	35	100	355
15	4	-34	50	44	-28	339	311	320	35	44	355
16	4	-28	0	40	-68	383	315	320	35	40	355
17	4	-68	0	50	-118	423	305	320	35	50	355
18	4	-118	70	40	-88	403	315	320	35	40	355
19	5	-88	0	8	-96	443	347	320	35		355
20	5	-96	61	8	-43	382	339	320	35		355
21	5	-43	38		-5	344	339	320	35		355
22	5	-5	70		65	274	339	320	35		355
23	6	65	100	100	65	174	239	320	35	116	355
24	6	65	44		109	246	355	320	35		355
25	6	109	40		149	206	355	320	35		355
26	6	149	50		199	156	355	320	35		355
27	7	199	40	201	38	116	154	320	35	201	355
28	7	38	0	9	29	317	346	320	35		355
29	7	29	0		29	317	346	320	35		355
30	7	29	0		29	317	346	320	35		355
31	7	29	0	101	-72	317	245	320	35	110	355
32	8	-72	116	6	38	311	349	320	35		355
33	8	38	0		38	311	349	320	35		355
34	8	38	0		38	311	349	320	35		355
35	8	38	0	100	-62	311	249	320	35	106	355
36	9	-62	201		139	216	355	320	35		355
37	9	139	0		139	216	355	320	35		355
38	9	139	0		139	216	355	320	35		355
39	9	139	0		139	216	355	320	35		355
40	10	139	110		249	106	355	320	35		355
41	10	249	0		249	106	355	320	35		355
42	10	249	0		249	106	355	320	35		355
43	10	249	0	11	238	106	344	320	35		355
44	11	238	106		344	0	344	320	35		355
45	11	344	0	60	284	0	284	320	35	71	355
46	11	284	0	1	283	71	354	320	35		355
47	11	283	0	59	224	71	295	320	35	60	355
48	12	224	0	12	212	131	343	320	35		355
49	12	212	0	51	161	131	292	320	35	63	355
50	12	161	0		161	194	355	320	35		355
51	12	161	0	23	138	194	332	320	35		355
52	12	138	0		138	194	332	320	35		355

ORDER QUANTITY SIMULATION: A MIN-MAX POLICY (M*)
P/NO: AA00007

Wk	Month	Stock OHO	Dlry Qty	Order Qty	Stock OHC	Stock On order	OSD Stock	ROP	Q*	PO Qty	M*
1	1	3011		376	2635		2635	3139	392	896	3531
2	1	2635			2635	896	3531	3139	392		3531
3	1	2635		335	2300	896	3196	3139	392		3531
4	1	2300			2300	896	3196	3139	392		3531
5	1	2300		300	2000	896	2896	3139	392	635	3531
6	2	2000		412	1588	1531	3119	3139	392	412	3531
7	2	1588		55	1533	1943	3476	3139	392		3531
8	2	1533		300	1233	1943	3176	3139	392		3531
9	2	1233		702	531	1943	2474	3139	392	1057	3531
10	3	531	896	508	919	2104	3023	3139	392	508	3531
11	3	919	0	333	586	2612	3198	3139	392		3531
12	3	586	0	79	507	2612	3119	3139	392	412	3531
13	3	507	0	46	461	3024	3485	3139	392		3531
14	4	461	635	371	725	2389	3114	3139	392	417	3531
15	4	725	412		1137	2394	3531	3139	392		3531
16	4	1137	0	402	735	2394	3129	3139	392	402	3531
17	4	735	0	34	701	2796	3497	3139	392		3531
18	4	701	1057	398	1360	1739	3099	3139	392	432	3531
19	5	1360	508	60	1808	1663	3471	3139	392		3531
20	5	1808	0	582	1226	1663	2889	3139	392	642	3531
21	5	1226	412	2	1636	1893	3529	3139	392		3531
22	5	1636	0	526	1110	1893	3003	3139	392	528	3531
23	6	1110	417	595	932	2004	2936	3139	392	595	3531
24	6	932	0	30	902	2599	3501	3139	392		3531
25	6	902	402	345	959	2197	3156	3139	392		3531
26	6	959	0	346	613	2197	2810	3139	392	721	3531
27	7	613	432	300	745	2486	3231	3139	392		3531
28	7	745	0	50	695	2486	3181	3139	392		3531
29	7	695	642	444	893	1844	2737	3139	392	794	3531
30	7	893	0	300	593	2638	3231	3139	392		3531
31	7	593	528	207	914	2110	3024	3139	392	507	3531
32	8	914	595	300	1209	2022	3231	3139	392		3531
33	8	1209	0	64	1145	2022	3167	3139	392		3531
34	8	1145	0	417	728	2022	2750	3139	392	781	3531
35	8	728	721	478	971	2082	3053	3139	392	478	3531
36	9	971	0	20	951	2560	3511	3139	392		3531
37	9	951	0	305	646	2560	3206	3139	392		3531
38	9	646	794	261	1179	1766	2945	3139	392	586	3531
39	9	1179	0	460	719	2352	3071	3139	392	460	3531
40	10	719	507	37	1189	2305	3494	3139	392		3531
41	10	1189	0	930	259	2305	2564	3139	392	967	3531
42	10	259	0	166	93	3272	3365	3139	392		3531
43	10	93	781	22	852	2491	3343	3139	392		3531
44	11	852	478	539	791	2013	2804	3139	392	727	3531
45	11	791	0	600	191	2740	2931	3139	392	600	3531
46	11	191	0	90	101	3340	3441	3139	392		3531
47	11	101	586	124	563	2754	3317	3139	392		3531
48	12	563	460	500	523	2294	2817	3139	392	714	3531
49	12	523	0	256	267	3008	3275	3139	392		3531
50	12	267	967	662	572	2041	2613	3139	392	918	3531
51	12	572	0		572	2959	3531	3139	392		3531
52	12	572	0		572	2959	3531	3139	392		3531

