Inventory Policy Improvement for a Kitchenware Trader

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การปรับปรุงนโยบายพัสดุคงคลังสำหรับผู้ขายเครื่องใช้ในครัว

นางสาวณัชชา เจิดจำนงวิทยากุล

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิศวกรรมศาสตรมหาบัณฑิต
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ณัชชา เจิดจำนงวิทยากุล : การปรับปรุงนโยบายพัสดุคงคลังสำหรับผู้ขายเครื่องใช้ในครัว (Inventory Policy Improvement for a Kitchenware Trader) อ.ที่ปรึกษาวิทยานิพนธ์หลัก: ดร. พิศิษฏ์ จารุมณีโรจน์, 149 หน้า.

วัตถุประสงค์หลักของวิทยานิพนธ์นี้เพื่อปรับปรุงนโยบายสินค้าคงคลังสำหรับผู้ประกอบการที่นำเข้าเครื่องครัวหลากหลายรายการจากประเทศญี่ปุ่น เพื่อลดระดับสินค้าคงคลัง และปรับปรุงการดำเนินงานภายใน การเคลื่อนไหวของสินค้าใน 12 เดือนในปี พ.ศ. 2558 สำหรับสินค้า 738 ประเภท ได้รับการประเมินและจัดหมวดหมู่ ห้ากลุ่มคือ 1) ไม่เคลื่อนไหวหุ้น 2) ไม่มีการขายล่าสุด 6 เดือน 3) ระยะเวลาสั้นหุ้น 4) สต็อกสินค้าใหม่และ 5) สินค้าที่เหลือ 185 ชนิด โดยมีการเสนอนโยบายการบริหารเชิงกลยุทธ์สำหรับแต่ละกลุ่มม ส่วนที่เหลืออีก 185 SKUs จะถูกจำแนกตามลักษณะการดำเนินงานโดยใช้ ทฤษฎีการแบ่ง ABC ความต่อเนื่องของความต้องการสินค้าเป็นเกณฑ์แรกสำหรับการจัดลำดับความสำคัญของผลิตภัณฑ์ เพราะสามารถแบ่งกลุ่มสินค้าที่มีความต้องการอย่างต่อเนื่องและสินค้าที่มีความต้องการไม่ต่อเนื่อง เกณฑ์ที่สองคือจำนวนของการสั่งซื้อในปี พ.ศ. 2558 หลักเกณฑ์ที่สามคือมูลค่าการขายและหลักเกณฑ์สุดท้ายคือมูลค่าสินค้าคงคลังเฉลี่ยตามลำดับ หลังจากนั้นทำการประเมินรูปแบบความต้องการสินค้าสำหรับแต่ละกลุ่ม และนำเสนอวิธีการพยากรณ์และตัวชี้วัดข้อผิดพลาดและระบบสินค้าคงคลัง สำหรับนโยบายในการสั่งซื้อสำหรับกลุ่มทั้งหมดเป็น การจัดซื้อเป็นรอบตามระยะที่กำหนด เพราะต้นทุนการขนส่งสูง นอกจากนี้มีการนำเสนอกระบวนการทำงานและขั้นตอนการสั่งซื้อสินค้าการไหลของคลังสินค้า และขั้นตอนการตรวจสอบคลังสินค้ารวมทั้งมีการเสนอเอกสารที่ใช้ประกอบกระการต่าง

ผลการทดลองของวิธีการที่นำเสนอเพื่อประเมินนโยบายโดยใช้โปรแกรม ไมโครซอฟต์เอกเซล (Microsoft Excel) โดยทำการเปรียบเทียบกับการดำเนินงานที่เกิดขึ้นจริงในห้าเดือนระหว่างเดือนมกราคมถึงเดือนพฤษภาคม ปี พ.ศ. 2559 พบว่าผลของนโยบายที่นำเสนอ สามารถลดระดับสินค้าคงคลังสำหรับผลิตภัณฑ์ในกลุ่ม เอ และ บี ในขณะที่ระดับการให้บริการของนโยบายที่นำเสนอสามารถดำเนินการได้โดยไม่มีระยะที่ขาดสินค้าในคลัง แต่สำหรับผลิตภัณฑ์ที่เคลื่อนไหวช้าในกลุ่มซี ไม่สามารถสรุปผลได้ เนื่องจากพิจารณาว่ามีข้อมูลที่ไม่เพียงพอและมีช่วงการเปรียบเทียบที่สั้นเกินไป

ภาควิชา	ศูนย์ระดับภูมิภาคทางวิศวกรรมระบบการผลิต	ลายมือชื่อนิสิต	....
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The research objectives are to improve inventory policy for a kitchenware trader in order to reduce the inventory level and improve internal operations. The product movement in 12 months of 2015 for 738 SKUs is evaluated and categorised. Five groups are 1) Non-moving stock 2) Stock with no sales last 6 months 3) Short-period stock 4) New product stock and 5) Remaining185 SKUs. Strategic managements for each group are proposed. The remaining 185 SKUs are classified based on operational aspect by using ABC Pareto. The continuity of demand is the first criteria for sequencing the importance of products, since it can divide groups of continuous and intermittent demand items. The second criteria is number of order in 2015. The third and fourth criteria are the value of sales and average inventory value, respectively. Forecasting approaches and error indicators, and inventory system are proposed. Periodic review policy is proposed for all groups because of high transportation costs. The simulations of the proposed methodology are performed for the policy assessment by using Microsoft Excel. Actual operations in five months between January to May, 2016 are compared with the implementation of the proposed policy. The results show the reduction of inventory level for group A and B, while the service level of the proposed policy can perform without stock out period. Finally, the slow moving products in group C cannot be concluded as it is considered inadequate historical data and comparison period.

Department:	Regional Centre for Manufacturing Systems Engineering	Student's Signature	....
		Advisor's Signature	....
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INTRODUCTION

Japanese food has become popular in Thailand in the last 16 years (Sushi, 2016), and the Japanese restaurant market in Thailand has been continually growing since then. JETRO Bangkok (JETRO, 2015) reported that, in August 2015, Japanese restaurants in Thailand are the largest market in ASEAN which experiences a 11.5 percent growth rate each year.

With the rising popularity of Japanese restaurants in Thailand, associated businesses in the supply chain are increasing in consequence such as raw materials, food products, Japanese style kitchenware and tableware.

1.1 BUSINESS OVERVIEW

The studied company is one of the leading traders providing various types of Japanese style kitchen products including tableware, frozen food, kitchen machines and equipment, food packaging, and miscellaneous disposable products. The company was founded in Thailand in 1993 whose headquarters is located in Japan. *Figure 1.1* illustrates examples of products provided by the studied company.

Figure 1.1 Example Products of the Studied Company based in Thailand

The company value proposition is to provide convenience to customers (see *Figure 1.2*). The customers are ranging from restaurants, supermarkets, and food factories whereas the main suppliers are the headquarters in Japan, a subsidiary company in Singapore and 30 other companies supplying local goods in Thailand.

Kitchen products are gathered from both overseas and local suppliers. After that, the company manages its inventory and delivers the products to customers at the specified service level. As a result, it helps customers reduce their costs of inventory and transaction since they do not need to have high buffering merchandises. Moreover, customers spend less time on ordering process because most of the products used in their units are provided by the company.

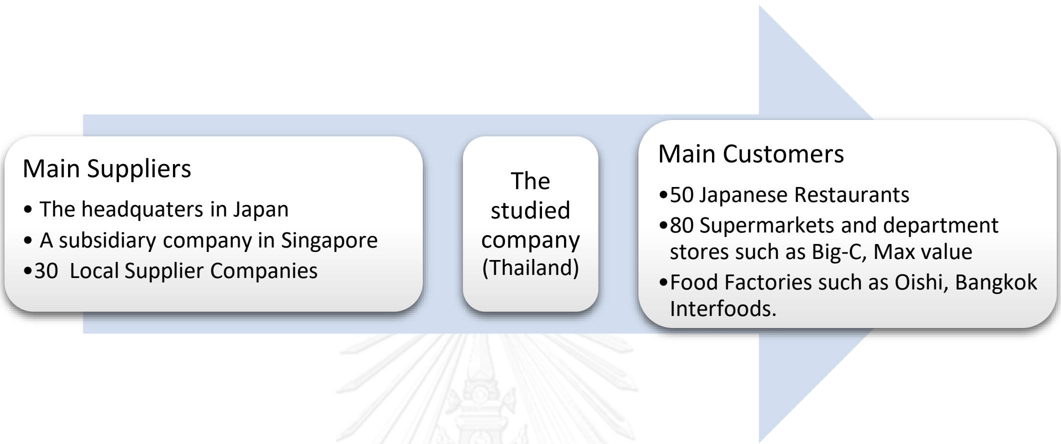


Figure 1.2 Suppliers' and Customers' base of the Studied Company

Currently, 12 staff members work for the studied company under four main departments which are sales, accounting & administration, purchasing, and warehousing. The organization chart is shown in *Figure 1.3*. The number in the blanket is the number of team members in the department.

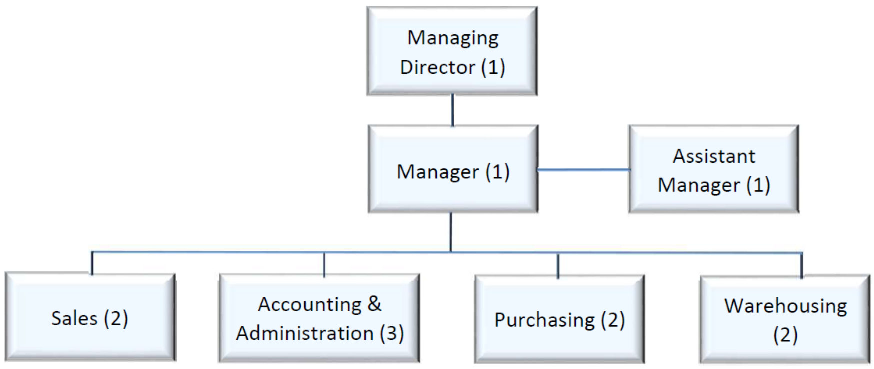


Figure 1.3 Organization Chart of the Studied Company

1.2 PRODUCT PROFILE

The studied company, based in Thailand, provides over 1,800 SKUs (Stock Keeping Units) of products for restaurants which can be divided into four groups, sorted by usage as follows.

- **Kitchen equipment and machines**, such as built-in stove and sushi machine.
  These products are used for food preparation purposes supplied by headquarters in Japan. Generally, the product design is specific with long usage life. The company places orders of these products only on customer demand. Thus, there is no stock for the equipment and machines.
- **Tableware**, such as glasses, pottery, and ceramics.
  The company offers Japanese-style tableware, which is for setting tables and serving food, or even decorative purposes. The products are supplied by the headquarters in Japan and local suppliers. They are generally stocked in the company warehouse (Thailand).
- **Food packages and disposable products**, such as paper cups and plates, and plastic bags.
  These products are for containing food and drinks supplied by the headquarters in Japan, a subsidiary company in Singapore, and local suppliers. They are usually made of paper, plastic, or any disposable materials. The inventory of these types of products occupy most of the company's space in its warehouse. In addition, a concerning factor is that a long holding period deteriorates the product's quality.
- **Frozen products**, such as steak sauce, curry sauce, tomato sauce, and teriyaki sauce.
  The frozen products, which are supplied by local suppliers, require appropriate conditions to be stored. The company has to rent a freezer room in order to keep them.

1.3 INVENTORY INFORMATION

1.3.1 Inventory Classification by Operation

The suppliers' locations, especially Japan and Singapore, directly affect to the transportation time and operational cycle. Imported goods require a longer transportation time of 45 days, while local products require a shorter transportation time of 2 to 7 days depending on the suppliers' location.

Furthermore, frozen products supplied by local suppliers require a lead time of 30 days. They are kept in a rental freezer room (outside of the company's warehouse) and have an additional constraint of the product lifespan (6- 8 months). *Table 1.1* illustrates the details of the various suppliers' locations and storage places.

Table 1.1 Details of Supplier Locations and Storage Places

Groups of Product	***Supplier locations***	***Storage***
Kitchen equipment and machines	Japan	Warehouse
Tableware	Japan, Thailand	Warehouse
Food package and disposable products	Japan, Thailand, Singapore	Warehouse
Frozen products	Thailand	Freezer room

In addition, there is a group of spare parts stocked in the warehouse for machine maintenance services, for non-selling purposes. Thus, there exist 5 groups of inventories classified by the operations that are as follows;

1) Products from Japan
2) Products from Thailand
3) Products from Singapore
4) Frozen products
5) Spare parts for kitchen machines

1.3.2 Inventory Record of 2015

The company uses CD Organizer software for accounting information system. The types of product record extracted from the software are shown in *Table 1.2*. Groups of product are classified as section 1.3.1. The record shows the total 1,805 SKUs in 2015. Japanese products rank the highest in terms of numbers of items (67 percent of the total SKUs), while frozen products rank the lowest with 1 percent of the total SKUs.

It is observable that more than half of the total SKUs (58 % of the total SKUs) are defined as short-period inventory which the products are ordered on the customers' request only. The order quantities are typically equal to the customers' orders. In other words, these products require no stock. They are placed in the warehouse for a few days before being delivered to the customers.

Moreover, the last column shows that there is 10 percent of total SKUs having no sale record over the year. Most of them are products from Japan which are 106 SKUs.

Table 1.2 Inventory Record of 2015 Extracted from CD-Organizer Software

Groups of Product	***Types of Product***	***%Total***	***Short- period inventory***	***%Group***	***Non-moving inventory***	***%Group***
Products from Japan	1217	67%	769	73%	106	56%
Products from Thailand	407	23%	231	22%	15	8%
Products from Singapore	55	3%	6	1%	0	0%
Frozen products	25	1%	8	1%	0	0%
Spare parts for kitchen machines	101	6%	33	3%	68	36%
Total	***1805***		1047	**58%**	189	**10%**

In addition, the company performs physical stock checking, on the last Saturday of every month. The periodic stock recorded by types, amount, and value are illustrated in *Figure 1.4 1.5, and 1.6* respectively.

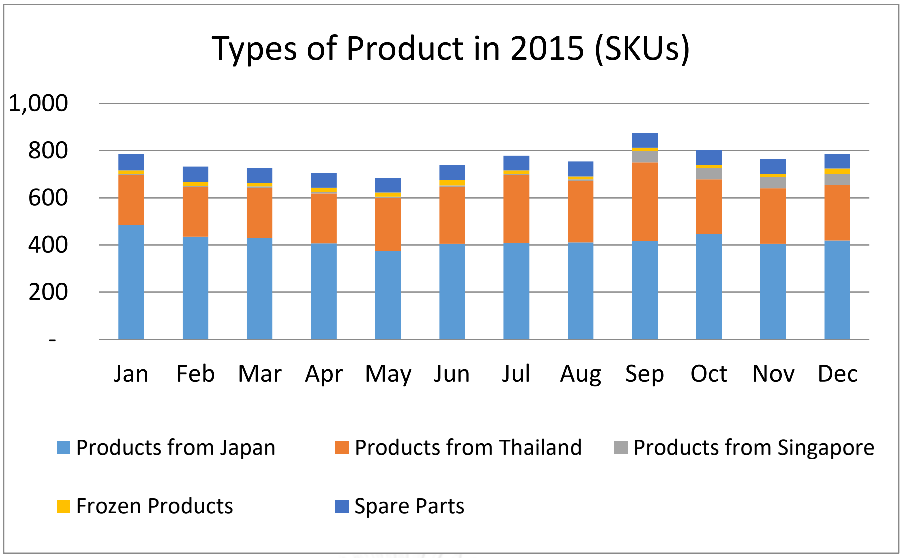


Figure 1.4 Types of Product Record in 2015 (SKUs)

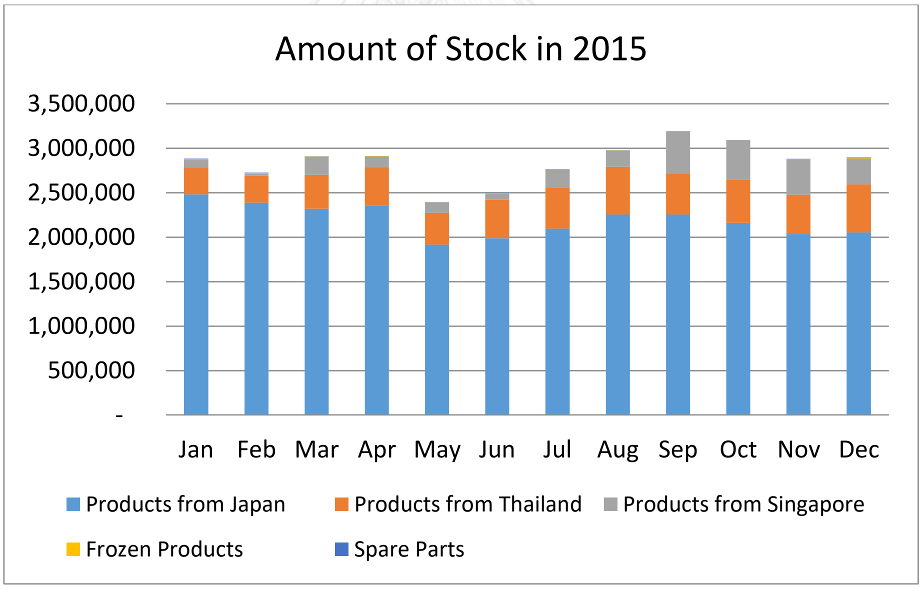


Figure 1.5 Amount of Stock Record in 2015

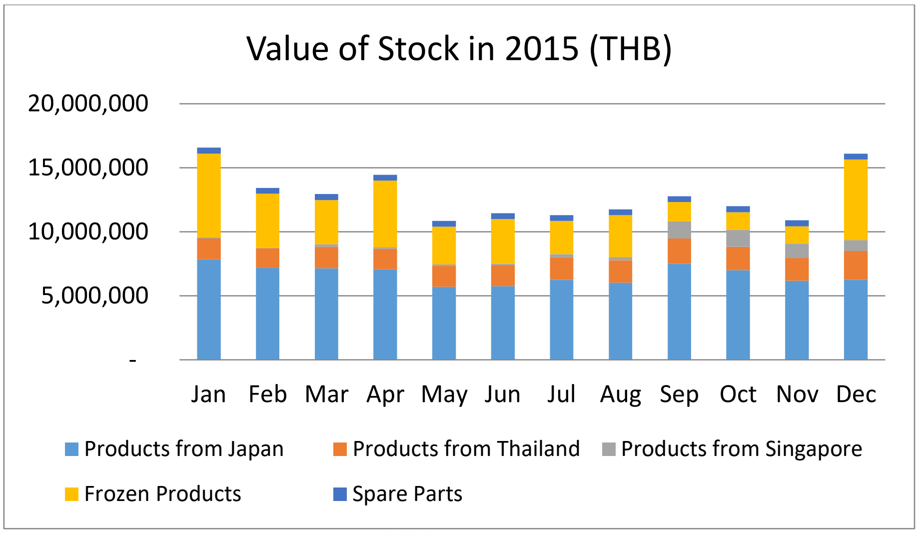


Figure 1.6 Value of Stock Record in 2015

The graphs demonstrate that products from Japan are the highest in terms of types, amount, and stock value. Products from Thailand rank the second in terms of types and amount. However, it can be seen that frozen products have the highest value per unit since its low number of unit ranks the second in terms of value. On the other hand, products of Singapore are gradually increasing in the inventory. Lastly, the group of the spare parts records stays steady in 2015.

1.4 STATEMENT OF PROBLEM

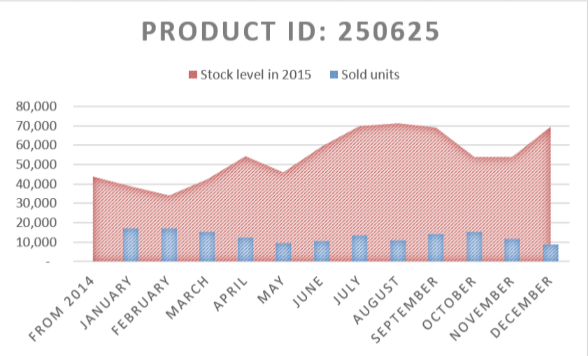
1.4.1 Problem Identification

Regarding historical data, it is evident that some products are ordered and stocked in abundance compared to customer demands causing unnecessary expenses for stock holding such as the cost of units, warehouse cost, opportunity cost and risk of inventory holding cost. However, contrarily, stock outs also occur with some products as shown by the 2015 record. It results in shortage costs, including lost opportunity for sales and creating customer dissatisfaction. As a result, the company aims to improve its inventory system in order to improve their overall operational performance and achieve the higher profits.

In order to illustrate the problem of the current ordering system that results in high level of stock and stock out events, six examples of stock keeping units in 2015 are shown in *Figure 1.7 and 1.8*. *Figure 1.7* shows three units that had high inventory level compared to the demand level, whereas *Figure 1.8* shows three units that had their inventory level go down to zero in 2015.

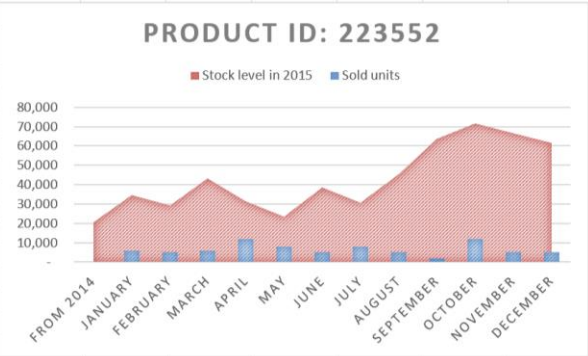
a) Product ID: 250625

	Product ID: 250625		
Month	Order In	Sold units	Stock level in 2015
from 2014			43,900
January	12,000	17,000	38,900
February	12,000	17,000	33,900
March	24,000	15,400	42,500
April	24,000	12,300	54,200
May	1,100	9,400	45,900
June	24,000	10,600	59,300
July	24,000	13,300	70,000
August	12,000	10,800	71,200
September	12,000	14,100	69,100
October	-	15,200	53,900
November	12,000	11,800	54,100
December	24,000	8,600	69,500



b) Product ID: 223552

	Product ID: 223552		
Month	Order In	Sold	Stock level in 2015
from 2014			20,600
January	20,000	6,000	34,600
February	-	5,300	29,300
March	20,000	6,000	43,300
April	-	12,000	31,300
May	300	8,000	23,600
June	20,000	5,000	38,600
July	-	8,000	30,600
August	20,000	5,000	45,600
September	20,000	2,000	63,600
October	20,000	12,000	71,600
November	-	5,000	66,600
December	-	5,000	61,600



c) Product ID: 375080

	Product ID: 375080		
Month	Order In	Sold	Stock level in 2015
from 2014			697
January	-	24	673
February	-	52	621
March	-	10	611
April	-	5	606
May	-	80	526
June	180	22	684
July	180	76	788
August	-	265	523
September	-	12	511
October	720	61	1,170
November	360	121	1,409
December	120	11	1,518

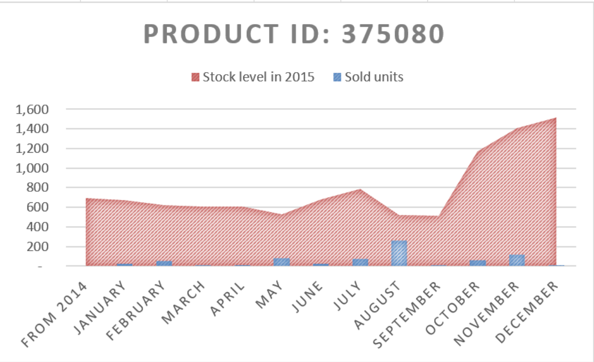
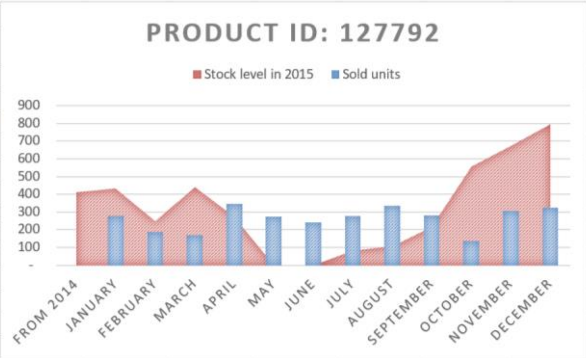


Figure 1.7 Examples of Overstock Record in 2015

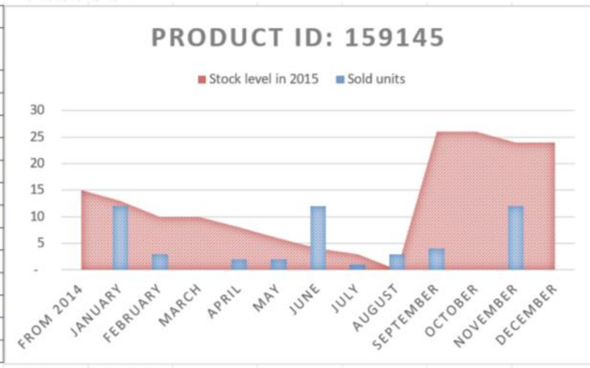
a) Product ID: 127792

	Product ID: 127792		
Month	Order In	Sold	Stock level in 2015
from 2014			411
January	300	276	435
February	-	186	249
March	360	168	441
April	180	348	273
May	-	273	-
June	240	240	-
July	360	277	83
August	360	336	107
September	390	282	215
October	480	138	557
November	420	306	671
December	450	324	797



b) Product ID: 159145

	Product ID: 159145		
Month	Order In	Sold	Stock level in 2015
from 2014			15
January	10	12	13
February	-	3	10
March	-	-	10
April	-	2	8
May	-	2	6
June	10	12	4
July	-	1	3
August	-	3	-
September	30	4	26
October	-	-	26
November	10	12	24
December	-	-	24



c) Product ID: 230136

	Product ID: 230136		
Month	Order In	Sold	Stock level in 2015
from 2014			1,950
January	1,800	300	3,450
February	1,800	1,400	3,850
March	-	700	3,150
April	600	2,400	1,350
May	-	900	450
June	600	1,050	-
July	1,200	1,200	-
August	1,800	600	1,200
September	1,200		2,400
October	600	800	2,200
November	1,200	1,200	2,200
December	2,400		4,600

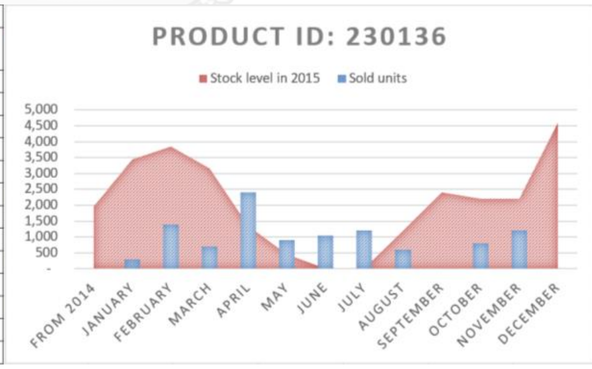


Figure 1.8 Examples of Stock-out Record in 2015

1.4.2 Root Causes Analysis

According to the problem statement in the previous section, root causes analysis is performed, as shown in *Figure 1.9*, in order to identify the viable improvement. Information is collected from interviews with the manager, warehousing operators, sales, and purchasing departments' staff. The causes of current problems are separated into internal and external factors. Internal factors concern internal operations, whereas external factors represent external environmental circumstances affecting the organization.

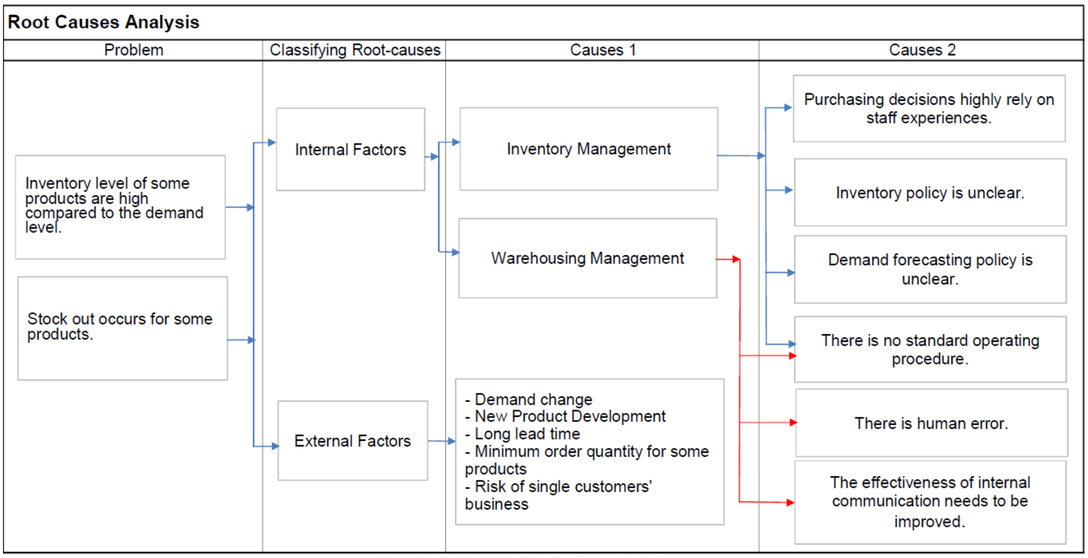


Figure 1.9 Root Causes Analysis

To begin with, internal operations consist of inventory management and warehousing management. The potential causes are listed in *Figure 1.9*. It is observable that the current inventory policy and demand forecasting are unclear. The purchasing decisions are made by a staff member, who highly relies on his experience. Additionally, there is no standard operating procedure for both inventory and warehousing management. Miscommunication and human error can also be found. For example; a stocked product is missing because someone moved it without notifying others.

External factors are change in demands and substitution from newly launched products. Long lead times impact the company's operations since the supplier is the headquarters located in Japan.

The minimum order quantity in this context means some items cannot be ordered in a single unit as they are supplied by packs or boxes. Then, the number of orders would be counted by the products' pack.

In addition, it is seen that there are many products stocked just for one single customer. Some products are screened with the customer logo which poses risks for the company. In the past, there was an incident that the customer's business had to be closed, while the company still carried a large number of the customer's stock.

Typically, external factors cannot be controlled. The operations in organization should have capabilities to cope with changes or issues from their environment, in order to survive in the industry. Hence, improvement of internal operations will be proposed.

Steps for improvement are proposed as shown in *Figure 1.10.* Firstly, standard operating procedure is proposed to clearly identify the roles of employees and improve internal communication. The methodology starts by reviewing the existing overall business operations. Then, the process improvement will be proposed.

Secondly, the inventory policy will be proposed regarding the specified steps. Groups of studied inventory will be identified and classified. Demand pattern will be evaluated. Lastly, the policy will be developed and assessed.

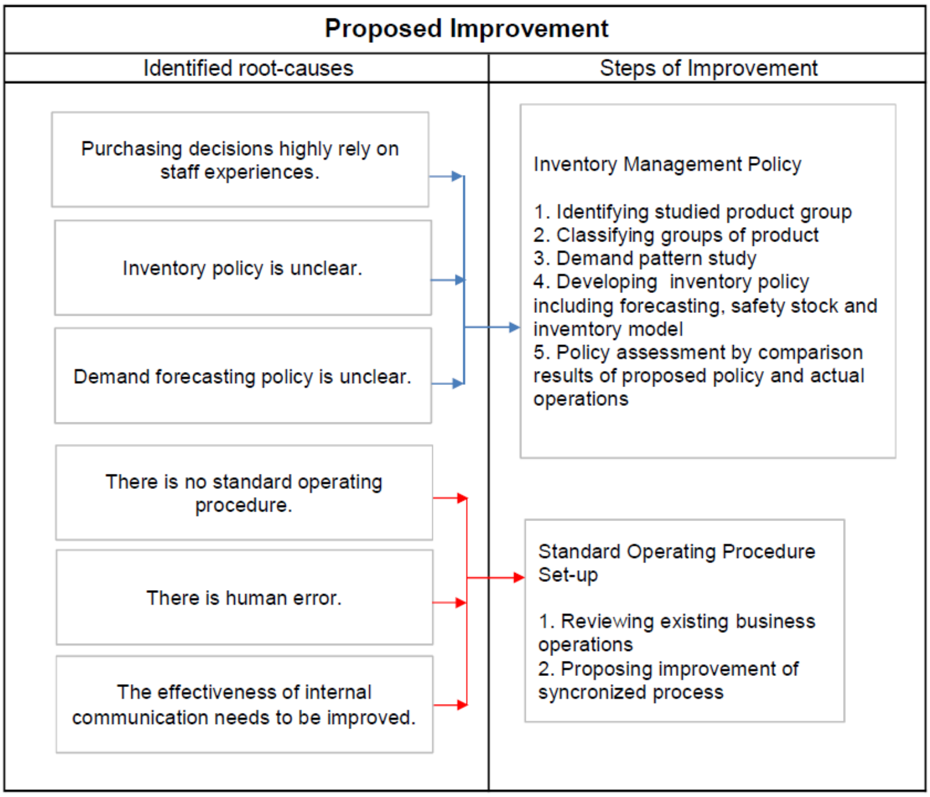


Figure 1.10 Steps of Improvement

1.4.3 Inventory Selection for the Study

According to the inventory classification by operations in section 1.3.1, Japanese products are the most critical items that affect the organization in terms of operations, due to their variety and their use of major areas in the warehouse. Moreover, the challenge of inventory management is the long transportation period of 45 days. It creates the risks and difficulty of the demand estimation. Thus, the products from Japan will be selected for the inventory policy improvement study.

In addition, frozen products have small fractions but high value, but they are not included in the study as the company recently reached a new agreement with the customer resulting in less inventory for this product type.

1.5 OBJECTIVES OF RESEARCH

The objective of the study is to propose an inventory policy improvement for a kitchenware trader based in Thailand. Three key performance index (KPIs) which are inventory level, inventory value and service level will be evaluated the performance of the proposed policy.

1.6 SCOPE OF RESEARCH

This research concentrates on the improvement of inventory system based on evaluation and analysis of the relevant data. The scopes are as follows;

- Japanese products will be the focus group for the study.
- Historical data up to 12 months (2015 data) will be evaluated and used for the research
- Current inventory process and policy will be evaluated.
- Demand characteristics of the studied products will be analysed.
- The inventory policy development will be proposed as follows;
    - Purchasing process improvement
    - Product Classification
    - Proposed managing strategy which includes proper forecasting method, safety stock with sensitivity of customer service level and inventory management policy

The results of the proposed policy will be compared with the company's actual performance for five months (January to May 2016). Discussion and recommendation will be summarised.

1.7 EXPECTED RESULTS AND BENEFITS

- A well-structured inventory policy for the studied company which results in a better inventory control management
- Reduction of inventory holding which results in a reduction of inventory unit cost and cost of holding inventory.
- Better internal communication

1.8 RESEARCH METHODOLOGY

The company overview, product profiles, inventory records, statement of problem, objectives, scope of the study, and expected benefits are demonstrated in this Chapter. This section will briefly outline the steps for the research by chapter in this thesis as illustrated in *Figure 1.11*.

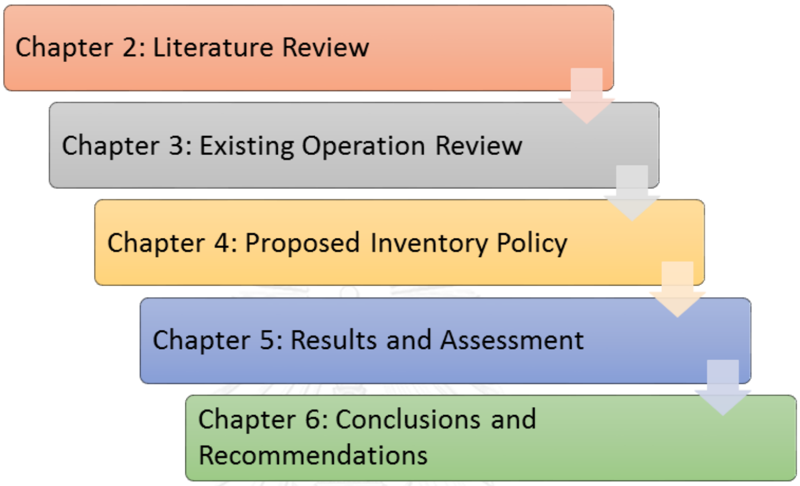


Figure 1.11 Outline for the Research Methodology

Chapter 2: Related theories and tools for inventory and warehouse management will be explored. Forecasting techniques and inventory system will be studied.

Chapter 3: Overall business operation and current operation processes will be demonstrated. Data of Japanese products inventory gathered from physical monthly checking records and retrieved from accountancy software will be evaluated and classified. Strategic management for each group will be proposed.

Chapter 4: Performance index will be identified for the assessment phase. ABC Pareto will be used for item classification. Demand patterns will be studied in order to propose appropriate forecasting techniques and error indicators. Furthermore, basis and assumptions for proposed inventory system will be listed.

Chapter 5: Results are evaluated and summarised for all groups. Identified forecasting errors will be used for forecasting technique verification and selection. Five months (January to May 2016) comparison of actual operation will be shown in a curve of continuous inventory level and periodic bar chart. The daily average inventory level and value will be determined and compared.

Chapter 6: Conclusions, recommendation, study limitations and future study will be described.

Chapter 2
LITERATURE REVIEW

Related theories and studies for the research are reviewed and described in this chapter.

2.1 INVENTORY MANAGEMENT

2.1.1 Importance of Inventory Management

Inventory is a stock of items or products that provide continuity of operations. The utilization of inventory is generally applied in the business world. For example, retail stores have to stock finished goods in order to response to the demand from customers. The ability to immediately deliver products to customers is the most distinctive value proposition (Donner, 2014). Stock out does not only cause an inability to provide products to customers but also causes the company to lose their opportunity to sell their products. Moreover, it might cause the company to lose their market share due to the decrease in customer satisfaction. On the other hand, it is essential for controlling economic inventory level (just enough). If the inventory level is above necessary (over-stock), it can create excessive costs to the operation. Some products also become expired or deteriorated when holding for a period.

Several purposes of inventory are summarised by Ganesan (Ganesan, 2014) as follows;

- To be capable for the demand fluctuations or shortage
- To ensure the unreliability of supply
- To take advantage of lot size discount
- To smooth production schedules

Inventory management takes an important role in supply chain management (Acar and Gardner, 2012). Chief Supply Chain Officer (CSCO, 2011) gathers the survey on supply chain network inventory management of 225 various sizes of enterprises and business units (under $500 million to over $10 billion). The response of how important of inventory management to the supply chain improvement of their companies is shown in *Figure 2.1*. It is evident that 24% choose it as a top supply chain management priority. More than half of organizations (52%) consider inventory management is highly important.

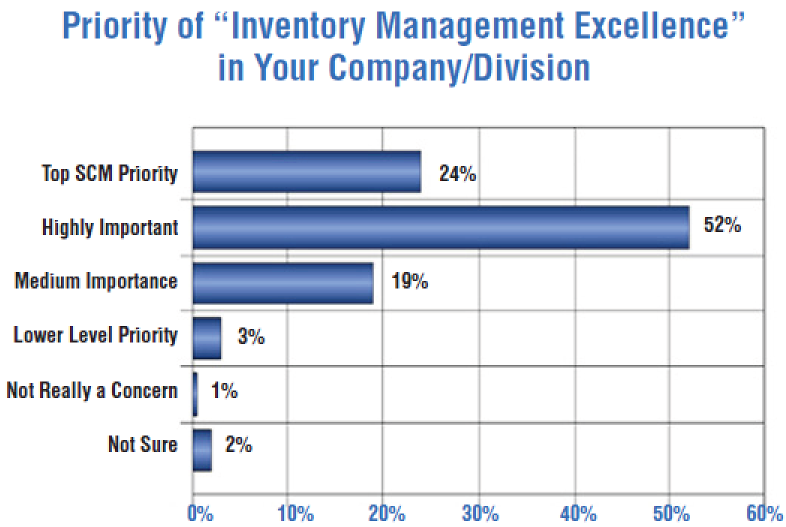


Figure 2.1 Survey Result of How Important of Inventory Management to Supply Chain Management
Source:(CSCO, 2011)

The effective inventory system, good ordering-receipt system, shorten inventory lead time and building forecasting accuracy can also increase sales production because salespeople do not have to spend time on stock reconfirmation to clients or order changing which allow them to contribute more to customer services (Jacobs and Chase, 2013).

Relph and Milner (Relph and Milner, 2015) identified three pillars (core activities) covered by inventory management;

- ***Inventory Planning***: is about defining the optimum levels of inventory which requires an understanding of product process flow, sales volume, and demand pattern. Planning need to be identified based on variously considered parameters such as frequency of order, safety stock policy, lead time, and minimum order quantity.
- ***Inventory Control***: is about managing the accuracy of the inventory data and physical inventory movement. Information alignment is crucial for inventory management as it can provide an effective operation. The well-structured system of record could help the organizations know where and what quantities they holding.

- ***Inventory Balancing***: is about managing and monitoring the inventory as a plan. The good business system would help inventory balancing management such as clear inventory planning policy and accurate inventory control.

The general process flow of inventory consists of three steps; Forecast, Plan and, Execute as shown in *Figure 2.2*.

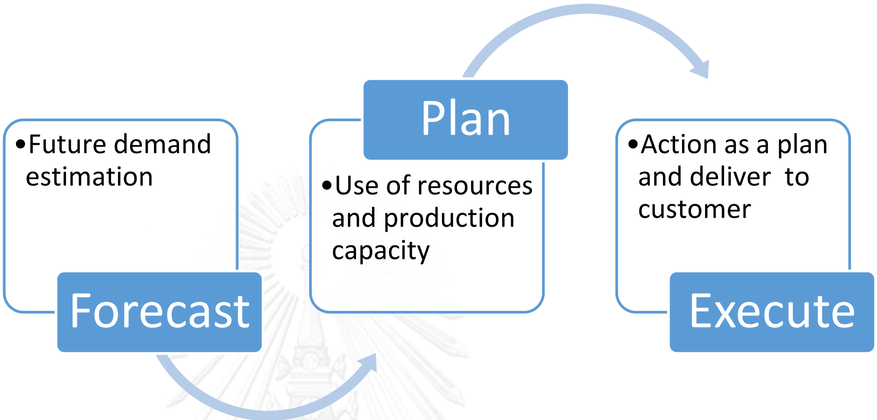


Figure 2.2 General Inventory Process Flow
Source: Adapted from (Relph and Milner, 2015)

2.1.2 Inventory Cost

Inventory cost is an important factor to perform inventory management (Abbasi, 2011). Relph and Milner (Relph and Milner, 2015) identified four main types of cost related to inventory cost.

1. ***Inventory Unit Cost*** – The cost per unit of holding products. In general, the larger order is the lower unit price.
2. ***Ordering Inventory Cost / Cost of Set-up*** – Associated cost of order replacement is considered as an ordering cost such as the cost of placing an order, packaging, transporting and receiving items. The cost of set-up is a machine or workstation set-up cost including consumed time and resources. EOQ or Economic Order Quantity is a tool to find the optimum ordering cost (section 2.6).
3. ***Inventory Holding Cost*** – There are many related activities considered in inventory holding cost like warehousing, handling cost (renting, insurance,

lighting or heating), tied up cost of inventory (working capital cost), risk costs (obsolete stock, deterioration) and opportunity costs (lost opportunity to invest in other areas).

The inventory holding cost is typically estimated as a percentage of the value of an item which is inaccurate since the cost may change from one accounting period to the next. Holsenback and McGrill (Holsenback and McGill, 2007) suggested that the determination by a percentage of value of inventory normally includes only variable cost. Fixed costs such as space, capital equipment, and personnel are essentially fluctuate with inventory volume, but it also depends on the industry and type of inventory.

4. ***Shortage Cost* –** It occurs when the inventory is not enough for the demands. The costs include cost of sales and cost of lost opportunity for sales. Moreover, it could result in customer dissatisfaction and affect to the relationship in the long run. Safety stock should be used for inventory management in order to prevent inventory shortage.

2.2 DEMAND FORECASTING

Forecasting is a process of future estimation or prediction which involves subjective nature and uncertainties. The subjectivity of forecasting can be explained like the differentiation of forecasting method selection, variable assumptions, knowledge and considered factors which are hard to be quantified and results various forecasting outcome (Welch, 2015).

The common purpose of forecasting is to have the least number of inventories which could serve customers' demand and would minimise inventory buying cost, inventory holding cost, and changing in the master schedule (Thomopoulos, 2015). Moreover, it is critical for an organization to have effective forecasting process in order to generate forecasting accuracy and organizational capability to fast react to a deviation from forecast (Shobrys and White, 2002). Forecasts can be used for many organizational functions; marketing, sales, production/purchasing, finance, manpower and etc.