ORDER QUANTITY SIMULATION: A MIN-MAX POLICY (M*)
P/NO: AA00008

Wk	Month	Stock OHO	Dlry Qty	Order Qty	Stock OHC	Stock On order	OSD Stock	ROP	Q*	PO Qty	M*
1	1	188			188		188	179	229		408
2	1	188		52	136	0	136	179	229	272	408
3	1	136			136	272	408	179	229		408
4	1	136			136	272	408	179	229		408
5	1	136		25	111	272	383	179	229		408
6	2	111			111	272	383	179	229		408
7	2	111		4	107	272	379	179	229		408
8	2	107		19	88	272	360	179	229		408
9	2	88		21	67	272	339	179	229		408
10	3	67	0	11	56	272	328	179	229		408
11	3	56	272	2	326	0	326	179	229		408
12	3	326	0		326	0	326	179	229		408
13	3	326	0	29	297	0	297	179	229		408
14	4	297	0	25	272	0	272	179	229		408
15	4	272	0	50	222	0	222	179	229		408
16	4	222	0	40	182	0	182	179	229		408
17	4	182	0	33	149	0	149	179	229	259	408
18	4	149	0	30	119	259	378	179	229		408
19	5	119	0	10	109	259	368	179	229		408
20	5	109	0	53	56	259	315	179	229		408
21	5	56	0	20	36	259	295	179	229		408
22	5	36	0	25	11	259	270	179	229		408
23	6	11	0	7	4	259	263	179	229		408
24	6	4	0	20	-16	259	243	179	229		408
25	6	-16	0	9	-25	259	234	179	229		408
26	6	-25	259	15	219	0	219	179	229		408
27	7	219	0	29	190	0	190	179	229		408
28	7	190	0	3	187	0	187	179	229		408
30	7	187	0	58	129	0	129	179	229	279	408
31	7	129	0	11	118	279	397	179	229		408
32	8	118	0	10	108	279	387	179	229		408
33	8	108	0		108	279	387	179	229		408
34	8	108	0	7	101	279	380	179	229		408
35	8	101	0	6	95	279	374	179	229		408
36	9	95	0	41	54	279	333	179	229		408
37	9	54	0	4	50	279	329	179	229		408
38	9	50	279		329	0	329	179	229		408
39	9	329	0	5	324	0	324	179	229		408
40	10	324	0	15	309	0	309	179	229		408
41	10	309	0		309	0	309	179	229		408
42	10	309	0	29	280	0	280	179	229		408
43	10	280	0	3	277	0	277	179	229		408
44	11	277	0	5	272	0	272	179	229		408
45	11	272	0		272	0	272	179	229		408
46	11	272	0	30	242	0	242	179	229		408
47	11	242	0	8	234	0	234	179	229		408
48	12	234	0		234	0	234	179	229		408
49	12	234	0	54	180	0	180	179	229		408
50	12	180	0		180	0	180	179	229		408
51	12	180	0		180	0	180	179	229		408
52	12	180	0		180	0	180	179	229		408