Forecasting approaches can be categorised into two types; *Qualitative Forecasting Method* (Subjective) and *Quantitative Forecasting Method* (Objective). *Figure 2.3* demonstrates forecasting types.

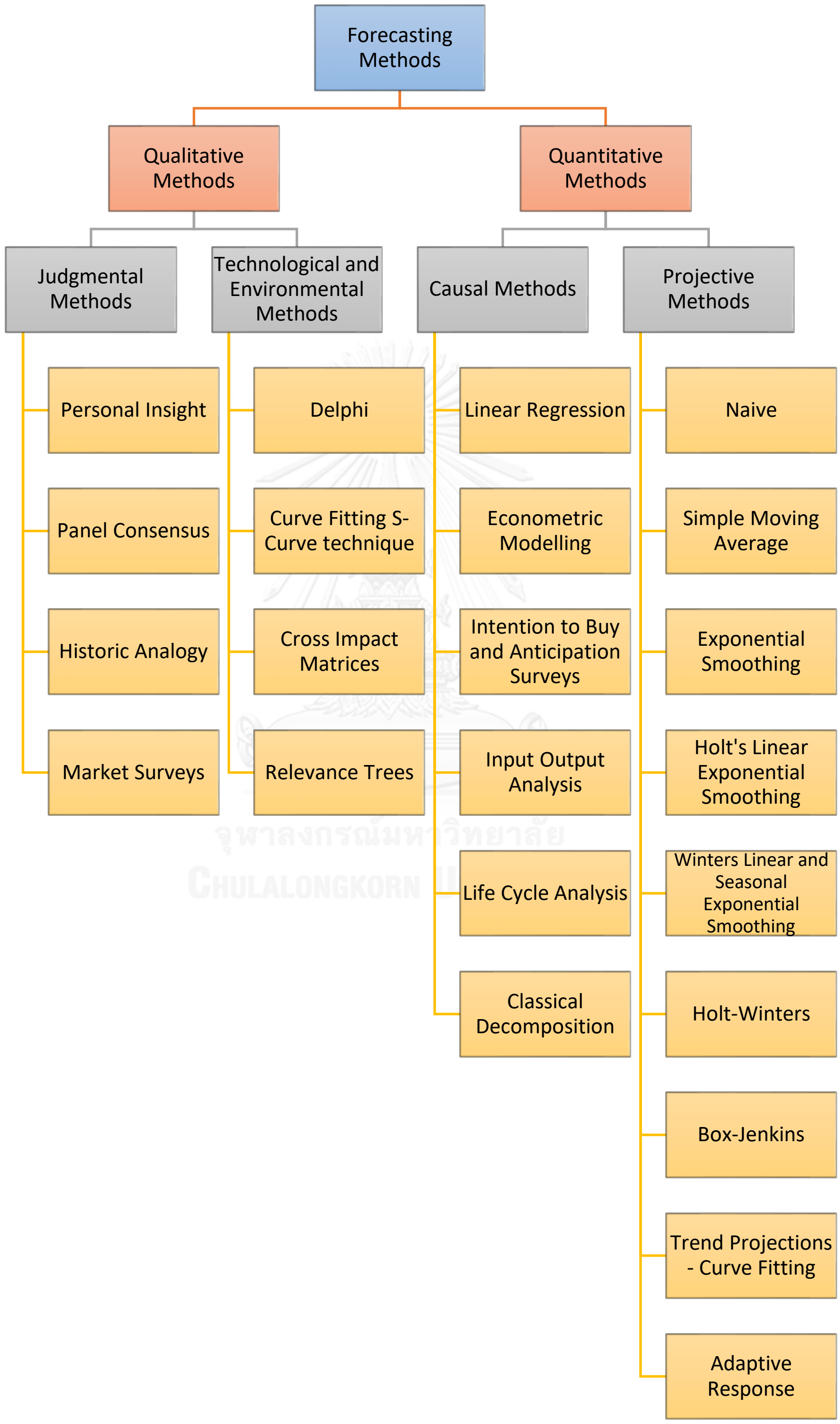


Figure 2.3 Forecasting Methods Category
Source: Adapted from (Welch, 2015)

Armstrong (Armstrong, 2001) compared and examined six ways of forecasting approach selection; Convenience, Market popularity, Structured judgement, Statistical Criteria, Relative track record and Guidelines from prior research.

The research found that convenience and market popularity are not recommended. Convenience is hard to demonstrate the logical details since it depends on perception decision and skills of the forecasting performer. Convenience also may lead to large errors from the large environmental change. The method could be selected based on convenience only when the situations are stable and the expectation of accuracy is not critical. Market popularity is what others do. It is not recommended because the conditions and details of what others do are not generally described. Also, their success of uses is not mentioned. Lastly, selection based on market popularity is the opponent of innovation.

Structured judgement, Statistical criteria, Relative tracking record and Guidelines from prior research can help in selecting method. Criteria of structured judgement such as accuracy, ease of use, flexibility and related cost consideration can be suitably specified for the individual system and organization. Score rating for the selection result should be made by an expert without prejudice. Statistical criteria approach is appropriate only for some situations such as a comparison between qualitative and quantitative method. It is not recommended for the narrow selecting method.

Relative track record is to compare the actual record to various forecasting techniques. It is important to have enough historical data and concern factors for the demand change in the business. Guidelines from prior research are also the useful way and result the lower cost for operations.

In addition, Acar and Gardner studies (Acar and Gardner, 2012) concluded that forecasting method selection based on the operational performance must be evaluated by trade-off between cost and service for the whole supply chain.

2.2.1 Qualitative Methods

The future prediction of qualitative approaches is typically based on gathered information from experiences, relationships, judgement and pattern intuition while quantitative approaches are concerned with estimating based on historical data (Welch, 2015). Two situations which qualitative methods could be applied suggested by Welch (Welch, 2015) are;

1. When there is no qualified and reliable quantity data or new market/product development.
2. When quantitative historical data is available but there could be other factors affecting the future occurs. In the other words, there is a reason that extrapolation of the past cannot be used for predicting.

There are some concerns about the qualitative methods using. Firstly information gathering has to be clear. Questions misunderstanding of surveys can occur because it cannot be counted by numbers. Secondly, the judgement also should be carefully considered. Overconfidence can be the enemy of precise forecasting. Lastly critical evaluation of decision-making process should be developed for the predictions. In-Group decision-making may be influenced by high cohesive or strong leadership group which may lead to deviation from consensus (Welch, 2015).

2.2.2 Quantitative Methods

Quantitative method requires the historical data to be analysed in order to project future quantities and trends. There are two types of methods; causal and time series.

Causal Models

The concept of causal models is knowledge of two or more variables relationships and able to identify what factors affect better prediction than others. For example; Sales volume would increase as advertising spending. Simple equation can be written;

Volume of Sales = A + (B x advertising spending)

Where A: sales without advertising

B: amount of unit that could increase as advertising spending

Users should concern that there is a limit of how much of advertising can raise the sales volume. Maximum cap is market size. Regression analysis is the main technique for causal models. However, causal variable identification requires long process and expensive cost. According to Armstrong (Armstrong, 2001), all seven case studies from long-term forecasts (large change) results that causal methods are more accurate than naïve method.

Time Series Methods

Repetition of past pattern of demand relies on time series method forecasting. Then this method is suitable for steady conditions and short-period forecasting (Welch, 2015).

Hyndman et al. (Hyndman et al., 2008) suggested four types of time series pattern as follows;

- ***Trend (T):*** The demand gradually increasing or decreasing over the time or a long-term direction of the series.
- ***Seasonal (S):*** A demand variation that repeats by day, week, month or year
- ***Cycle (C):*** A pattern that repeats with unknown changing periodicity (such as business cycle)
- ***Irregular or error (E):*** A random demand, neither increasing nor dropping over time and average demand is relatively steady.

Several time series methods are described as follows;

1) Naïve approach: The prediction of the next review period is equal to the last period

$$F_{t+1} = A_t$$

where F_{t+1}: Forecast for next period

A_t: Actual demand for present period

2) Simple moving average: The average of historical demand in a specific period is used such as 3 months and 5 months. The longer period suits to the steady

demand characteristic since it would result in slower to response the demand change.

$$F_{t+1} = \frac{1}{n}\sum_{i=0}^{n-1} A_t = \frac{1}{n}\left(A_t + A_{t-1} + \cdots + A_{t-n+1}\right)$$

where F_{t+1}: Forecast in period t+1

A_t: Actual demand in period t

n : The number of period used for forecast

3) Simple exponential smoothing: All observations are used for forecasting. The weight of observations is heaviest for the most recent data and exponential decreased for the older data. Alpha (α) is the weight factor which typically values between 0 and 1.

   a. If the alpha is equal to 1, the previous observations are entirely neglected (Kalekar, 2004). The forecasting results will only rely on the most recent data. Thus, the forecasting will be the same Naïve method.

   b. If the alpha is equal to 0, the current observation is ignored. All forecasting results will be equal to the initial value.

$$F_{t+1} = \propto A_t + (1 - \propto) F_t$$

where F_{t+1}: Forecast in period t+1

F_t: Previously forecast demand in period t

A_t: Actual demand in period t

$\propto$: Weighting factor, smoothing constant

4) Double exponential smoothing (Holt's method): This method suits for the data that has a trend. Two dimensions which is a smoothed estimate of value and growth are considered (Kalekar, 2004). The concept works quite similar to the simple exponential smoothing except it updates two components each period.

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

$$F_{t+1} = \propto A_t + (1 - \propto)F_t$$

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

where

AF_{t+1}: Double exponential smoothing forecast in period t+1

F_{t+1}: Forecast with basic exponential smoothing

F_t: Previously forecast demand in period t

A_t: Actual demand in period t

$\propto$: Weighting factor, smoothing constant

T_{t+1}: Exponential smoothing trend factor

T_t: The last period trend factor

β : Smoothing constant for trend

5) Croston's method: A popular method for the data that contains many zeros or intermittent demand is developed by Croston (Croston, 1972). The method takes account of demand magnitude and inter-arrival time between demands. It applies simple exponential smoothing separately to each derived time series. The forecast result is the ratio of the non-zero forecast demand and the time gap.

$$CF_{t+1} = Z_t/P_t$$

If $A_t = 0$

$$Z_t = Z_{t-1}$$

$$P_t = P_{t-1}$$

If $A_t > 0$

$$Z_t = \propto A_t + (1 - \propto)Z_{t-1}$$

$$P_t = \alpha N_t + (1 - \alpha)P_{t-1}$$

where

CF_{t+1}: Croston forecast in period t+1

Z_t: Forecast magnitude of the individual transaction in period t

Z_{t-1}: Forecast magnitude of the individual transaction in period t-1

A_t: Actual demand in period t

$\propto$: Weighting factor, smoothing constant

P_t: Forecast number of period of trancsaction occur in period t

P_{t-1}: Forecast number of period of transaction occur in period t-1

N_t: Actual number of period since last transaction

It is common to understand that there is no universal forecasting approach. Factors and situation should be considered for method selection such as available time, data pattern, budget, the size of information intended use (control/planning), and accuracy needs. Adequate effort for forecasting should be spent. Excessive resources and time will be a waste for the organization. The importance of required forecasting accuracy needs could be based on the volume of products (vary to the value of money) and customer categorization.

The whole planning flow in the organization including production and inventory management should be analysed for defining the whole process of forecasting (Kerkkänen et al., 2009). Capacity utilization should be concerned with both planning and forecasting. Information sharing and keeping update among supply chain of planning, forecasting and inventory replenishment can improve forecasting effectiveness (Shobrys and White, 2002).

2.2.3 Forecasting Error

Perfectly correct forecasting is almost impossible. There are tons of different factors which could affect the actual demand. However, demand forecasting is better than do nothing. Blinding operation without critical consideration is surely not a good idea. As mention above there are many forecasting methods. Forecast error is to justify what method is suitable for each specific demand.

The forecast error (e) is the difference between the actual value (a) and forecast value (f) observed at the same period. It came from the idea that actual demand is a sum of forecast value and forecast error.

$$e = a - f$$

There are four main forecast error measurements (Hyndman, 2006).

- Forecast Error Metrics i.e. MAE or MAD
- Percentage Error Metrics i.e. MAPE
- Relative Error Metrics i.e. MdRAE, GMRAE
- Scale-Free Error Metrics i.e. MASE

MAE or MAD (Mean Absolute Error or Mean Absolute Deviation)

$$MAD = \frac{1}{n}\sum |actual - forecast|$$

$$MSE = \frac{1}{n}\sum |actual - forecast|^2$$

MAD determines the size of the error in units. It results in the same standard deviation of the system (scale dependent) (Donner, 2014). It suits to intermittent and low-volume data. The caution of this method is when measuring MAD for multi-products, high volume items may dominate the results which could lead to data misinterpretation (Stellwagen, 2011). Other scale-dependent error methods are GMAE (Geometric Mean Absolute Error) and MSE (Mean Square Error).

MAPE (Mean Absolute Percent Error)

MAPE method is to measure the size of the error in percentage.

$$MAPE = \frac{1}{n}\sum \frac{|actual - forecast|}{|actual|} \times 100$$

This method can illustrate error in the proportion of total units. The comparison of forecast performance between different series could be performed. MAPE is scale sensitive. It does not suit for a low number of units or data because actual is the denominator. For example, the actual value is very low, it can result greatly MAPE result. MAPE is also unidentified if the actual demand is zero (Stellwagen, 2011). Hence, MAPE is inappropriate for intermittent demand information.

MdRAE (Median Relative Absolute Error)

Relative errors are an alternative method involves each error divided by the error from benchmarking of forecasting.

error*: forecast error obtained from benchmark method

$$MdRAE = median(\frac{error}{error *})$$

<u>*MASE (Mean Absolute Scaled Error)*</u>

Scale-free error (MASE) was proposed by Hyndman (Hyndman, 2006). The method suits for intermittent series. One-period-ahead forecast is generated from each data point by naive method.

$$MASE = \frac{1}{n}\sum \frac{error}{\frac{1}{n-1}\sum_{i=2}^{n}|actual_i - actual_{i-1}|}$$

Measuring errors for multi-items can be generally seen in the real business world. MAPE method potentially creates a problem with low amount items (resulting in high MAPE). The simple solution is to weight each item MAPE. Another practical solution is product categorization (ABC Pareto Analysis) to separate groups of products by volume, activities, sales or else.

2.3 ABC PARETO ANALYSIS

Warehouse activity profiling or ABC analysis is a statistical measurement of warehouse activity (Bartholdi III and Hackman, 2011). The main idea for inventory management is to identify groups of product in A, B, and C by using usage value of inventory management and procurement (Richards and Grinsted, 2013). It is usual of Pareto law that a small percentage of units sold to account high percentage of value of units (Muckstadt and Sapra, 2010). The usage value is the product of usage over the period of time. The determination needs to understand workload in the facilities, consumed resources, and customers ordering pattern. The period of time could be a year, a month or a week depending on the business characteristic. Results of classification are; A (small proportion of most activity usage), B (medium usage) and C (a large fraction of few usage value).

The model can apply for several alternative criteria related to the operations such as quantity of inventory, value of sales, frequency of sales, number of customer request and etc. *Figure 2.4* illustrates an example of ABC Pareto application to the sales value information.

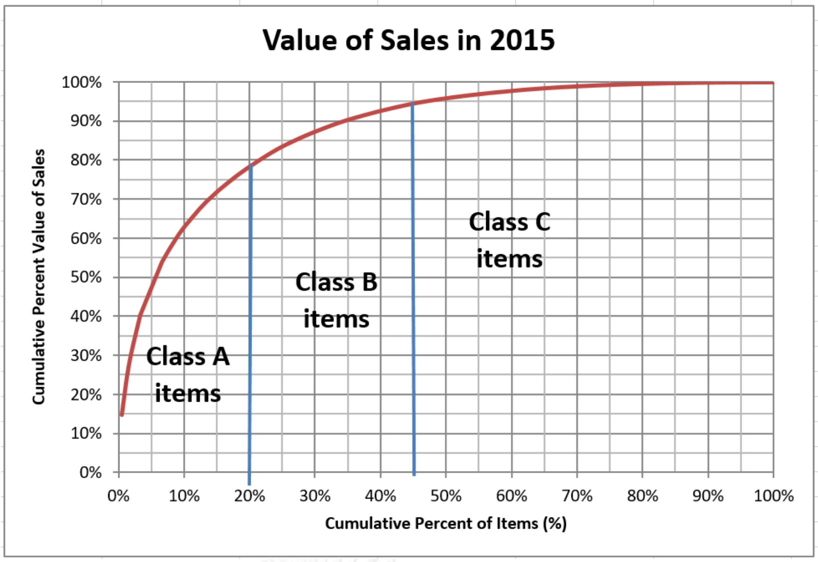


Figure 2.4 ABC Pareto Analysis
Source: Adapted from (Muckstadt and Sapra, 2010)

ABC analysis is a beneficial tool for inventory management. It can be used for balancing between administrative effort (consumed manpower for planning and ordering) and replenishment inventory (cycle stock level and inventory holding cost) (Richards and Grinsted, 2013). Moreover, the product classification can be used as a factor for storage decision for warehouse or retail shops which benefit for the operations.

According to Flores and Clay Whybark (Flores and Clay Whybark, 1986), ABC multi-criteria approach is proposed when there is more than one important dimension for categorization. An example is given in *Figure 2.5*. Ten items are categorised by dollar usage and lead time. The purpose is still to reclassify the items in three groups; AA, BB, and CC. An item like part number 3 could be applied numerical combinations of two dimensions. This example reclassifies A-B and B-A as A-A, A-C and C-A as B-B, and B-C and C-B as C-C. Item by item basis should be judged in order to achieve the reclassification.

The successful of the framework application was mentioned in a manufacturing in Mexico (Flores and Clay Whybark, 1986). Previously, the annual dollar usage had been the only criteria for the part classification. The company experienced shortages. The analysis showed the missing items were in C Class. Then, the company applied the second criteria of lead time in the categorisation. The new policy apparently improved the inventory investment and availability of the items since the lead time effect to the schedule change, obsolescence, and market fluctuations.

Part No.	Dollar Usage	Lead Time
1	B	A
2	C	C
3	A	C
4	B	B
5	A	A
6	B	C
7	C	B
8	C	C
9	C	B
10	C	C

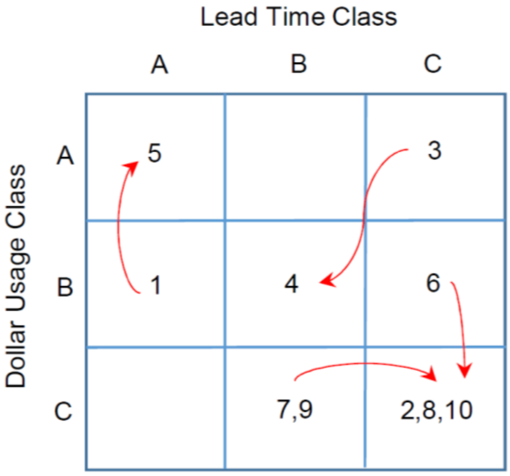


Figure 2.5 A Joint Criteria Metrix
Source: Adapted from (Flores and Clay Whybark, 1986)

Last but not least, application of the model is crucial to consider related operational and external factors like product life cycle and changes of consuming behaviour. Repetition of group classification should be performed in a suitable period of time.

2.4 INVENTORY SYSTEM

2.4.1 Typical Inventory System

Inventory planning process and replenishment policies are closely related. The ideal scenario is to establish the decision of inventory planning process which replenish the stock at the most optimum level. Jacobs and Chase (Jacobs and Chase, 2013) described three techniques for variable demand inventory management model;

Single-period model: The model is for products which have one time purchasing such as newspapers (renew every day), t-shirt for a sports event for one-time event, airline flights, and etc. The product demand will be zero after a specific time.

Fixed-order quantity model (Q model): The model is multi-period inventory system for maintaining in-stock items. It is a continuous review policy. The economic order quantity (EOQ) would be defined. The certain amount of order will be placed when the inventory drops to reorder level at any time.

Fixed-time period model (P model): The model is multi-period inventory system for maintaining in-stock items. It refers to periodic review system, fixed-order interval system, and P model. The inventory would be ordered in a particular period of time. The Certain time interval delivery is beneficial for a group of items which could be ordered together. Ordering cost can be saved such as resource, warehousing moving and etc.

The comparisons between two techniques for multi-period inventory models are illustrated in *Figure 2.6*. Expensive items or critical spare parts best suit with fixed-order quantity system as average inventory level is lower than fixed-time period model (Klassen and Menor, 2006). Fixed-order quantity system requires monitoring closely and fast responsiveness to potential stock-out. Then fixed-order quantity system would consume more time and resources compared to the fixed-time period system.

Feature	***Q-Model Fixed-Order Quantity Model***	***P-Model Fixed-Time Period Model***
Order quantity	*Constant (the same amount ordered each time)*	*Variable (varies each time order is placed)*
When to place order	*When inventory position drops to the reorder level*	*When the review period arrives*
Recordkeeping	*Each time a withdrawal or addition is made*	*Counted only at review period*
Size of inventory	*Less than fixed-time period model*	*Larger than fixed-order quantity model*
Time to maintain	*Higher due to perpetual recordkeeping*	
Type of items	*Higher-priced, critical or important items*	

Figure 2.6 Comparison of Fixed-Order Quantity and Fixed Time Method
Source: Adapted from (Jacobs and Chase, 2013)

2.4.2 Safety Stock

Safety stock is an amount of additionally carried items for an uncertainty of supply and demand. The intention of safety stock is to mitigate stock out event for the majority (required service level), not for all (King, 2011). Many different criteria can be used to determine safety stock. The simple approach is to identify the level of stock to be kept with consideration of variable demand.

According to Holsenback and McGrill (Holsenback and McGill, 2007), the methodology named "Statistical safety stock" is used to quantify variable factors. The result is determined based on probability, desired service level, and the product life cycle of finished goods. There are four variables considered for the study;

- The desired service level
- The variance of demand
- The lead time for replenishment
- The supplier reliability or process of manufacturing

It is found that the variance of forecast is usually the most impact to the safety stock. The second important factor is the service level. To ensure the high service level, safety stock is increased in consequence. Nevertheless, the more safety stock means the more cost. Hence, the trade-off between inventory investment and desired service level can be performed for the inventory ordering decision.

Regarding the complexity and uncertainty of variables, safety stock formulations model as *Figure 2.7* is proposed by Talluri et al. (Talluri et al., 2004)

		Lead Time	
		Constant	Variable
Demand	Constant	No Safety Stock required	$\bar{d}_L = \bar{d}L$ $\sigma_L = \sqrt{\bar{d}^2 S_L^2}$ $SS = \bar{Z}\sigma_L$
	Variable	$\bar{d}_L = \bar{d}L$ $\sigma_L = \sqrt{\sigma_T^2 L}$ $SS = \bar{Z}\sigma_L$	$\bar{d}_L = \bar{d}L$ $\sigma_L = \sqrt{\sigma_T^2 L + \bar{d}^2 S_L^2}$ $SS = \bar{Z}\sigma_L$

Figure 2.7 Safety Stock Formulations for Different Inventory Model
Source: Adapted from (Talluri et al., 2004)

Where

SS : Safety Stock

L : Lead time for replenishment

$\bar{d}$: Average demand in a review period

$\bar{d}_L$: Average demand during lead time

σ_T : Standard deviation of demand in a review period

σ_L : Standard deviation of demand during lead time

S_L : Standard deviation of lead time

Z : Number of standard deviation for a desired service probability (Areas of the Cumulative Standard Normal Distribution, can use Excel NORMSINV function)

In addition, the application of standard deviation for inventory level estimation is not recommended for seasonal demand pattern since it can result the excessive inventory level as the demand fluctuation (Ganesan, 2014).

2.4.3 Service Level Measurement

Service level is a critical concern for inventory management. Excessive service level results in cost due to too much inventory. On the contrary, inadequate service level may result in loss of opportunity for sales and creating customer's dissatisfaction.

The service level measuring is not absolute depending on the context and objectives of the operation. According to Ronen (Ronen, 1983), inventory service level must be defined and measured in an effective and relevant manner. For example; the retail store measures the service level from lost sales. Unfortunately, it is very difficult to measure. When the customer does not see the product on the shelf, he may just pass by and looks for it from other shops.

There are many ways for service level measuring such as the percentage of the total demand in units, the percentage of the demand in orders, and the percentage of the time spent with stock out over a total period. Typically, there are two types of service level measuring; cycle service and fill rate (Shivsharan, 2012).

Constantin (Constantin, 2016) stated that ABC analysis which categorise groups of product based on important can be assigned its own service level. For example; Group A items are high service level (96 – 98%), group B items are medium service level (91 – 95%), and group C items are lower service level (85 – 90%).

2.5 SINGLE-PERIOD MODEL

Probability approach is generally used for estimating numbers of product which can reduce the risk of stock-out. An example will be given in order to illustrate the determination.

An example is given in order to illustrate the methodology of probability approach;

> *Situation:* The average of weekly magazine demand is 50. A few months record shows that the standard deviation is 4. The sales probability distribution is assumed normal. If magazine retailer stock 50 every week, it will be 50%

chance of stock-out and 50% over-stock. The retailer wants 80% chance of not stock out.

Methodology:

In order to pursue 80% service level, the extra stock will be calculated.

$$\text{The extra stock} = Z\sigma$$

Z : The cumulative standard normal distribution
σ : The standard deviation

The cumulative standard normal distribution of 80% is 0.84. (Microsoft Excel function also can be used (NORMSINV(0.8) = 0.84162)).

The additional stock that retailer should take is equal to 0.84162 x 4 = 3.36648 or 4.

Thus, a total stock keeping units of weekly magazine is 54.

Moreover potential profit and loss can be considered for extra stock consideration.

Situations of profit and loss consideration;

Cost per unit of the magazine is 20 THB (Cost per unit of demand overestimated, Co).

Profit per unit of sold magazine is 30 THB (Cost per unit of demand underestimated, Cu).

Probability (P) is the probability that magazine will not be sold.

Then, 1 – P is the probability that magazine will be sold.

The expected marginal cost equation is;

$$P \leq \frac{C_u}{C_o + C_u}$$

Methodology:

The probability is 30/(20 +30) = 0.6.

The cumulative standard normal distribution of 60% is 0.253.

Thus, the additional stock is 0.253 x 4 = 1.012 or 2.

Therefore, the retailer should stock weekly magazine 52 each week from consideration of potential loss and profit. This model simply considers loss and profit in term of money. In reality, there will be other associated costs which are not simple to convert in value. For example; cost of underestimated may not be only 30 THB, but also customers' preference that this bookstore cannot provide required product. Customers might choose to go to other stores to find the magazine in the future.

2.6 FIXED-ORDER QUANTITY MODEL

The model attempts to calculate the quantity of order (Q) and reorder point (R). According to Jacobs and Chase (Jacobs and Chase, 2013), inventory position consists of on-hand items plus on-order minus back ordered quantity. Followings are assumptions for optimal order quantity. They are unrealistic but they represent the basic concept of the determination.

1. Product demand is constant over the period.
2. Price per unit is constant.
3. Lead time is constant.
4. Ordering cost is constant.
5. Inventory holding cost is referred to average inventory.
6. No back order is allowed

Figure 2.8 illustrates the fixed-order quantity cycle including the relation of order quantity (Q), lead time (L) and reorder point (R).

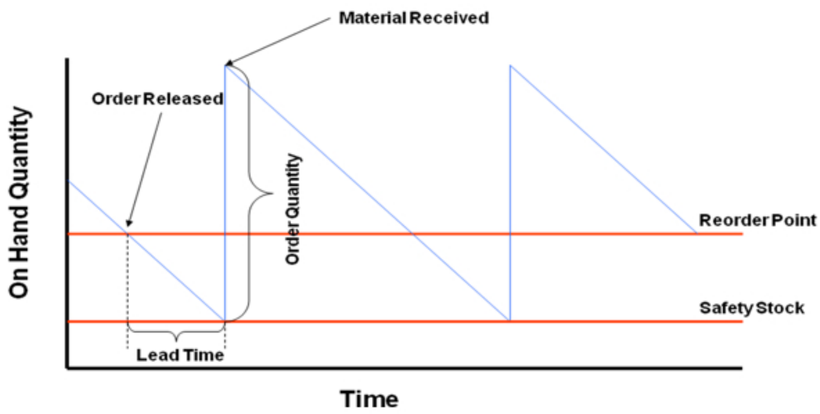


Figure 2.8 Fixed-order Quantity Model

The equation for the inventory model is as follow;

Total annual cost = Annual purchase cost + Annual ordering cost + Annual

$$TC = DC + \frac{D}{Q}S + \frac{Q}{2}H$$

Where

TC	: Total annual cost
D	: Annual demand
C	: Cost per unit
Q	: Order Quantity (EOQ, economic order quantity)
S	: Set up cost or cost of placing order
R	: Reorder point
L	: Lead time
H	: Annual holding cost (generally taken in percentage of cost per unit)

Derivation of the total annual cost by quantity and setting equation to zero results in the Economic order quantity equation (the minimum total cost, Q_{opt}) which is helpful for optimising inventory level (Holsenback and McGill, 2007).

$$TC = DC + \frac{D}{Q}S + \frac{Q}{2}H$$

$$\frac{dTC}{dQ} = 0 + \frac{-D}{Q^2}S + \frac{H}{2} = 0$$

$$Q_{opt} = \sqrt{\frac{2DS}{H}}$$

Reorder point (R) is considered from the effect of lead time and safety stock. The safety stock is needed as the uncertainty of forecast (Thomopoulos, 2015).

Therefore;

Reorder Point = Normal consumption during lead time + Safety Stock

$$R = \bar{d}L + SS$$

According to section 2.4.2;

$$R = \bar{d}L + Z\sigma_L$$

Where

R : Reorder point

SS : Safety Stock

L : Lead time for replenishment

$\bar{d}$: Average demand in a review period

σ_L : Standard deviation of demand during lead time

Z : Number of standard deviation for a desired service probability (Areas of the Cumulative Standard Normal Distribution, can use Excel NORMSINV function)

2.7 FIXED-TIME PERIOD MODEL

Particular interval time is set for inventory ordering. This model is suitable when a buyer wants to combine orders to reduce transportation cost. The stock will be counted at a specific time for review (such as every two weeks, month). It is possible to stock out when highly demand occurs. The actual operations would not be tracked until the next review period. *Figure 2.9* shows fixed-time period model system. Time of review (T) and lead time (L) are constant.

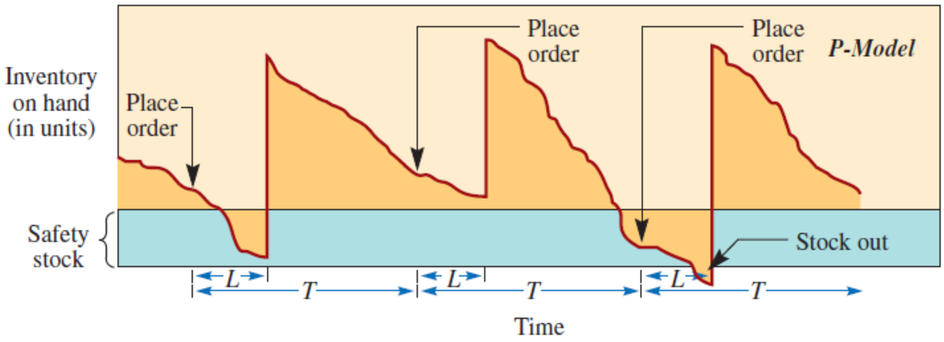


Figure 2.9 Fixed-time Period Inventory Model
Source:(Jacobs and Chase, 2013)

Time of review (T) must be considered in safety stock determination. Safety stock for fixed- time period model is;

$$Safety\ stock\ = Z\sigma_{T+L}$$

The quantity to be ordered will be demand over the period plus safety stock value and minus current inventory. Hence, the equation is;

Order Quantity = Average demand over the period + Safety stock - Current inventory

$$q\ =\ \bar{d}(T + L)\ +\ Z\sigma_{T+L} - I$$

Where

q : Order Quantity

$\bar{d}$: Average demand in a review period

T : The review period

L : Lead time for replenishment

Z : Number of Standard deviation for a desired service probability (Areas of the Cumulative Standard Normal Distribution, can use Excel NORMSINV function)

σ_{T+L} : Standard deviation of demand over the review period and lead time

I : Current inventory level *(including items on order)*

Note: The demand, lead time and review period can be any time units (days, weeks or months). They all need to be consistency.

2.8 STORAGE MANAGEMENT

Warehouse is a critical intermediate part between supply chain parties (Faber et al., 2013).Warehouse management includes the control and optimisation of warehouse and distribution process. Warehouse management system (WMS) typically improves accuracy, eliminates unnecessary operations, and creates better pick system (Sharp, 2001).

The layout designing of warehouse purpose is to achieve the most efficiency of space utilisation and minimise the unnecessary movement.

2.8.1 Warehouse Operations

Functions of warehouse are to provide area for storage and transfer items. Bartholdi III and Hackman (Bartholdi III and Hackman, 2011) defined the typical process in warehouse as follows;

- Inbound processes
    - Receiving: is a process of unloading goods from shipment vehicles.
    - Put-away: is a process of transporting goods to storage place.
- Outbound processes
    - Order-picking: is a process of retrieving goods when the order comes. This activity is one of the most labour-intensive operation in warehouse. Typically, order-picking account 60% of total warehouse operating cost (Abbasi, 2011).
    - Checking and packing: is a process preparing orders from customers. The activity mostly rely on labour.
    - Shipping :is a process of transporting goods to shipping area before delivery to customers.

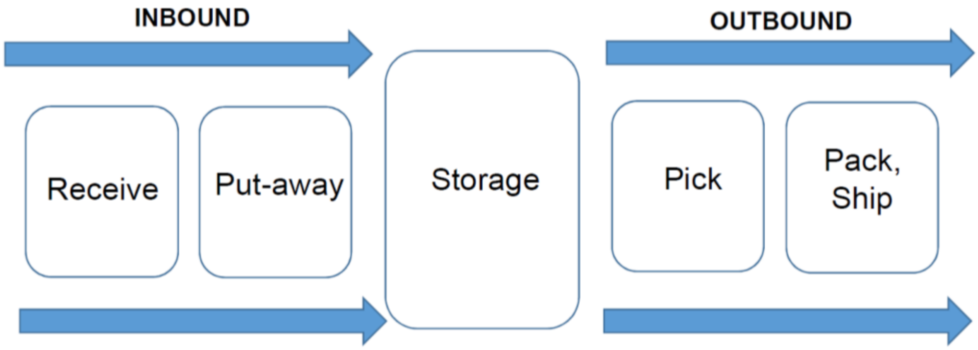


Figure 2.10 Physical Process in Warehouse
Source: Adapted from (Bartholdi III and Hackman, 2011)

Chapter 3
EXISTING OPERATIONS REVIEW

This chapter discusses the existing operations of the studied company. Overall business operations will be described. The current operation process will be demonstrated and summarised, followed by the evaluation of the information of Japanese products inventory from 2015. Proposed strategic management for each product group will then be specified.

3.1 OVERALL BUSINESS OPERATIONS

The overview business operation of the studied company is illustrated in *Figure 3.1*.

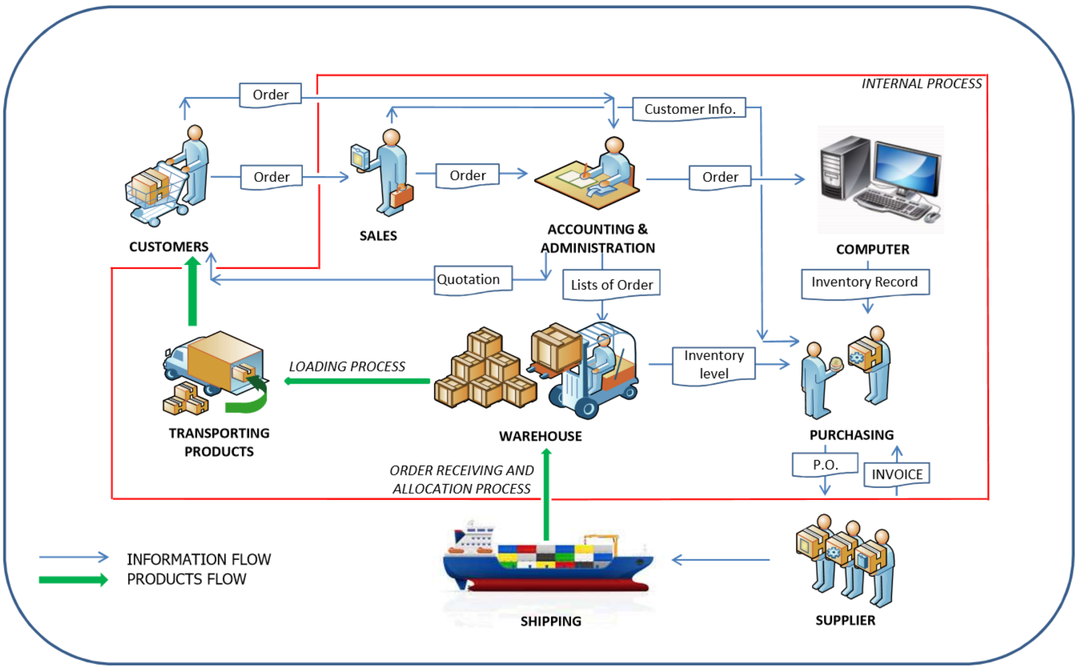


Figure 3.1 Overall Business Operation of the Studied Company

Customers: Customers regularly place their orders to the sales department. Then, the sales staff transfer the order to the accounting and administration department in order to register the order on the computer system. In a case that the current customer regularly orders the products, the customer directly place his order to the accounting and administration staff.

Sales Department: The two main responsibilities of sales staff are searching for the new customers and retain a relationship with the existing customers.

Accounting & Administration Department: Financial records and overall various documents are gathered and summarised by this department.

Purchasing Department: Decisions on ordering stock are made by purchasing staff. They generally retrieve inventory level information from the computer base system and also cross check with warehousing staff.

Warehousing Department: The staff is responsible for receiving, storing and off-loading items. It is found that there is no record of the storage place of every item in the warehouse.

3.2 EXISTING PROCESS OF OPERATION

3.2.1 Ordering Process

As mentioned in section 1.4.2 that the current inventory policy of the studied company is unclear, as a result, the current ordering process is observed and illustrated in *Figure 3.2*.

Periodic review policy is currently adopted for Japanese products since all SKUs are received from the headquarters in Japan. It results high transportation cost and long lead time. Therefore, products are ordered on intervals, in order to share the transportation cost.

When the ordering review period arrives, the purchasing staff will check the stock level from the computer system and on-site checking of the stock in the warehouse. Currently, the studied company must submit their order on the date of 22^{nd} of every month. Generally, the products will have arrived at the warehouse 45 days later.

Quantity of order is estimated from observations of historical data and customer information.

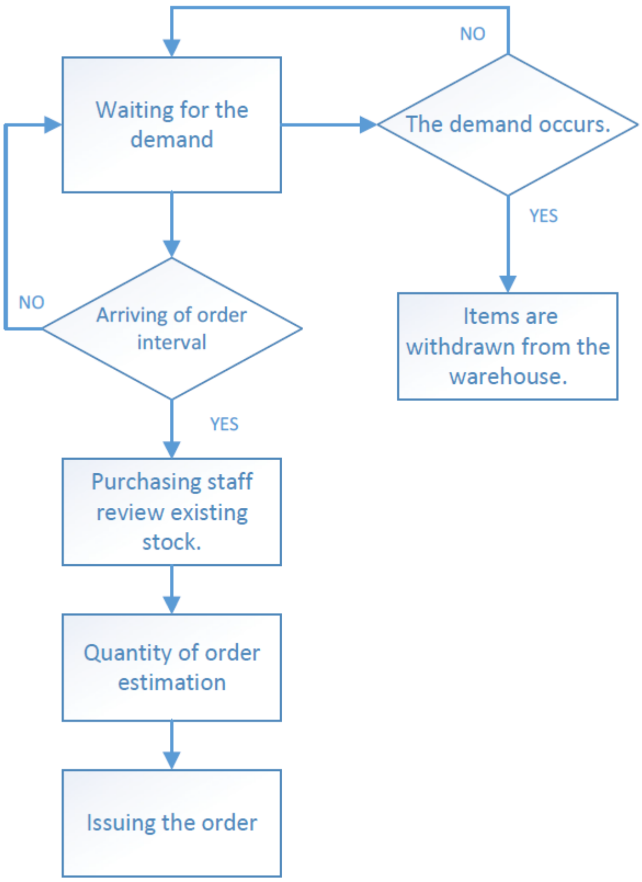


Figure 3.2 Current Work Flow Process of Periodic Review Policy

3.2.2 Warehouse Process

The warehouse management is observed as shown in *Figure 3.3*. Racks and shelves are used for item storage. Zones in the warehouse are divided and named as shown in *Figure 3.4*.

The layout shows that the office area is at the front of the item storage place. Moreover, there are shelves for small item storage in the office defined as zone O, P, Q and R. Zone A to J store items on racks, while zone K and L store items on pallets. The door on the left side of the warehouse is for receiving and offloading items.

Regarding the staff interview, there is no standard procedure for warehouse operations including storage judgement. As a preliminary evaluation of product code and storage place, it is determined that products which tend to move slowly are placed on the top of the rack and the small items are placed in the office area.

Figure 3.3 Current Warehouse Management

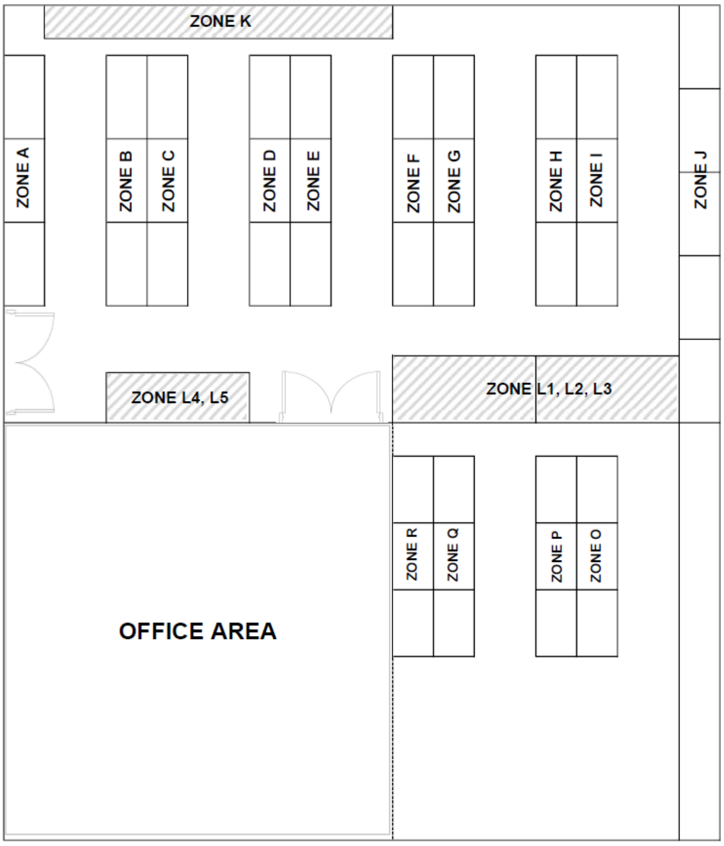
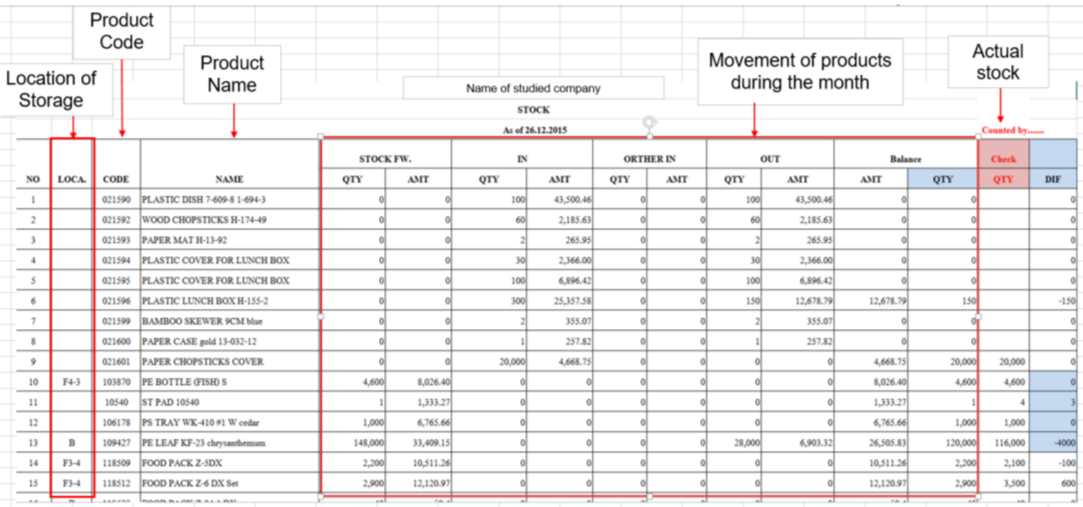


Figure 3.4 Current Warehouse Layout

Warehouse checking is performed on the last Saturday of each month. The checking process is also observed. *Figure 3.5* illustrates the record sheet of the monthly warehouse checking. It is observed that the storage locations were not fully recorded for all items.