ORDER QUANTITY SIMULATION: A MIN-MAX POLICY (M*)
P/NO: AA00009

Wk	Month	Stock OHO	Dlry Qty	Order Qty	Stock OHC	Stock On order	OSD Stock	ROP	Q*	PO Qty	M*
1	1	4991		1	4990		4990	4874	900		5774
2	1	4990		343	4647	0	4647	4874	900	1127	5774
3	1	4647		800	3847	1127	4974	4874	900		5774
4	1	3847		101	3746	1127	4873	4874	900	901	5774
5	1	3746		290	3456	2028	5484	4874	900		5774
6	2	3456		220	3236	2028	5264	4874	900		5774
7	2	3236		895	2341	2028	4369	4874	900	1405	5774
8	2	2341		104	2237	3433	5670	4874	900		5774
9	2	2237		1340	897	3433	4330	4874	900	1444	5774
10	3	897	0	244	653	4877	5530	4874	900		5774
11	3	653	1127	1419	361	3750	4111	4874	900	1663	5774
12	3	361	0	200	161	5413	5574	4874	900		5774
13	3	161	901	130	932	4512	5444	4874	900		5774
14	4	932	0	100	832	4512	5344	4874	900		5774
15	4	832	0	101	731	4512	5243	4874	900		5774
16	4	731	1405	1232	904	3107	4011	4874	900	1763	5774
17	4	904	0	106	798	4870	5668	4874	900		5774
18	4	798	1444	330	1912	3426	5338	4874	900		5774
19	5	1912	0	519	1393	3426	4819	4874	900	955	5774
20	5	1393	1663	450	2606	2718	5324	4874	900		5774
21	5	2606	0	1125	1481	2718	4199	4874	900	1575	5774
22	5	1481	0	297	1184	4293	5477	4874	900		5774
23	6	1184	0	701	483	4293	4776	4874	900	998	5774
24	6	483	0		483	5291	5774	4874	900		5774
25	6	483	1763	206	2040	3528	5568	4874	900		5774
26	6	2040	0	818	1222	3528	4750	4874	900	1024	5774
27	7	1222	0	137	1085	4552	5637	4874	900		5774
28	7	1085	955	632	1408	3597	5005	4874	900		5774
29	7	1408	0	1392	16	3597	3613	4874	900	2161	5774
30	7	16	1575	447	1144	4183	5327	4874	900		5774
31	7	1144	0	874	270	4183	4453	4874	900	1321	5774
32	8	270	998	131	1137	4506	5643	4874	900		5774
33	8	1137	0		1137	4506	5643	4874	900		5774
34	8	1137	0	1134	3	4506	4509	4874	900	1265	5774
35	8	3	1024	740	287	4747	5034	4874	900		5774
36	9	287	0	90	197	4747	4944	4874	900		5774
37	9	197	0	1005	-808	4747	3939	4874	900	1835	5774
38	9	-808	2161	137	1216	4421	5637	4874	900		5774
39	9	1216	0	201	1015	4421	5436	4874	900		5774
40	10	1015	1321	15	2321	3100	5421	4874	900		5774
41	10	2321	0	1010	1311	3100	4411	4874	900	1363	5774
42	10	1311	0	135	1176	4463	5639	4874	900		5774
43	10	1176	1265	553	1888	3198	5086	4874	900		5774
44	11	1888	0	1300	588	3198	3786	4874	900	1988	5774
45	11	588	0	514	74	5186	5260	4874	900		5774
46	11	74	1835	697	1212	3351	4563	4874	900	1211	5774
47	11	1212	0	1230	-18	4562	4544	4874	900	1230	5774
48	12	-18	0	330	-348	5792	5444	4874	900		5774
49	12	-348	0	2570	-2918	5792	2874	4874	900	2900	5774
50	12	-2918	1363		-1555	7329	5774	4874	900		5774
51	12	-1555	0		-1555	7329	5774	4874	900		5774
52	12	-1555	0		-1555	7329	5774	4874	900		5774

Appendix G:
Table of normal loss integral

TABLE OF NORMAL LOSS INTEGRAL

z	**L (z)**
0.00	0.3989
0.10	0.3970
0.20	0.3910
0.30	0.3814
0.40	0.3683
0.50	0.3521
0.60	0.3332
0.70	0.3123
0.80	0.2897
0.90	0.2661
1.00	0.2420
1.10	0.2179
1.20	0.1942
1.30	0.1714
1.40	0.1497
1.50	0.1295
1.60	0.1109
1.70	0.0940
1.80	0.0790
1.90	0.0656
2.00	0.0540
2.10	0.0440
2.20	0.0355
2.30	0.0283
2.40	0.0224
2.50	0.0175
2.60	0.0136
2.70	0.0104
2.80	0.0079
2.90	0.0060
3.00	0.0044
3.10	0.0033
3.20	0.0024
3.30	0.0017
3.40	0.0012
3.50	0.0009
3.60	0.0006
3.70	0.0004
3.80	0.0003
3.90	0.0002
4.00	0.0001

Biography

Ms.Narumon Burapachayanont was born in 1977 in Bangkok, Thailand. She graduated from Kasetsart University in the Faculty of Humanities majoring in mass communication and minoring in marketing in 1998. She had almost 10 years experiences in logistics functions such as import and export, material handling, order processing, customs clearance and international trade business etc. She realized the necessity in the knowledge of logistics management is important in today business. Then, she became a post graduate student in Master of Sciences in Logistics Management at Chulalongkorn university.