Only warehouse staff know where the items are placed. This can be problematic as there was once a case where the warehouse staff could not find the products needed as someone in the office moved them without noticing others.



Name of studied company

STOCK

As of 26.12.2015

NO	LOCA.	CODE	NAME	STOCK FW.		IN		ORTHER IN		OUT		Balance		Check	
				QTY	AMT	QTY	AMT	QTY	AMT	QTY	AMT	AMT	QTY	QTY	DIF
1		021590	PLASTIC DISH 7-609-8 1-694-3	0	0	100	43,500.46	0	0	100	43,500.46	0	0		0
2		021592	WOOD CHOPSTICKS H-174-49	0	0	60	2,185.63	0	0	60	2,185.63	0	0		0
3		021593	PAPER MAT H-13-92	0	0	2	265.95	0	0	2	265.95	0	0		0
4		021594	PLASTIC COVER FOR LUNCH BOX	0	0	30	2,366.00	0	0	30	2,366.00	0	0		0
5		021595	PLASTIC COVER FOR LUNCH BOX	0	0	100	6,896.42	0	0	100	6,896.42	0	0		0
6		021596	PLASTIC LUNCH BOX H-155-2	0	0	300	25,357.58	0	0	150	12,678.79	12,678.79	150		-150
7		021599	BAMBOO SKEWER 9CM blue	0	0	2	355.07	0	0	2	355.07	0	0		0
8		021600	PAPER CASE gold 13-032-12	0	0	1	257.82	0	0	1	257.82	0	0		0
9		021601	PAPER CHOPSTICKS COVER	0	0	20,000	4,668.75	0	0	0	0	4,668.75	20,000	20,000	0
10	F4-3	103870	PE BOTTLE (FISH) S	4,600	8,026.40	0	0	0	0	0	0	8,026.40	4,600	4,600	0
11		10540	ST PAD 10540	1	1,333.27	0	0	0	0	0	0	1,333.27	1	4	3
12		106178	PS TRAY WK-410 #1 W cedar	1,000	6,765.66	0	0	0	0	0	0	6,765.66	1,000	1,000	0
13	B	109427	PE LEAF KF-23 chrysanthemum	148,000	33,409.15	0	0	0	0	28,000	6,903.32	26,505.83	120,000	116,000	-4000
14	F3-4	118509	FOOD PACK Z-5DX	2,200	10,511.26	0	0	0	0	0	0	10,511.26	2,200	2,100	-100
15	F3-4	118512	FOOD PACK Z-6 DX Set	2,900	12,120.97	0	0	0	0	0	0	12,120.97	2,900	3,500	600

Figure 3.5 Current Warehouse Checking Record

3.3 JAPANESE PRODUCTS INVENTORY REVIEW

3.3.1 Inventory Classification

The last Saturday of each month are used to perform stock checking of the warehouse. According to the monthly inventory record of 2015, there are 738 SKUs of Japanese products.

Observation of the inventory flow is to be performed. There is a group of product which moves quite fast. These items stay in the warehouse only for a short period of time since they are ordered in same amount as the customers' requests. The other group is a product group which has its inventory level remains the same in 12 months record. In addition, new products are included in the record.

Five groups of holding inventory are separated for the purpose of different operational management based on its characteristic;

1) Non-moving stock: The stock level remains the same for 12 months.

2) Stock with no sales last 6 months stock

3) Short-period stock: The products are ordered equal to the customers' orders (no stock requirement).

4) New product stock: The products which have less than 12 months of historical data.

5) Remaining: The remaining SKUs for the study

Table 3.1 illustrates the average product holding value (costs of product) and number of SKUs for each inventory type. Average value of holding inventory of each SKU in 12 months is determined by an average number of holding stock multiplied by the cost per unit. The average number of holding stock is from monthly interval record of 2015.

Table 3.1 Average Holding Value of Japanese Products in 2015

	Average Holding Value (THB)		SKUs	
Non-Moving	985,997	15%	106	14%
No sales in last 6 months	493,747	7%	34	5%
Short-period units	927,057	14%	344	47%
New Products	328,796	5%	69	9%
Remaining	3,925,757	59%	185	25%
Total	6,661,354		738	

Non-moving items in the 12 months record represent 15% of the total inventory value. 47% of total items in the records are short-period items which are ordered on notice from the customers. The remaining 185 SKUs which are 25% of the total Japanese items represent 59% of total Japanese product inventory value.

3.3.2 Proposed Strategic Management

The strategic managements for each group of inventory except for the remaining SKUs are proposed in this section. The summary of strategy is shown in *Table 3.2*.

Table 3.2 Proposed Strategic Management

	Proposed Strategic Management
Non-Moving	Liquidating Stock Strategy
No sales last 6 months	Liquidating Stock Strategy
Short-period units	Effective Communication with Customer
New Products	Recommendations for New Products Management
Remaining	To be verified and proposed in Chapter 4

Liquidating Stock Strategy

The stock which remains in the warehouse with no sales for a long period is considered as a dead stock. Dead stock does not only affect to the financial balance of the business, but also affects resources utilisation such as space in the warehouse, labour, and other facilities.

Almost every products in the studied company's warehouse are made from paper and plastic such as paper plate and plastic wrap for food which could be deteriorated because of a long holding period. A stock which has not been moved in the last 12 months is considered potentially dead stock, while the stock which has had no movement in the last 6 months is considered as slow moving products and potentially dead stock. The strategy is to be applied to these two groups, to mitigate them from the warehouse.

The inventory is to be divided into dead stock and marketable products. *Figure 3.6* is the proposed flowchart for item segmentation. Items that are broken, damaged, deteriorated, and/or screened by customer's logos are considered as dead stock. These items should be destroyed and removed from the warehouse.

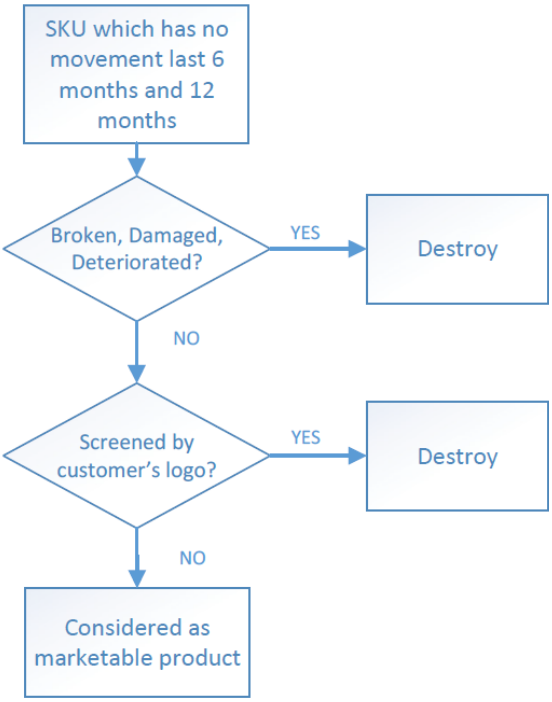


Figure 3.6 Flowchart for Item Segmentation

The items which pass the screen as the flowchart are considered as marketable products. There are many ways to move these stocks. Unfortunately, returning them to the supplier cannot be done in this case because of expensive transportation cost. Following strategies are proposed to liquidate them;

- Turning them into cash by;
  - Clearance sale or offering large discount
  - Re-package them with active items and sell as a package deal
  - Bundle them into groups and ask customers to take entire groups at a certain price or set up an auction
- Use them as promotions such as using them as a free sample when customer purchase products
- Donation: If items cannot be turned into cash, donation is another idea for liquidating the stock. It can be a benefit for others and could give a good corporate image to the organization.
- Disposal: just destroying and throwing items away can be a good idea since it consumes less cost and resources compared to other options.

In order to properly manage the dead stock in the future, the studied company can adopt four steps as proposed by Wilson (Wilson, 2005) for liquidating dead stock in warehouse management.

Figure 3.7 Steps of Liquidating Dead Stock
Source: Adapted from (Wilson, 2005)

STEP 1 Prevention: is to stop the accumulation of excessive inventory. Prevention includes the current stock management, new product management, purchasing decision (confirmation of the existing inventory number before ordering the new stock) and ensuring the appropriate level of inventory management

STEP 2 Identification: is to keep monitoring the slow moving stock and potential dead inventory. The organization should have capabilities to identify any dead stock in order to quickly respond and manage them.

STEP 3 Coordination: internal communication is crucial for inventory management. Manager, planner, sales, purchasing and warehousing staff must share information.

STEP 4 Disposition: After the dead stock is properly identified, it should be disposed of. Several ways are suggested as previously mentioned.

<u>*Short-Period Stock Strategy*</u>

Short-period stock are the products that stay in the warehouse for a short period and no stock requirement for this product type is required. According to the historical data from 2015, three types of short-period stock can be defined as described in *Table 3.3*;

Table 3.3 Types of Short-period Stock

Short-period Stock Types	***Definitions***
I) Short-period stock with no waiting period	The company would receive the products. They are then placed in the warehouse for a few days before being delivered to the customers at the exact amount.
II) Short-period stock with waiting period	The company would receive the products. They are placed in the warehouse for a period of a few months before being delivered to the customers at the equal amount.
III) Short-period stock with continuous sales period	The company would be receive the products. They are placed in the warehouse for a period such as a few months. Then, the products are continuously delivered to the customers until the stock is depleted.

Mostly SKUs in this group are in the first type (no waiting period) which the studied company currently operates well. The second and third types are to be suggested the effective communication with the customers. The short-period stock with waiting period is expected to decrease the waiting period, while short-period stock with continuous sales period is expected to have an accurate prediction.

Customer Relationship Management (CRM) is proposed to manage the appropriate relationship and sharing information with the customers. Parvatiya and Sheth (2001) suggested the different level of customer relationship management based on customers' importance toward the organization as shown in *Figure 3.8*.

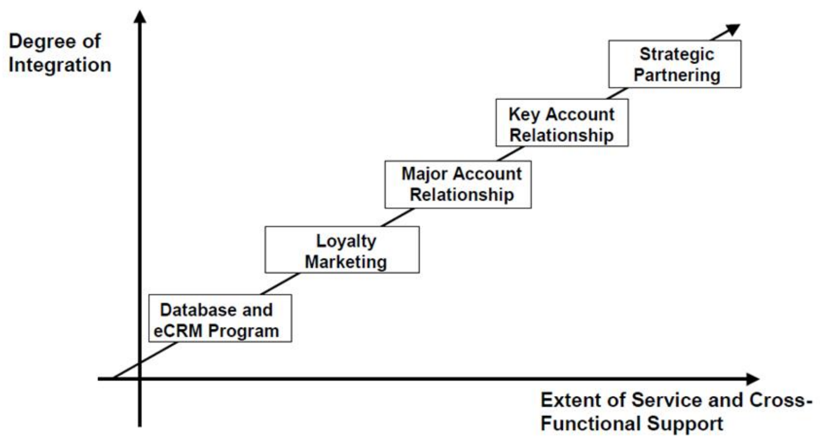


Figure 3.8 Customer Segmentation
Source: (Parvatiyar and Sheth, 2001)

After identified appropriate level of customer relationship, the studied company should develop and keep sharing the information, especially the customers who are the strategic partner.

Information sharing from the customer is very important. More direct and immediate information in a supply chain instantly impacts to the accuracy of forecasts (Yu et al., 2010). In addition, misunderstanding can enlarge the bullwhip effect.

New Products Strategy

When a new product is first introduced to the market, the demand forecast is crucial. The company should classify and understand the market's and customers' needs in order to support the demand estimation more accurately. If the product is for a single customer, working closely with the customer is the most effective solution to identify the appropriate inventory level. Thereafter, historical demand data should be collected and evaluated for future plan.

Remaining Stock Strategy

Above inventory screening process results in 185 SKUs as a remaining stock for the simulation study which will be described in Chapter 4.

3.4 CHAPTER SUMMARY

The overall business operations and current processes for the studied company are reviewed. Japanese products are evaluated and divided by characteristics of product flow in the operation. Strategic management for all groups of product will be proposed. The remaining 185 SKUs will be studied in the next chapter.

Chapter 4
PROPOSED INVENTORY POLICY

Key performance index (KPI) for the policy assessment will identified in Chapter 4. For starters, the inventory policy improvement for remaining 185 SKUs will be proposed. Firstly, ABC Pareto will be applied to categorise the inventory. Demand pattern will be studied. Then, a proposal on how to move forward for inventory management will be discussed. Lastly, the proposed operation processes will be described.

4.1 PERFORMANCE MEASUREMENT

The key performance index is set to compare the results of proposed inventory policy with the actual operations of the company during January to May 2016. The KPIs are;

- Inventory level
- Inventory value
- Service level

Due to the fluctuation of the Japanese currency, the basis of inventory value is calculated from inventory level multiplied by the average unit value during January to May 2016.

Service level can be measured in many ways depending on what the company values. The loss of sales is considered the most crucial aspect to the studied company. Unfortunately, there were no record of unfulfilled demand. Therefore, the stock out period will be considered as an indicator for the service level since the information can be retrieved from the accountancy software. It will be determined as a percentage of numbers of stock out day in 152 days (5 months) assessment period.

The comparison of three KPIs will be performed in the results and assessment phase (Chapter 5).

4.2 PROPOSED INVENTORY POLICY IMPROVEMENT FOR REMAINING STOCK

4.2.1 Inventory Classification for a Studied Group

185 SKUs of Japanese products are a focus group for the proposed inventory policy, and 12 months inventory record in 2015 will be analysed. ABC Pareto tool is used for stock classification, the criteria being listed in order to define the groups.

- *Average inventory value:* an average of 12 months record for each SKU value
- *Continuity of demand:* numbers of months with demands (the number will be 1 to 12).
- *Number of order:* number of order records retrieved from the company software
- *Value of sales:* value of sales retrieved from the company software

Microsoft Excel is used for items sequencing and grouping. Since the study aims to reduce the inventory level, average inventory value is first used to sequence the SKUs. The result shows that a mix of items which cannot be sold every month, also called intermittent demands, and items which can be sold every month, known as continuous demands. The ‘zero’ data may result in the high variance of data, especially a large number data, which may lead to higher safety stock than it really needs. Thus, the continuity of order is also another criteria for inventory classification.

Number of orders is considered because it represents the usage of resources in the company. Finally, the value of sales is also selected to be taken into considerations, as it represents the revenue to the company.

Four criteria are considered for sequencing item orders. Two options of group separation are studied as *Table 4.1.* Option 1 is to sequence items by number of order. If the number of order is equal, the second criteria for sequencing is continuity of demand. The third and fourth criteria are value of sales and average inventory value, respectively. Option 2 is to consider the continuity of demand first followed by number of order, value of sales and average inventory value.

Table 4.1 Options for ABC Classification

Options	ABC Classification
1	No. of Order > Continuity of demand > Value of sales > Average inventory value
2	Continuity of demand > No. of Order > Value of sales > Average inventory value

Option 1							
GROUP	No. of item	No. of Order	%No. of Order	Avg. inventory value (THB)	%Avg. inventory value	Value of order (THB)	%Value of order
A	66	4,729	80%	1,498,243	38%	6,552,969	55%
B	55	888	15%	1,136,045	29%	4,143,804	35%
C	64	274	5%	1,291,469	33%	1,249,629	10%
Total	185	5,891		3,925,757		11,946,402	
Option 2							
GROUP	No. of item	No. of Order	%No. of Order	Avg. inventory value (THB)	%Avg. inventory value	Value of order (THB)	%Value of order
A (12)	59	4,270	71%	1,348,877	34%	6,097,779	51%
B (11-8)	54	1,239	21%	1,005,475	26%	3,534,279	30%
C (7-1)	72	382	8%	1,571,406	40%	2,314,344	19%
Total	185	5,891		3,925,757		11,946,402	

For option 1, the 80-15-5 rule for group separation is applied. Option 2 divides groups by number of demand by month. The comparison between the two options is generated as *Table 4.2* for the purpose of decision making.

Table 4.2 Comparison of Options for ABC Classification

	Continuity of demand	
Group	A	B
Option 1	- Mostly continuous demand data (48 of 66 units) - MAPE (Mean Absolute Percentage Error) cannot be used for error determination.	- A mix of continuous and intermittent demand data (11 from 55 units are continuous demand.)
Option 2	- Results continuity of all data in group A	- A group of intermittent demand data (demand between 8 and 11 from the total 12 months)

Option 2 completely separates the data of continuous demand (A) and intermittent demand (B and C), whereas option 1 results in a mix of continuous and intermittent demand in both groups. Thus, **option 2** will be selected since it can divide the relevant data in the same group.

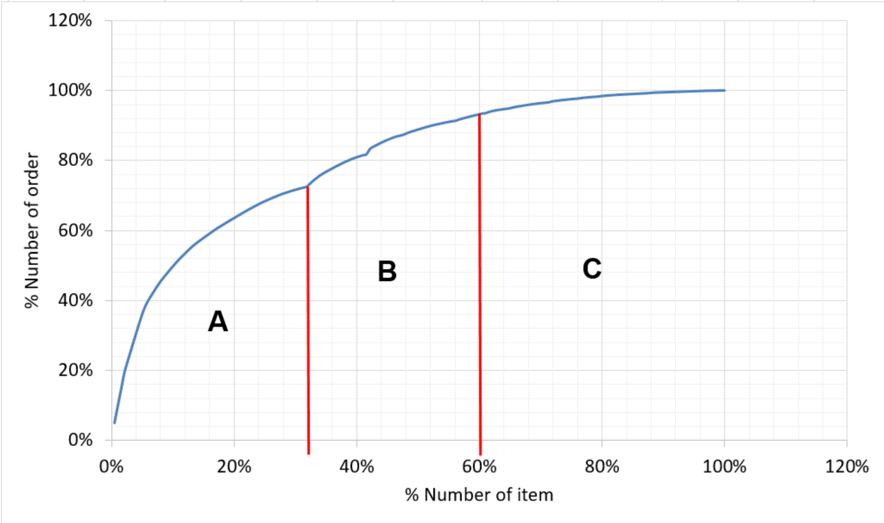


Figure 4.1 Application of ABC Classification

Figure 4.1 shows the sequencing of the item as continuity of demand. X axis is the percentage of number of item, and Y-axis is the percentage of number of order. The curve conforms to the Pareto concept that a small percentage of items account for large percentage of usage.

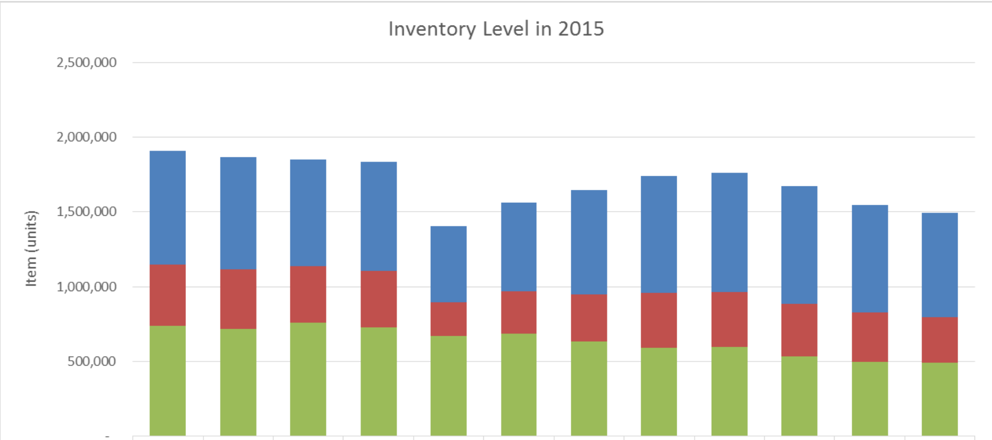
The discontinuity of the curve is a result of the criteria of continuity of demand. There may be lower numbers of order sequenced before the higher numbers of order because the order is more distributed by month.

Group A (32% of total items) are continuously purchased by customers' accounts high percentage of order (71% of total orders). Group B which is 29% of the total items accounts 21% of total orders. Lastly, group C which is 39% of total items only accounts for 8% total orders.

Inventory data in 2015 for ABC classification is then analysed. *Figure 4.2* illustrates inventory level for group A, B, and C in 2015. The chart shows that the total inventory for all groups fluctuates with low variance. Group A and C items are stocked at approximately the same level and group B items have the lowest stock.

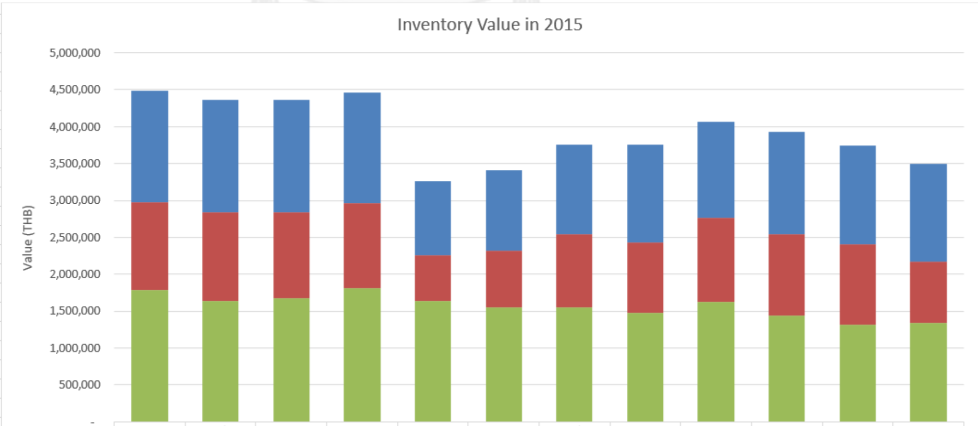
However, the number of items is summarised directly. The data may be distorted by the high volume items. Then the value of inventory for all groups is observed as *Figure 4.3*. It is seen that group A and C inventory values are more or less at the same level. Thus, the inventory level proportion in *Figure 4.2* represents the inventory value in *Figure 4.3*.

Value of sales for all groups in 2015 is also plotted as *Figure 4.4*. Group A items generate the highest revenue, while group C items generate the lowest revenue. It is observed that all inventories and sales data are quite stable, without shifting trend.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
A	757,021	747,950	711,935	730,492	506,936	594,240	696,207	777,955	796,193	785,436	715,342	700,181
B	412,258	399,763	377,744	378,370	228,946	280,372	317,920	370,843	366,687	352,477	332,104	305,567
C	736,622	716,136	759,503	725,763	669,369	688,878	632,972	590,471	595,771	533,249	498,380	489,930

Figure 4.2 Inventory Level for ABC Classification in 2015



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
A	1,513,052	1,531,969	1,519,974	1,502,242	1,001,642	1,091,702	1,210,183	1,320,627	1,293,479	1,383,923	1,341,629	1,329,328
B	1,193,964	1,197,612	1,169,220	1,150,559	629,240	763,041	997,802	961,841	1,141,523	1,099,801	1,081,502	826,359
C	1,785,333	1,637,174	1,674,068	1,810,248	1,634,304	1,556,597	1,550,134	1,472,619	1,628,375	1,442,918	1,319,280	1,345,824

Figure 4.3 Inventory Value for ABC Classification in 2015

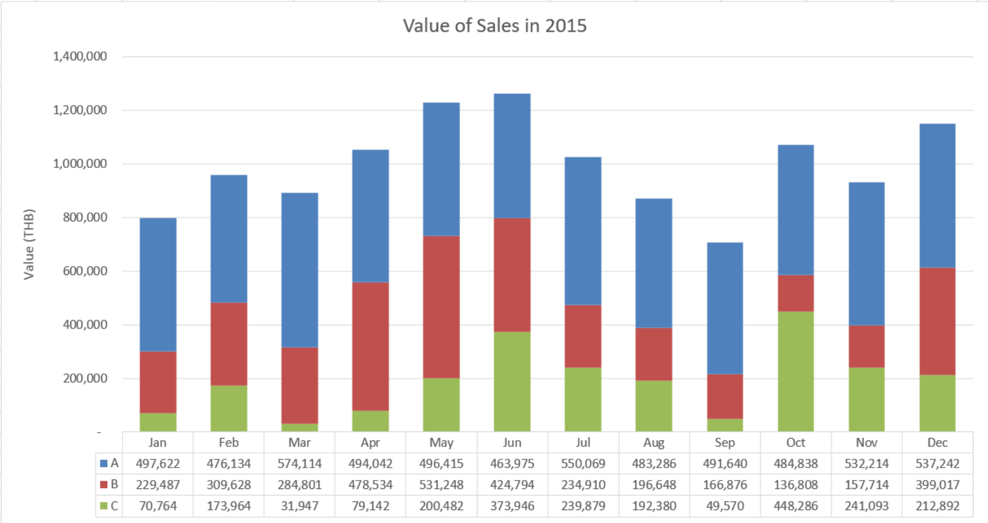


Figure 4.4 Value of Sales for ABC Classification in 2015

In summary, multi-criteria is used for sequencing the item order. The continuity of demand is considered the most important criteria since it can separate continuous demand and intermittent demand. Then, number of orders is the second criteria in terms of importance for the operation. The third criteria for sequencing is value of sales. Lastly, the average inventory value is considered.

4.2.2 Single Customer Verification

There are 107 SKUs of the 185 SKUs supplied for only a single customer. *Table 4.3* illustrates customers' name and numbers of item which the customer is the only one who orders the item. Values of sales and inventory value are also shown in the table. 'Yes' on the right column signifies that the customers who share the demand information in advance and acknowledge the stock level of the company.

Table 4.3 Single Customer Lists

Customer Name	Numbers of item	Sum of No. of Order	Sum of Value of sale (THB)	Sum of Inventory Value (THB)	Customer shares demand info.
Ko-ku-ra-en (Thailand)	20	132	131,233	77,046	Yes
UFM Fuji Super	19	312	1,115,870	217,758	No
Di-sho Food Service (Thailand)	14	367	1,591,214	188,826	Yes
Betagro Retuarant	14	363	107,277	119,161	No
Nodu Food	12	192	1,246,537	416,398	Yes
Ai-Bento YA	10	61	138,901	57,408	No
Thana Curry House	3	6	8,260	22,171	No
Big C Super Center	2	14	152,609	229,480	No
Thana Food and Beverage	2	9	207,913	80,098	No
Mi-ou Japan Food	2	7	10,921	21,620	No
Anniversary	1	68	353,818	31,065	No
Ion (Thailand)	1	7	45,461	23,913	No
Taneeya Siam	1	6	232,421	543,466	No
Ex-part Enterprise	1	6	21,087	10,163	No
Ar-o-ai	1	6	13,381	15,950	No
Tanaryya Thailand	1	6	10,884	4,776	No
MOS Food (Thailand)	1	5	95,308	96,879	No
Nipponte	1	2	3,487	11,784	No
TCC Logistic and Warehouse	1	1	12,316	13,126	No
Total	107	1570	5,498,901	2,181,088	

The separation of single and multi-customer group is evaluated. *Table 4.4* illustrates the proportion of single customer in each group. It implies that the items which have high numbers of orders tend to be ordered by more than one customer, while the items which have lower numbers of orders like items in group B and C tend to be ordered by a single customer. However, the separation of single and multi-customer group does not help for demand classification, since it results in a mix of continuous and intermittent demand for both groups.

Table 4.4 Single Customer Verification

GROUP	No. of Item	Single customer item	%Single customer	%Multi customer
A (12)	59	25	42%	58%
B (11 - 8)	54	28	52%	48%
C (7 - 1)	72	54	75%	25%
Total	*185*	*107*		

4.2.3 Inventory Classification Selection

Option 2 will be selected for sequencing the items. The groups of products are divided as shown in *Table 4.5.*

Table 4.5 ABC Pareto Analysis Result

GROUP	No. of Item	No. of Order	Avg. holding value (THB)	Value of order (THB)
A (12)	59	4270	1,348,877	6,097,779
B (11 - 8)	54	1239	1,005,475	3,534,279
C (7 - 1)	72	382	1,571,406	2,314,344
Total	*185*	*5,891*	*3,925,757*	*11,946,402*

In summary, four criteria which are the monthly demand continuity, the amount of orders, the value of sales, and the inventory value are considered for ABC analysis. The inventory value is weighted the least important from the four factors. This judgement results in a mix of inventory value items in the three groups. It can be seen from *Table 4.5* that the inventory holding value for group C is the highest among the three groups. However, items in group C generate the lowest revenue for the studied company compared to the others.

4.2.4 Demand Pattern

Demand pattern for all inventory groups is assessed. Two examples of each group will be represented in *Figure 4.5, 4.6 and 4.7* for items in group A, B, and C, respectively. Trend, cycle and seasonal pattern cannot be seen from the charts. Since the historical data is limited to only 12 months, the pattern may not be captured accurately.

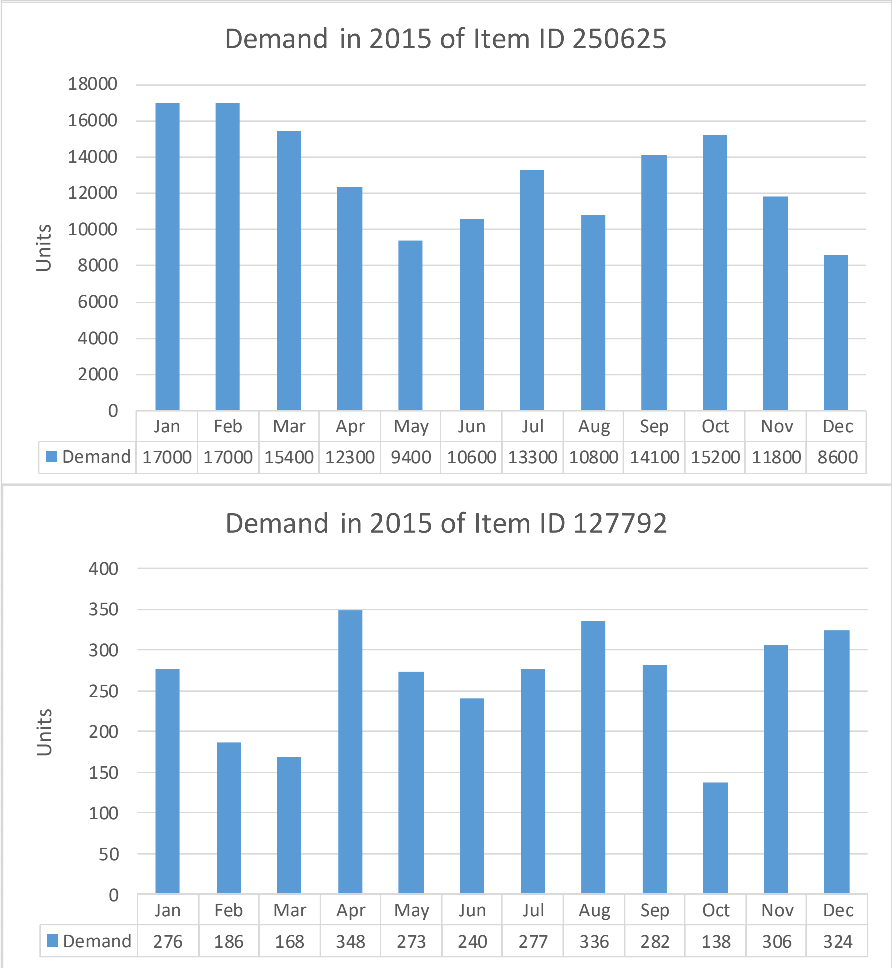


Figure 4.5 Monthly Demand of Group A

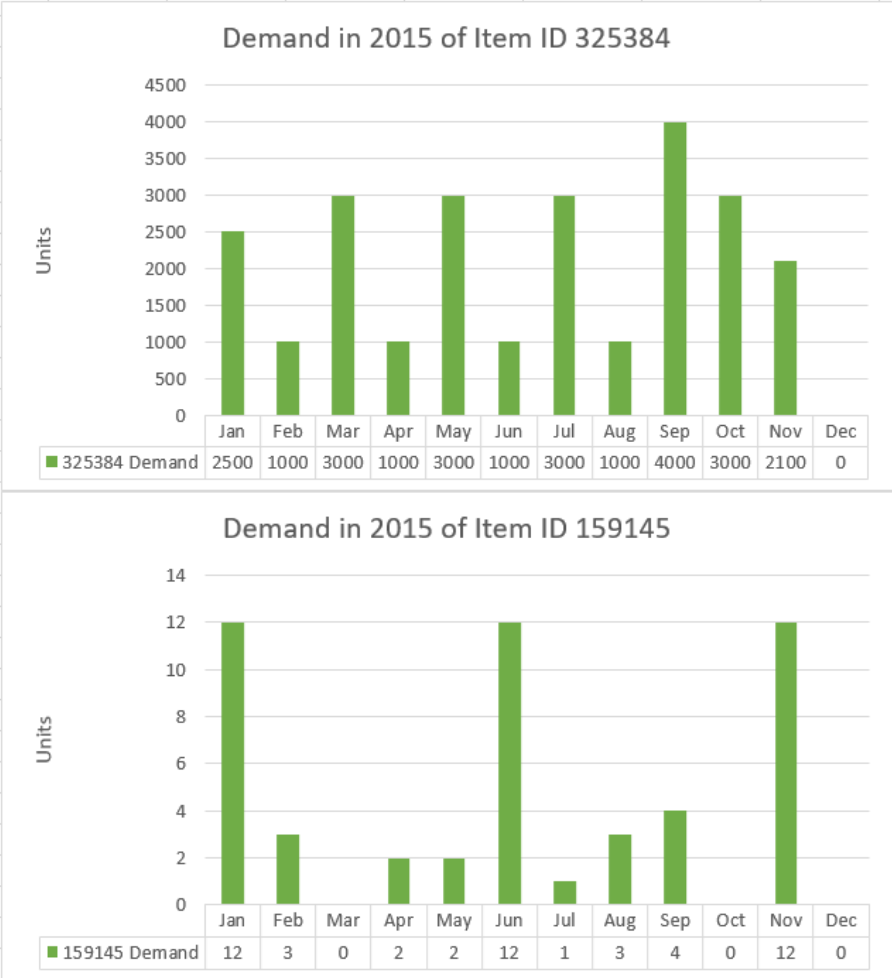


Figure 4.6 Monthly Demand of Group B

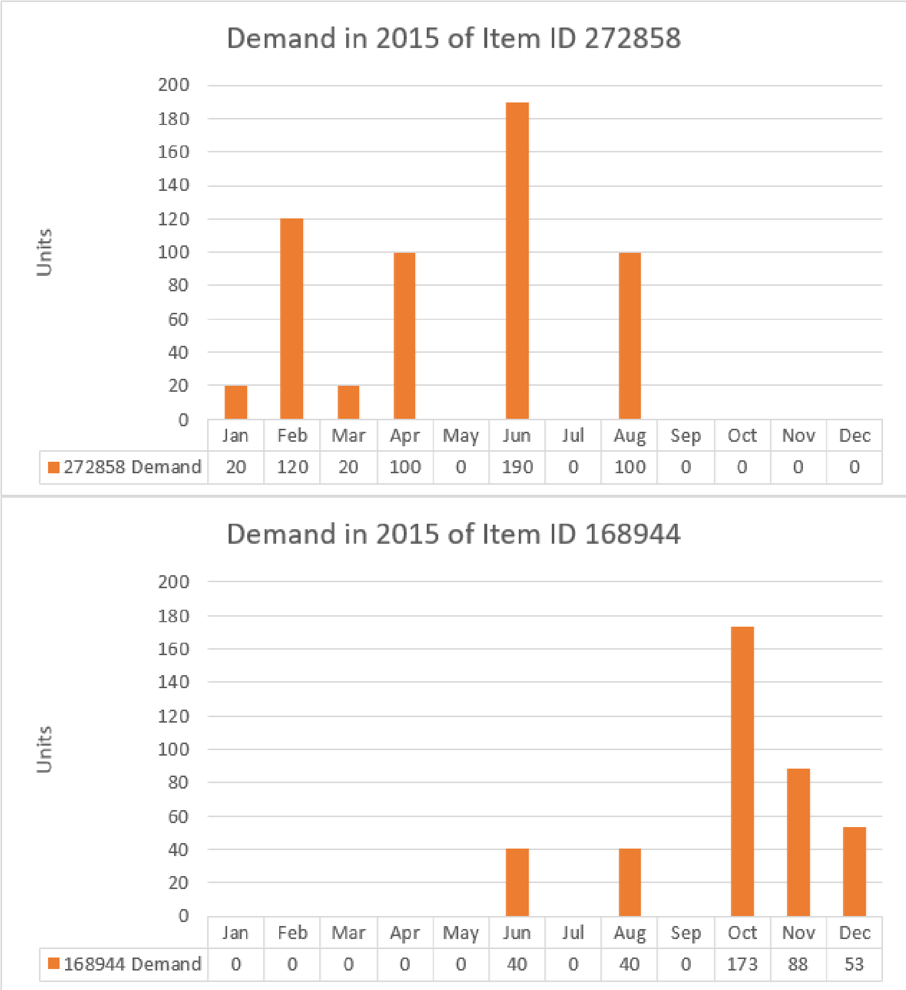


Figure 4.7 Monthly Demand of Group C

In order to evaluate the variability of data, coefficient of variation (CV) or relative standard deviation (RSD) is used for measuring the variability of a series of numbers. According to Abdi (Abdi, 2010), the coefficient can be applied to a ratio scale only. Negative value scale or interval scale like temperature cannot be verified by CV. The coefficient of variability is computed by the standard deviation divided by the mean of data. Typically, distribution of CV higher than 1 is considered high-variance and CV lower than 1 is considered low-variance.

$$CV = \frac{Standard\ Deviation}{Mean}$$

Coefficient of variation for six examples is determined as *Table 4.6*.

Table 4.6 Coefficient of Variation Determination for Demand

Demand				
GROUP	CODE	SD	Mean	CV
A	250625	2719	12958	0.21
	127792	65	263	0.25
B	325384	1029	2236	0.46
	159145	4.7	4.6	1.00
C	272858	63	50	1.26
	168944	52	31	1.69

In conclusion, the demand for group A is high and considered steady with low fluctuation. Group B and C show the sporadic demand as sequencing criteria in the previous section and result high variance of demand referred to a CV above 1.

4.2.5 Inventory Model Selection

Factors that affect the inventory model selections are system structure, the items, market characteristics, lead time and cost (Muckstadt and Sapra, 2010). According to the theoretical review in Chapter 2, fixed-time period model is suited to the situation of the studied company because of two main reasons. Firstly, the transportation cost is high (shipping from Japan). Secondly, most items have a low unit cost. Therefore the periodic review policy will be selected for all product groups.

Periodic review policy is currently adopted by the studied company as reviewed in section 3.2.1. However, the decision-making such as order quantity, safety stock determination, and forecasting techniques are not structured.

4.2.6 Periodic Review Policy

The periodic review curve for the studied items is generated in *Figure 4.8*. The review period (T) is 30 days which is on the date of 22^{nd} every month. Lead time (L) is 45 days after the order is placed.

This model is proposed for group A, B and C items. 20 SKUs of each group will be randomly selected for the study. Unusual demand like large orders with advanced notice will not be included in the study.

Regarding high numbers of product which are ordered from a single customer, there are but some customers who share their demand information with the studied company. These items are also included and verified in the study.

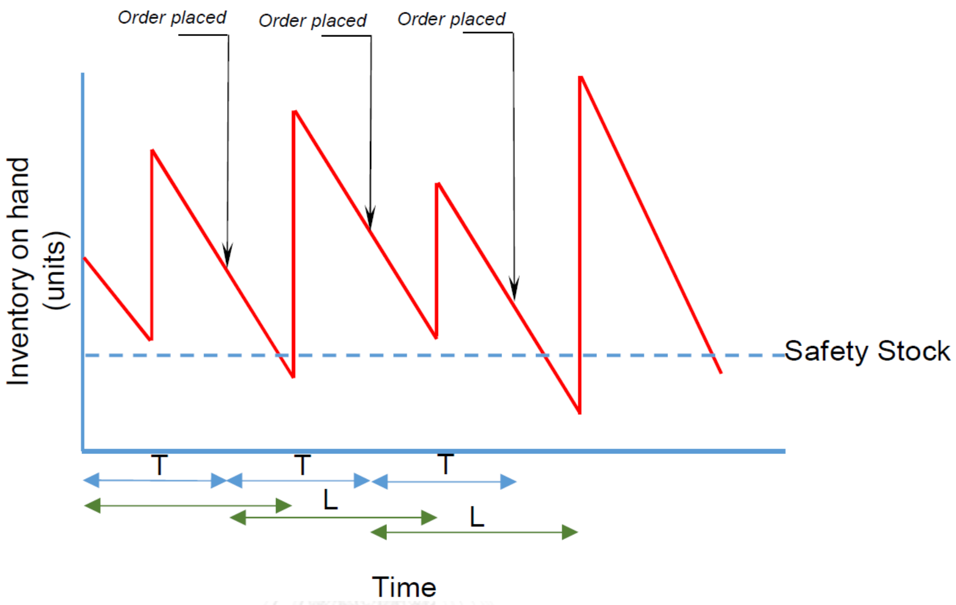


Figure 4.8 Periodic Review Policy

The quantity of orders will be determined when one-month intervals arrive. The equation of the quantity to be ordered will be demand over the period and lead time plus safety stock value and minus the current inventory. The current inventory should be the inventory on hand and on order.

Order Quantity = Average demand over the period + Safety stock - Current inventory on hand

$$q = \overline{d}(T + L) + Z\sigma_{T+L} - I$$

Where

q : Order Quantity

$\bar{d}$: Average demand in a review period

T : The review period

L : Lead time for replenishment

Z : Number of Standard deviation for a desired service probability (Areas of the Cumulative Standard Normal Distribution, can use Excel NORMSINV function)

σ_{T+L} : Standard deviation of demand over the review period and lead time

I : Current inventory level *(including items on order)*

Estimated monthly demand will be determined by the forecasting technique. Proposed methods will be described in section 4.2.5.

The used unit for the above equation must be consistent. The study is based on a unit of a month. Thus, the review period plus lead time is 2.5. Safety stock will be determined based on the service level of 95% and 98%.

The decision of order quantity will be decided based on the calculated order quantity and minimum order quantity (MOQ). The number will be rounded up when it is more than 50% of the minimum order. For example; if MOQ is 30 units and the calculated quantity is 34, the ordering decision will be 30. The decision will be 60 units if the calculated value is between 45 to 74 units.

Last but not least, Microsoft Excel will be used to develop the simulation for the model application. An example of a simulation implementation is shown in *Figure 4.9*.

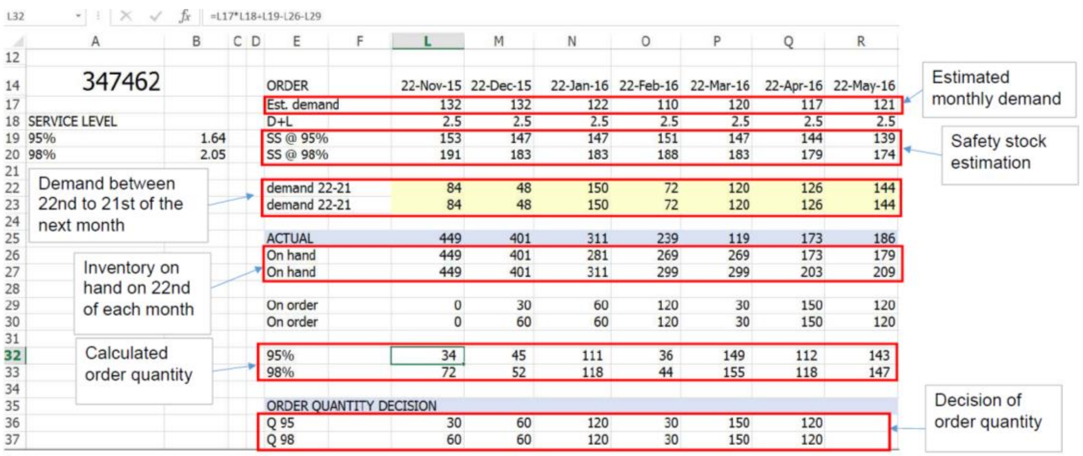


Figure 4.9 An Example of Periodic Review Simulation

4.2.7 Forecasting Techniques

Monthly demand will be forecasted. Formulas shown in section 2.2.2 will be applied for the 12 months recorded in 2015. Three techniques; Naïve, 3 months moving average, and simple exponential smoothing will be applied for items in all groups.

The empirical study conducted by Johnston and Boylan (Johnston and Boylan, 1996) resulted that Croston's method suggested for intermittent demand is always better than simple exponential smoothing only if average interval time of demand is greater than 1.25 intervals. Considering the 12 months of data, 1.25 intervals is when there is demand less than 9.6 months. Thus, the additional technique of Croston's model will be applied for group C items which have demand between 1 to 7 months within a 12 months period.

Average forecasting error will be used for evaluating the accuracy of forecasting techniques towards the demand data. MAPE, MAD and, MSE will be compared for items in group A. MASE, MAD and MSE will be compared for items in group B and C. MAPE is not applied for items in group B and C because it cannot be determined for zero data. MASE is selected for group B and C evaluation as it were suggested for intermittent data (Hyndman, 2006).

The forecasting technique which results in the minimum error for the most sampled items will be selected. In addition, simple exponential smoothing and Croston's method require weight factor (α, alpha) which is a variable number. Solver analysis in Microsoft Excel is used to find the optimum value for each identified error (MAPE, MAD, MSE, and MASE). The statistical data of weight factor will be summarised and evaluated.

Average forecasting error of month 4 to 12 for all techniques will be assessed and compared since 3 months moving average will give the first result on the 4th month.

4.2.8 Summary Basis of Implementation

The steps of the policy implementation will, first of all, start on forecasting technique verificationม in order to receive the estimated number of demands for the policy review. *Table 4.7* summarises the way forward for inventory policy implementation.

<u>*Summary basis for forecasting technique verification*</u>

1. In order to compare the accuracy of the proposed forecasting techniques with the demand data, average forecasting error of month 4 to 12 will be assessed since 3 months moving average will give the first result on the 4th month.
2. The initial value of demand size for simple exponential smoothing and Croston's method is the first value of demand.
3. The initial value of interval for Croston's method is 2.
4. Pivot table function in Microsoft excel is used for summarize monthly data, and VLOOKUP function is used for retrieved data of the sampled items from the database.

<u>*Table 4.7 Way Forward for Inventory Policy Implementation*</u>

GROUP	Inventory Model	Forecasting Method	Forecasting Error
A	Periodic Model	- Naïve	MAPE
		- 3 months moving average	MAD
		- Simple exponential smoothing	MSE
B	Periodic Model	- Naïve	MASE
		- 3 months moving average	MAD
		- Simple exponential smoothing	MSE
C	Periodic Model	- Naïve	MASE
		- 3 months moving average	MAD
		- Simple exponential smoothing	MSE
		- Croston Method	

<u>*Summary basis for inventory simulation*</u>

1. The first review period is on the 22nd of November 2015 in order to receive items in early January 2016.
2. Estimated monthly demands are determined from the results of the selected forecasting technique.
3. Unusual demands like large orders with advance notices will not be included in the study.
4. Safety stock will be based on the service level of 95% and 98%.

5. Standard deviation for safety stock determination will be determined based on the previous data. Once the next review period arrives the additional data will be included.
6. Microsoft Excel is used to calculate standard deviation (STDEVP(range of data)).
7. The review period of demand is between the 22^{nd} of each month until the 21^{st} of the following month.
8. The inventory on hand (I) includes both on hand and on order stock.
9. The decision of order quantity will be based on the calculated number and minimum order quantity of each item. The number will be rounded up when it is more than 50% of the minimum order quantity.
10. The arrival date of items in the simulation will be the same as actual operation (approximately 45 days after submitted order).

4.3 PROPOSED OPERATION IMPROVEMENT

The overall process of the company remains the same. Nevertheless, flows of ordering process, warehousing process, and warehouse checking process are proposed in order to improve internal communications and reduce the chance of human error.

4.3.1 Ordering Process

Periodic review policy is proposed, with the reasons described in section 4.2.3. The workflow steps are the same as the current existing process. Moreover, the ordering interval of group B and C will be evaluated between monthly or bi-monthly in chapter 5.

Figure 4.10 shows that the proposed warehouse checking process will improve the accuracy of stock tracking which relates to the efficiency of ordering decision. The proposed forecasting method and quantity of order determination will provide the methodology for decision-making.

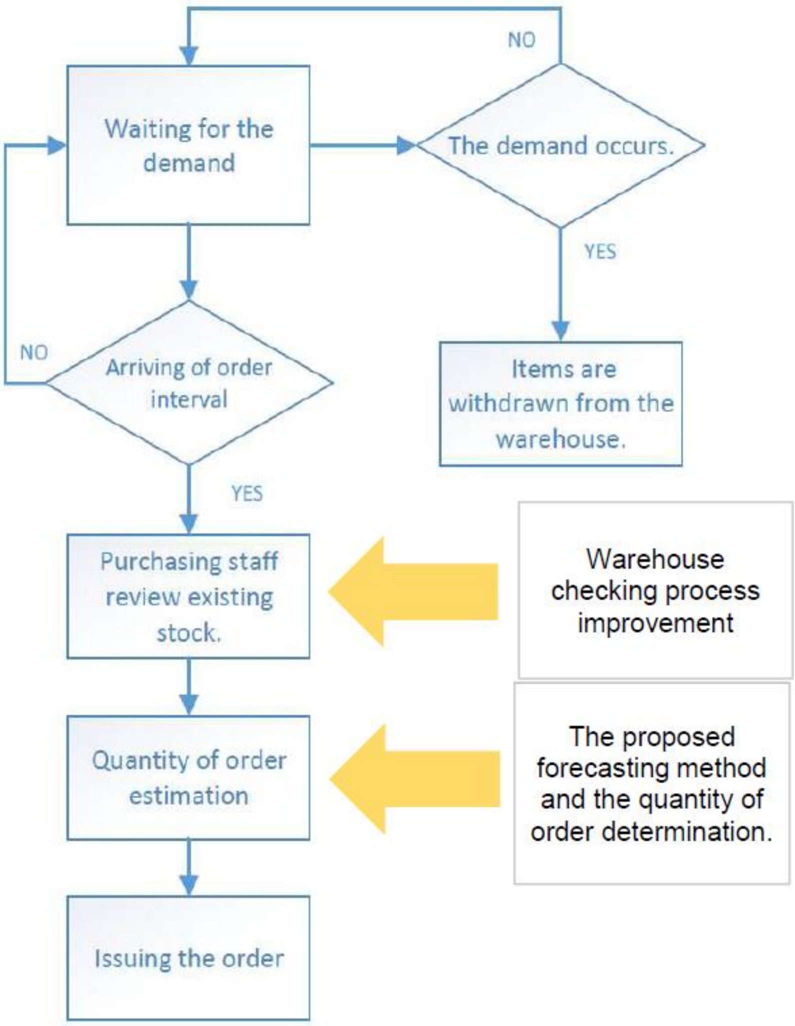


Figure 4.10 Proposed Work Flow Process of Periodic Review Policy

4.3.2 Warehouse Flows

The overall warehouse operating flows consist of inbound and outbound processes illustrated in *Figure 4.11*.

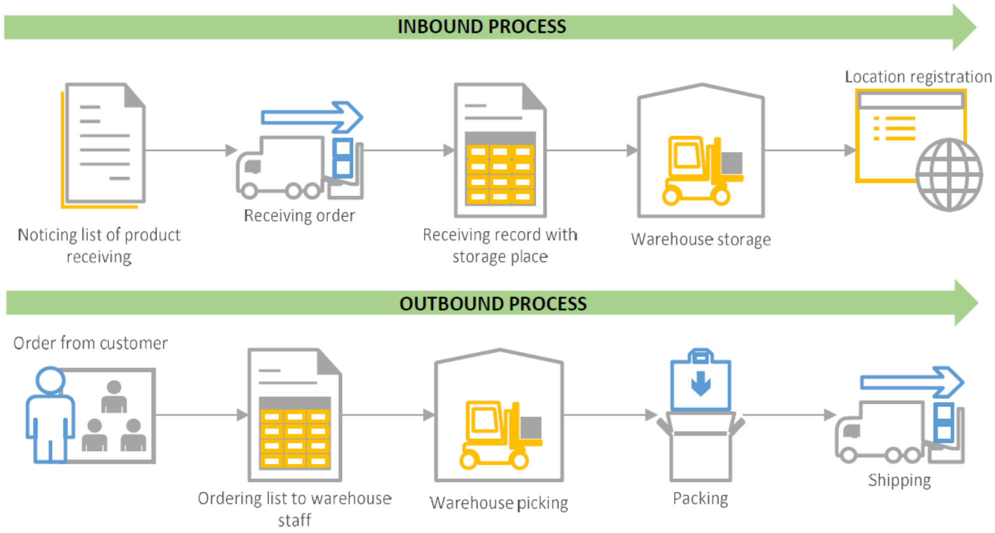


Figure 4.11 Proposed Warehouse Flows

Inbound processes consist of receiving and put-away processes. The workflow steps are described as follows;

1. Warehousing staff receive the noticing list of products that will be delivered to the warehouse. Order number, product code, name and amount shall be specified in the list. *Figure 4.12* illustrates an example of receiving-Item and location list. The noticing list generated by an administrator is the left part of the form.
2. The ordered items arrive at the warehouse. They are placed in the receiving area.
3. Warehousing staff check the amount of items as per the advance noticing list and inspect the quality.
4. The items are assigned a storage location which shall be recorded on the receiving item location sheet (the right side) as *Figure 4.12*.
5. Item label is sticked to the pack of items. Proposed label is shown in *Figure 4.13*. Code, name, receiving date, and assigned location must be shown. The remaining blanks designed for amount, checked date, and location will be useful for the inventory checking process. Details will be demonstrated in section 4.3.3.
6. The items are placed at the assigned location.

7. The receiving-item location sheet is scanned and saved into the computer's public folder. The hard copy should be gathered in a file.
8. Administrator updates receiving-item details and storage location in the CD organizer program.

Generally, the administrator records the order receiving into the CD organizer software (accountancy program) which can generate details of received items into Microsoft Excel. Only the location of storage needs to be added and saved from the original work.

The existing process does not have a record of any received items' location. It means only the warehousing staff who allocates the storage place knows where the stock is kept.

The proposed methodology to record the location of receiving item may consume more labour hours due to an increase in documentation tasks, but the location record definitely reduces numbers of missing items and risks in operations (for example; when the only one warehouse staff who knows where the stock is placed is on leave, more time is consumed in order to find it). Moreover, the record improves the efficiency of purchasing process decision since the purchaser can accurately track the location of items. It decreases the labor hours of the warehouse staff as he does not need to advise and guide the purchasing staff every time.

Receiving-Item and Location List					
Date:				**Originated by**	
Noticing List				*Assigned Location List*	
Order No.	Product Code	Product Name	Amount	Receiving Date	Location
			Recorded to the electronic file by		

Noticing List

Assigned Location List

Figure 4.12 Receiving-Item and Location List

Product Code:	373250			
Product Name:	WOOD UDON PAIL # 7 M-6 402000022			
Receiving date:			**Location:**	
Amount:		Checked on Date:	Location:	
Amount:		Checked on Date:	Location:	
Amount:		Checked on Date:	Location:	
Amount:		Checked on Date:	Location:	
Amount:		Checked on Date:	Location:	
Amount:		Checked on Date:	Location:	

Figure 4.13 Proposed Item Label

Picking, packing and shipping processes constitute the outbound process. The workflow steps are described as follows;

1. Warehouse staffs are given the picking list by an administrator. An example of picking list is shown in *Figure 4.14*. Each picking list represents only one order number. Warehouse staff members use the list to check the right quantity of order and record the status Y or N. ‘Y’ is when the items’ quantity are available as the ordered. ‘N’ is when there is no items or insufficient items as ordered. If

'N' is on the list, warehouse staff must report to the administrator in order to inform the customer.

2. Listed items are gathered and properly packed.
3. Warehouse staff load all packed items onto the delivery vehicle.
4. The driver delivers the products to the customers.

Picking List			
Order No.		**Picking By**	
Date:			
Notes:			
Product Code	Product Name	Amount	Status (Y/N)

Figure 4.14 Picking List

4.3.3 Warehouse Checking Process

The format for monthly warehouse checking process is proposed as *Figure 4.15*. Two columns are added on the right side of the original format, indicating the location and changes during the months

The CD organizer program, which records the amount of delivered and sold products during the month includes the storage place recorded from the receiving process, can generate data into Microsoft Excel program.

Warehouse checking should be performed as shown in *Figure 4.16*. The additional steps from the existing operation are to record the storage location into the checking form and write the remaining amount, checked date, and location on the item label. If the location is the same, '-'(dash) can be noted.

The electronic files of checking records should be kept in the public folder of the company, where everyone has access. Location changes during the checking interval must be recorded. New moved location and name of the employee who displaces the item should be noted. Lastly, the Excel file should be generated monthly as to follow the interval of stock checking process.

Proposed column

COMPANY NAME																	
DATE of XX / XX / 2016																	
			STOCK FW.		IN		ORTHER IN		OUT		Balance		Check		LOCATION	LOCATION CHANGE DURING THE MONTH
NO	CODE	NAME	QTY	AMT	QTY	AMT	QTY	AMT	QTY	AMT	AMT	QTY	QTY	DIF		
1	018851	Glass Bottle #300-15	3	3,957	0	0	0	0	0	0	3,957	3	3	0		
2	018934	WOOD LID QIN-08 2-1494-0502	4	687	0	0	0	0	0	0	687	4	2	-2		
3	019019	ABS TRAY 30-1	50	12,261	0	0	0	0	0	0	12,261	50	85	35		
4	019128	PS Tray B-4 Ranntai	1,350	9,811	0	0	0	0	0	0	9,811	1,350	1,350	0	A3	
5	019158	BAMBOO BLIND 1-539-1A	20	1,720	0	0	0	0	0	0	1,720	20	20	0		
6	019166	Handle for Pottery Teapot	100	3,179	0	0	0	0	0	0	3,179	100	100	0		
7	019167	SAKAZUKI for Pottery Teapot	300	25,321	0	0	0	0	0	0	25,321	300	288	-12		
8	019168	Cover for Pottery Tea Pot	100	7,433	0	0	0	0	0	0	7,433	100	87	-13		
9	019169	Body for Pottery Tea pot	30	9,130	0	0	0	0	0	0	9,130	30	30	0		
10	019544	POTTERY SAKE CUP 265-06	1	94	0	0	0	0	0	0	94	1		-1		
11	019545	POTTERY SAKE CUP 273-30	6	1,691	0	0	0	0	0	0	1,691	6	6	0		
12	019559	POTTERY BOWL 214-16	9	12,686	0	0	0	0	0	0	12,686	9	2	-7		
13	019560	POTTERY BOWL 8.0 233-16	8	8,262	0	0	0	0	0	0	8,262	8	8	0		
14	019611	WOOD TRAY SL	320	133,150	0	0	0	0	0	0	133,150	320		-320		

Figure 4.15 Format for Monthly Warehouse Checking Record

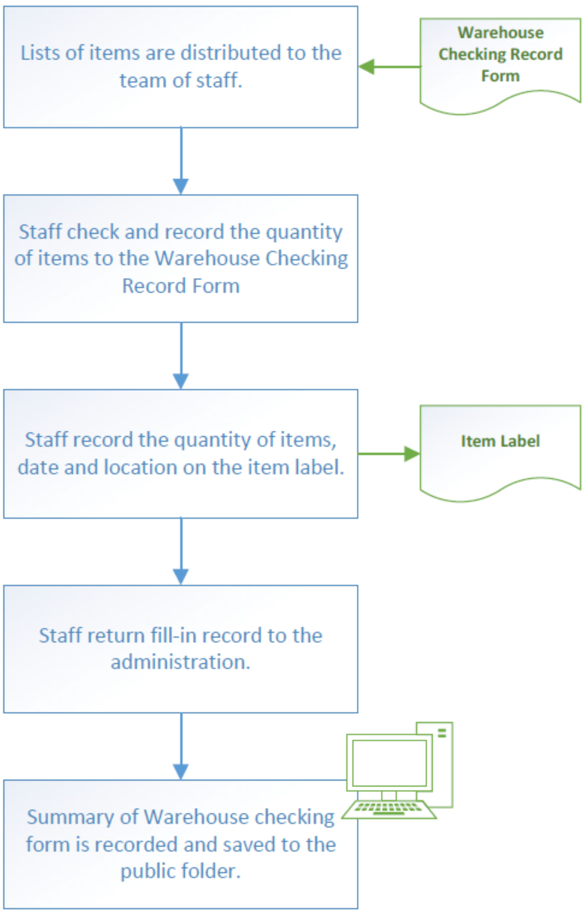


Figure 4.16 Proposed Warehouse Checking Process

4.3.4 Summary of Proposed Documents

Four documents for warehousing management are proposed in section 4.3.2 and 4.3.3. The summary of document forms, number and descriptions are shown in *Table 4.8*. The format can be updated by revision updating. The electronic file of the index file and forms shall be saved into the public folder, where everyone can access.

Table 4.8 Summary of Proposed Documents

Forms	Doc. No.	Rev.	Figure of example	Descriptions
Receiving-Item and Location List	THF-01	0	Figure 4.12	- An advance noticing list of receiving items - Recording storage place by warehousing staff
Item Label	THF-02	0	Figure 4.13	- A form showing details of stock item (code, number, and receiving date)
Picking List	THF-03	0	Figure 4.14	- A list of ordering items from customer
Monthly Warehouse Checking Record	THF-04	0	Figure 4.15	- A monthly warehouse checking record

4.4 CHAPTER SUMMARY

In conclusion, this chapter presents the proposed development for inventory and warehouse management based on the current data and operations. The summary is shown in *Table 4.9*.

Performance measurements are firstly defined for the assessment. Then, items are evaluated and separated as ABC Pareto based on specified criteria. Demand pattern analysis is performed in order to apply appropriate tools and techniques. Furthermore, basis and assumptions of inventory policy assessment are described.

In addition, procedures for warehouse operation and inventory checking process are developed. Documentations for recording and item labelling are developed. Electronic files are proposed to be kept in specified public folder in the computer network.

Table 4.9 Summary of Proposed Policy

Management Area	**Proposed Development**
Inventory Management	- Performance measurement - Demand pattern analysis - Forecasting approach analysis - Periodic review policy - Sensitivity analysis for service levels - Ordering process flow
Inventory & Warehouse Management	- Inventory Classification based on characteristic of product flow - Public folder for updating storage location
Warehouse Management	Warehouse operation flow Standard work flow for warehouse checking process Documentations; - Item label, - Receiving-item list & location list, - Picking list, and, - Monthly warehouse checking record

Last but not least, all employees shall be consistently reminded of the procedures and roles of each other in order to operate the organization in the same direction. The proposed steps and documents will be worthless if nobody understands or follows the new directives. The meeting for workflow clarification shall be arranged before process implementation. Any feedback or recommendations from employees can be adopted if deemed suitable.

Chapter 5
RESULTS AND ASSESSMENT

The verifications and results of the proposed policy for the Japanese products from Chapter 4 will be described in this chapter based on specified performance measurement in section 4.1. Twelve months of historical data from 2015 are used to evaluate the most appropriate forecasting technique for each inventory group (A, B, and C). Five months of periodic review policy simulation and the actual operation will be assessed and compared.

Forecasting errors such as MAPE, MAD, MSE, and MASE are used for the forecasting accuracy comparison. Each error indicator is suited for the different characteristic of data as demonstrated in Chapter 2.

For example; MAPE is scale sensitive. The low number of unit applied with MAPE will result in a large error factor which may lead to misinterpretation of data. Moreover, MAPE cannot be applied for items with zero demand as the percentage result is based on the actual demand. On the other hand, MASE is suggested for intermittent demand data as it never gives infinite value (Hyndman, 2006). MAD signifying Mean Square Deviation cannot be compared across series as it scales independently. MSE is suitable for forecasting the means of the future distribution based on past observations.

Regarding a mix characteristic of demand data for the Japanese products, each indicator will be evaluated individually. The most suitable of error indicator for all data cannot be selected. Moreover, the study will weight each item equally for the analysis for all groups.

5.1 GROUP A INVENTORY

Twenty (20) items out of the fifty nine (59) items in group A are randomly selected to be tested for the study evaluation.

5.1.1 Forecasting Approach Evaluation

Regarding evaluation basis in section 4.2 and *Table 4.7*, three forecasting techniques, Naïve, 3 months moving average, and simple exponential smoothing will be simulated and will have their average errors of MAPE, MAD, and MSE compared, for month 4 to 12 for group A items.

Firstly, the weight factor (smoothing factor) for simple exponential smoothing approach will be assessed. Since there are three forecasting-error indicators, the solver function in Microsoft excel is used to determine the weight factor (alpha) which results in the optimum average error for each technique. An example of solver function being used is shown in *Figure 5.1*. The minimum and maximum number of the factor is set to 0.1 and 0.9, respectively.

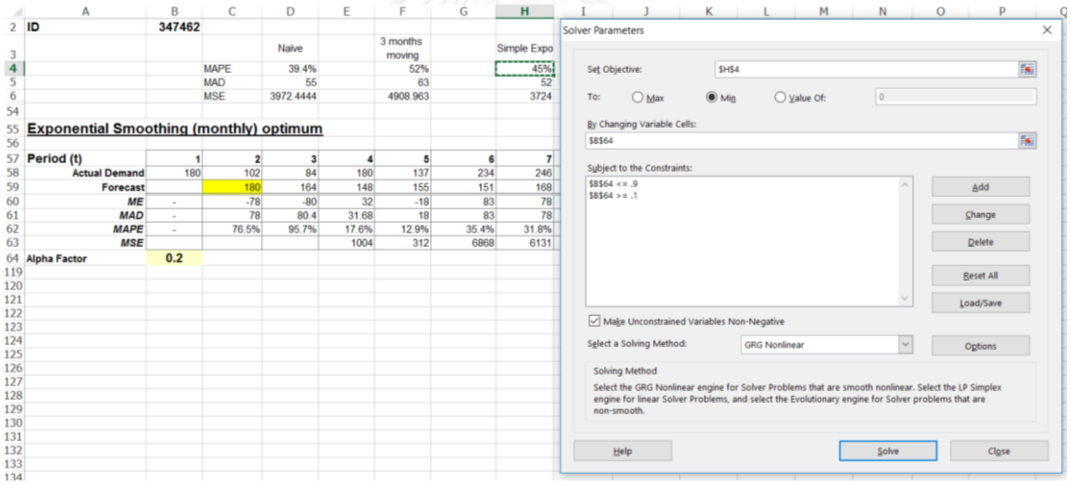


Figure 5.1 An Example of Solver Function used for Finding Optimum Number for Weight Factor

The weight factors that give the minimum error for each indicator are shown in Table 5.1. 20 items in group A are randomly selected. The “Seq. Order” column shows the sequencing order of the data in section 4.2.1. Results show the average values of the optimum result are 0.27 for MAPE, and 0.29 for MAD and MSE indicator. The medians for all indicators are 0.1.

It can be seen from the table that 0.1 is the value which mostly results in the optimum error for all indicators. However, the average numbers show that there are some demand data which suit for the values far from 0.1. As the result, 0.2 is selected as a fixed-factor for all data evaluation for group A.

Table 5.1 Group A Items - Weight Factors Analysis for Exponential Smoothing Technique

Alpha for Simple Exponential Smoothing Method (Group A)						
No.	Code	Group Check	Seq. Order	Optimum Weight Factor (alpha)		
				MAPE	MAD	MSE
1	250625	A	2	0.70	0.70	0.70
2	322283	A	3	0.69	0.69	0.71
3	183114	A	6	0.32	0.34	0.41
4	186874	A	8	0.11	0.10	0.10
5	347462	A	9	0.20	0.20	0.15
6	127792	A	10	0.10	0.10	0.10
7	147246	A	11	0.90	0.84	0.70
8	517544	A	12	0.50	0.50	0.10
9	293460	A	15	0.10	0.10	0.10
10	184514	A	18	0.10	0.10	0.24
11	307112	A	24	0.10	0.14	0.10
12	157923	A	30	0.34	0.34	0.90
13	184288	A	33	0.10	0.10	0.10
14	375080	A	39	0.10	0.10	0.10
15	184336	A	44	0.10	0.63	0.64
16	220997	A	45	0.24	0.10	0.10
17	371296	A	46	0.31	0.31	0.24
18	223552	A	52	0.10	0.10	0.10
19	184624	A	57	0.10	0.10	0.10
20	388633	A	58	0.10	0.13	0.21
	Average			**0.27**	**0.29**	**0.29**
	Median			**0.1**	**0.1**	**0.1**

Then, the average values from specified error techniques are determined for the three forecasting methods as shown in *Table 5.2, 5.3, and 5.4.* The approach that result the minimum error is named on the right column of the table.

The comparison of the least error forecasting techniques with the least errors toward three forecasting indicators is shown in *Table 5.5*. The table shows that simple exponential smoothing approach with a fixed alpha at 0.2 appears to be a technique which results in the most accurate technique for the selected data from all three indicators.

Table 5.2 Average MAPE for Group A Items and the Minimum Error Forecasting Approach

MAPE / month (4 - 12)						Approach Resulting Minimum Error
No.	Code	Seq. Order	Naïve	3 Months Moving Average	Exponential Smoothing (Alpha = 0.2)	
1	250625	2	23%	26%	29%	Naïve
2	322283	3	54%	61%	89%	Naïve
3	183114	6	25%	14%	18%	3 Months Moving Avg
4	186874	8	38%	32%	30%	ES (Alpha = 0.2)
5	347462	9	39%	52%	45%	Naïve
6	127792	10	35%	29%	24%	ES (Alpha = 0.2)
7	147246	11	72%	114%	159%	3 Months Moving Avg
8	517544	12	44%	51%	53%	3 Months Moving Avg
9	293460	15	44%	34%	29%	ES (Alpha = 0.2)
10	184514	18	52%	53%	41%	ES (Alpha = 0.2)
11	307112	24	54%	37%	36%	ES (Alpha = 0.2)
12	157923	30	44%	47%	37%	ES (Alpha = 0.2)
13	184288	33	54%	77%	65%	Naïve
14	375080	39	426%	246%	219%	ES (Alpha = 0.2)
15	184336	44	36%	37%	34%	ES (Alpha = 0.2)
16	220997	45	217%	149%	152%	3 Months Moving Avg
17	371296	46	62%	57%	57%	ES (Alpha = 0.2)
18	223552	52	70%	54%	58%	3 Months Moving Avg
19	184624	57	44%	39%	29%	ES (Alpha = 0.2)
20	388633	58	117%	69%	62%	ES (Alpha = 0.2)

Table 5.3 Average MAD for Group A Items and the Minimum Error Forecasting Approach

MAD / month (4 - 12)						Approach Resulting Minimum Error
No.	Code	Seq. Order	Naïve	3 Months Moving Average	Exponential Smoothing (Alpha = 0.2)	
1	250625	2	2600	2881	3055	Naïve
2	322283	3	1711	1752	2404	Naïve
3	184336	6	666	403	513	3 Months Moving Avg
4	293460	8	1055	881	793	ES (Alpha = 0.2)
5	183114	9	55	63	52	ES (Alpha = 0.2)
6	184288	10	85	65	55	ES (Alpha = 0.2)
7	127792	11	26	29	35	Naïve
8	184514	12	4.9	5.0	6.1	Naïve
9	157923	15	4900	3600	2946	ES (Alpha = 0.2)
10	307112	18	239	213	190	ES (Alpha = 0.2)
11	375080	24	4300	2667	2538	ES (Alpha = 0.2)
12	186874	30	25556	28222	25777	Naïve
13	388633	33	489	459	365	ES (Alpha = 0.2)
14	371296	39	95	63	63	ES (Alpha = 0.2)
15	147246	44	2667	2678	2857	Naïve
16	517544	45	5.0	3.7	3.4	ES (Alpha = 0.2)
17	223552	46	2444	2074	2149	3 Months Moving Avg
18	347462	52	4333	2904	3001	3 Months Moving Avg
19	220997	57	889	770	620	ES (Alpha = 0.2)
20	184624	58	1122	800	815	3 Months Moving Avg

Table 5.4 Average MSE for Group A Items and the Minimum Error Forecasting Approach

MSE / month (4 - 12)						Approach Resulting Minimum Error
No.	Code	Seq. Order	Naïve	3 Months Moving Average	Exponential Smoothing (Alpha = 0.2)	
1	250625	2	7,433,333	10,911,852	12,681,942	Naïve
2	322283	3	5,033,889	5,428,395	7,465,647	Naïve
3	184336	6	666,137	326,269	507,159	3 Months Moving Avg
4	293460	8	1,592,646	1,046,463	885,150	ES (Alpha = 0.2)
5	183114	9	3,972	4,909	3,724	ES (Alpha = 0.2)
6	184288	10	10,685	6,870	4,977	ES (Alpha = 0.2)
7	127792	11	1,185	1,306	1,680	Naïve
8	184514	12	32	41	44	Naïve
9	157923	15	28,530,000	17,980,000	12,891,921	ES (Alpha = 0.2)
10	307112	18	82,500	88,981	70,983	ES (Alpha = 0.2)
11	375080	24	23,670,000	14,920,000	11,422,119	ES (Alpha = 0.2)
12	186874	30	811,333,333	1,242,839,506	1,148,043,274	Naïve
13	388633	33	345,556	252,654	205,716	ES (Alpha = 0.2)
14	371296	39	14,418	7,327	7,714	3 Months Moving Avg
15	147246	44	10,285,000	11,256,667	10,830,342	Naïve
16	517544	45	34	17	14	ES (Alpha = 0.2)
17	223552	46	7,555,556	6,913,580	6,302,008	ES (Alpha = 0.2)
18	347462	52	26,333,333	13,891,111	12,942,654	ES (Alpha = 0.2)
19	220997	57	1,422,222	726,914	536,905	ES (Alpha = 0.2)
20	184624	58	1,947,778	896,790	1,017,980	3 Months Moving Avg

Table 5.5 Group A - Comparison of Forecasting Approach Resulting Minimum Error for Each Indicator

No.	Code	Approach Resulting Minimum Average Error		
		MAPE	MAD	MSE
1	250625	Naïve	Naïve	Naïve
2	322283	Naïve	Naïve	Naïve
3	183114	3 Months Moving Avg	3 Months Moving Avg	3 Months Moving Avg
4	186874	ES (Alpha = 0.2)	ES (Alpha = 0.2)	ES (Alpha = 0.2)
5	347462	Naïve	ES (Alpha = 0.2)	ES (Alpha = 0.2)
6	127792	ES (Alpha = 0.2)	ES (Alpha = 0.2)	ES (Alpha = 0.2)
7	147246	3 Months Moving Avg	Naïve	Naïve
8	517544	3 Months Moving Avg	Naïve	Naïve
9	293460	ES (Alpha = 0.2)	ES (Alpha = 0.2)	ES (Alpha = 0.2)
10	184514	ES (Alpha = 0.2)	ES (Alpha = 0.2)	ES (Alpha = 0.2)
11	307112	ES (Alpha = 0.2)	ES (Alpha = 0.2)	ES (Alpha = 0.2)
12	157923	ES (Alpha = 0.2)	Naïve	Naïve
13	184288	Naïve	ES (Alpha = 0.2)	ES (Alpha = 0.2)
14	375080	ES (Alpha = 0.2)	ES (Alpha = 0.2)	3 Months Moving Avg
15	184336	ES (Alpha = 0.2)	Naïve	Naïve
16	220997	3 Months Moving Avg	ES (Alpha = 0.2)	ES (Alpha = 0.2)
17	371296	ES (Alpha = 0.2)	3 Months Moving Avg	ES (Alpha = 0.2)
18	223552	3 Months Moving Avg	3 Months Moving Avg	ES (Alpha = 0.2)
19	184624	ES (Alpha = 0.2)	ES (Alpha = 0.2)	ES (Alpha = 0.2)
20	388633	ES (Alpha = 0.2)	3 Months Moving Avg	3 Months Moving Avg
Naïve		4	6	6
3 Months Moving Avg		5	4	3
ES (Alpha = 0.2)		11	10	11

In conclusion, simple exponential smoothing with alpha 0.2 will be selected for demand estimation applied to the periodic simulation review in the next section.

5.1.2 Periodic Review Policy Simulation Results

The periodic review simulation is applied to 20 items from group A. Basis and assumption refers to section 4.2.8. 95% and 98% service level are sensitively determined for safety stock. The comparison results of actual inventory level are illustrated in *Figure 5.2 and 5.3* for 95% service level, and *Figure 5.4 and 5.5* for 98% service level. The actual inventory levels from January to May 2016 are shown in blue bold lines, and the proposed policy results are shown in red dash lines.

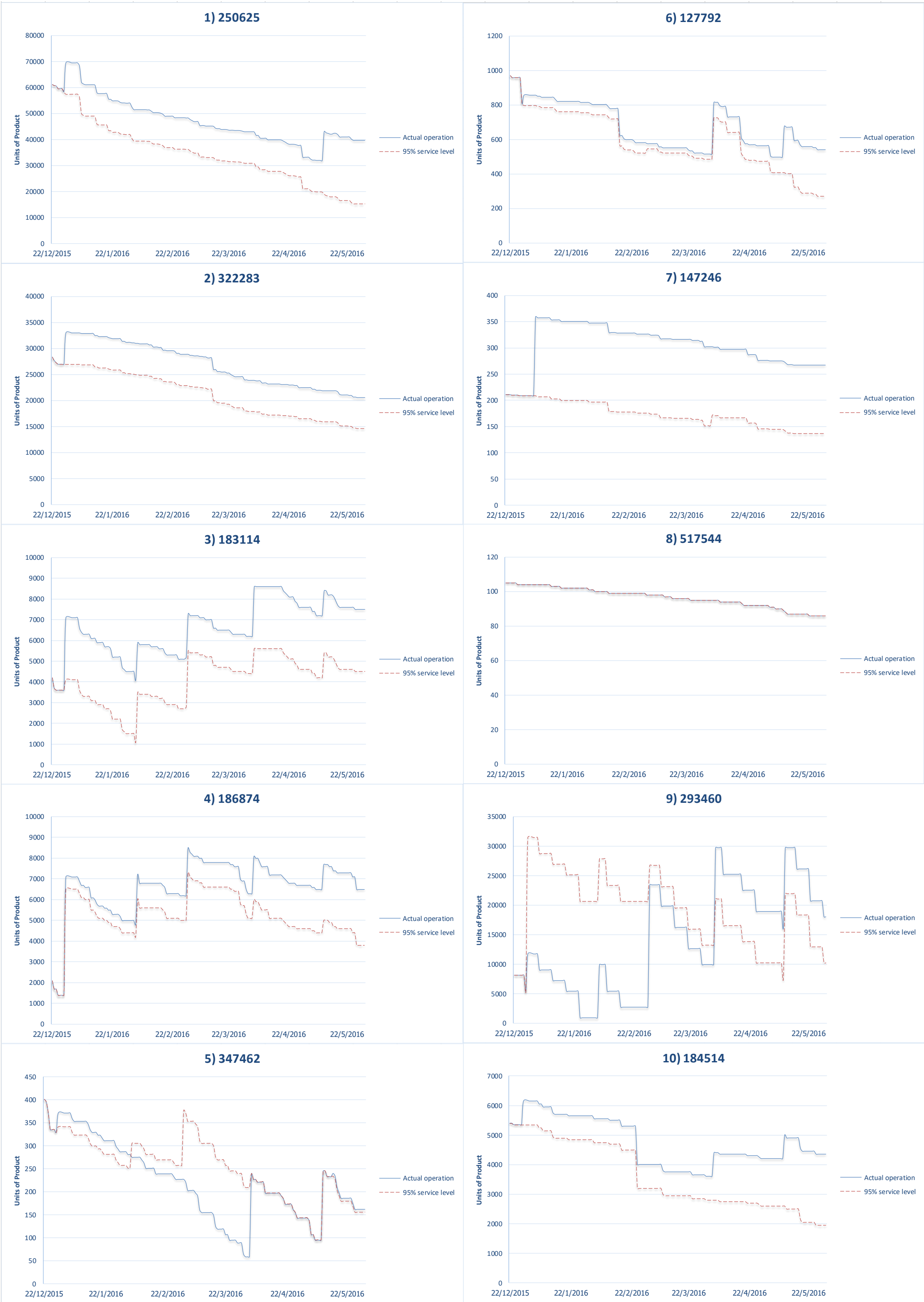


Figure 5.2 Group A - Periodic Review Policy Results for Item No. 1 – 10 (95% Service Level for Safety Stock)

Figure 5.3: Group A - Periodic Review Policy Results for Item No. 11 – 20 (95% Service Level for Safety Stock)

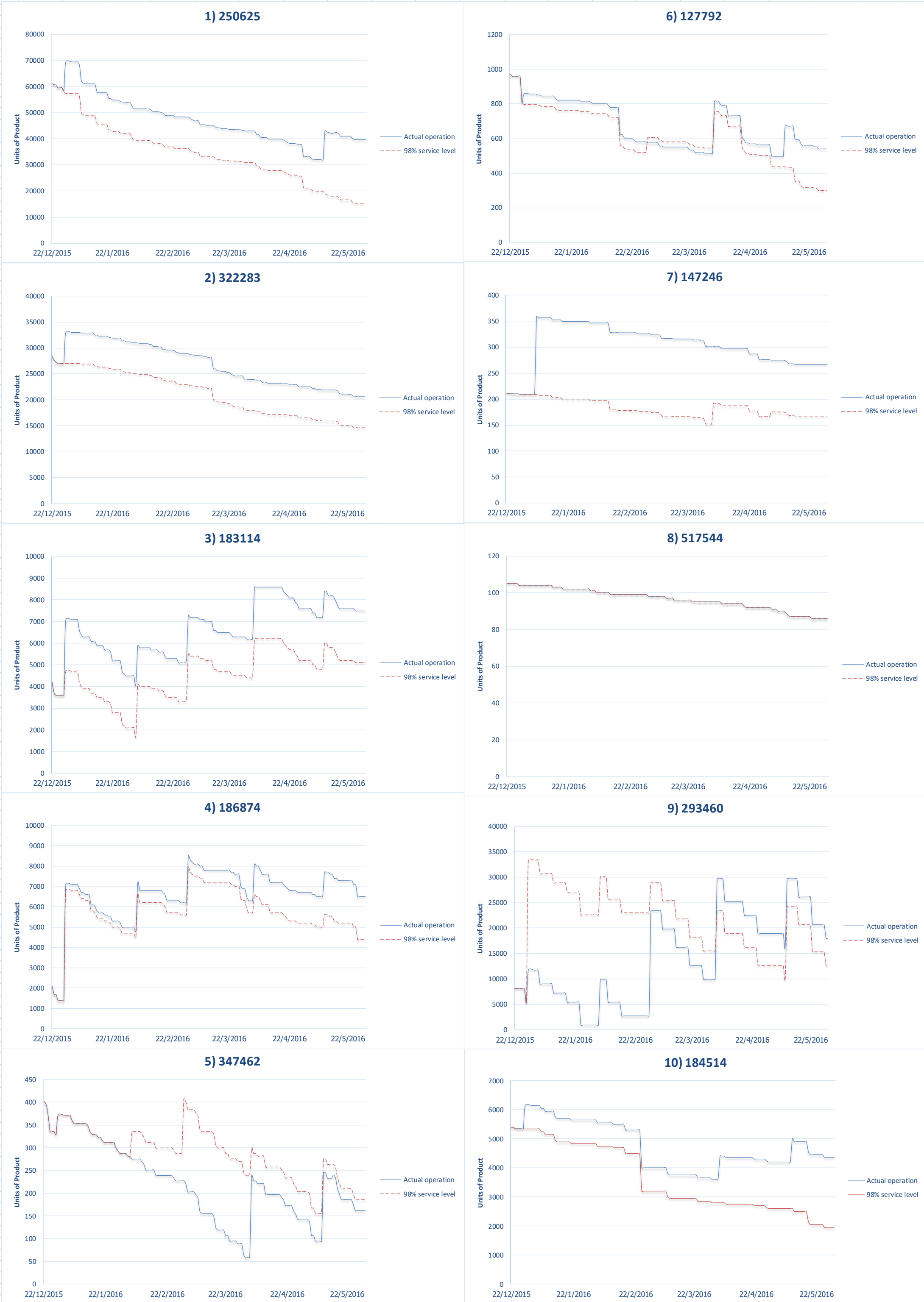


Figure 5.4 Group A - Periodic Review Policy Results for Item No. 1 – 10 (98% Service Level for Safety Stock)

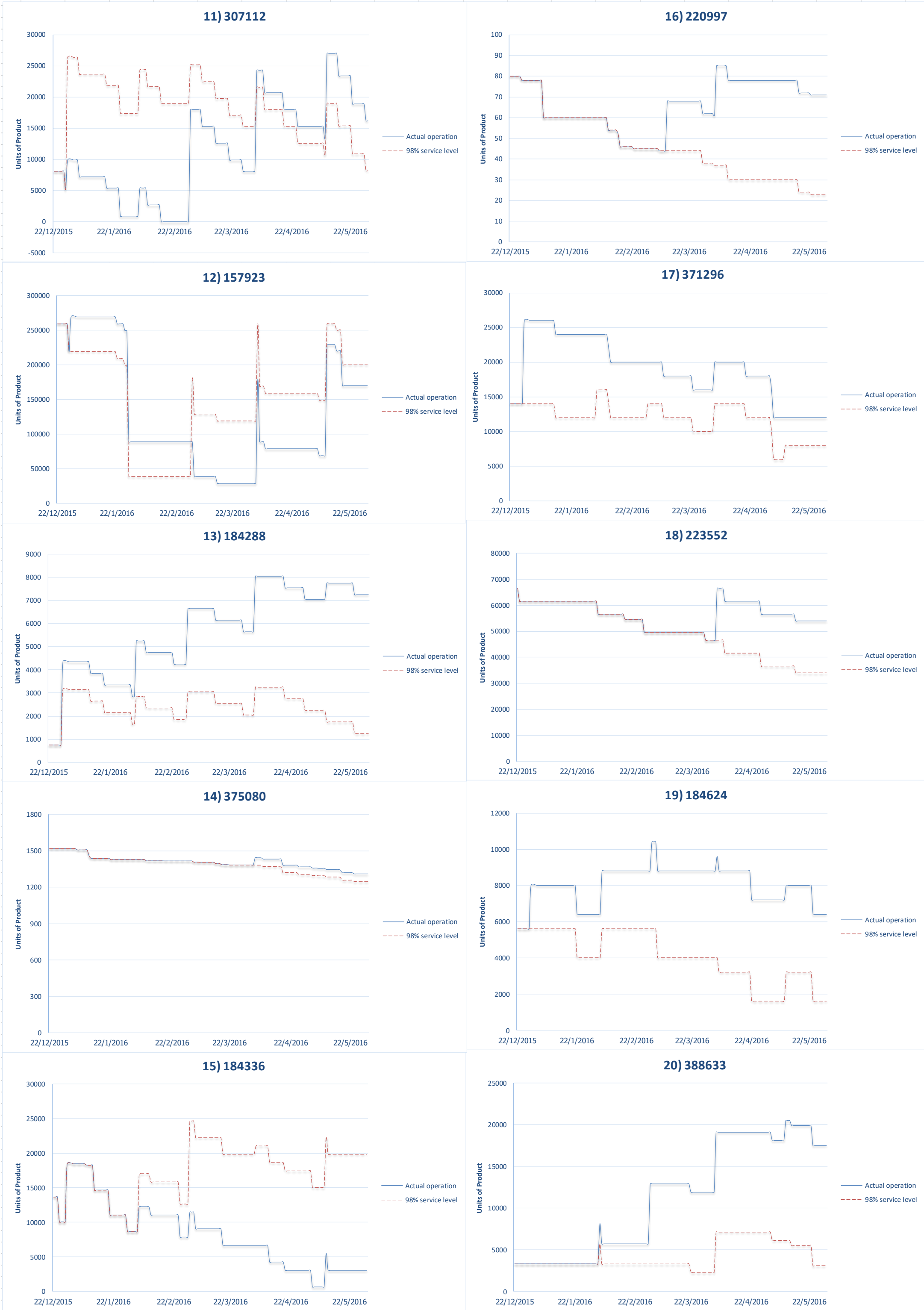
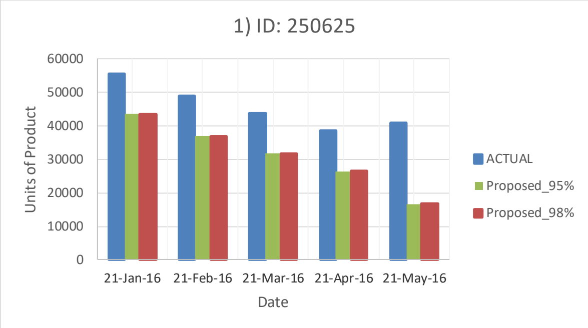
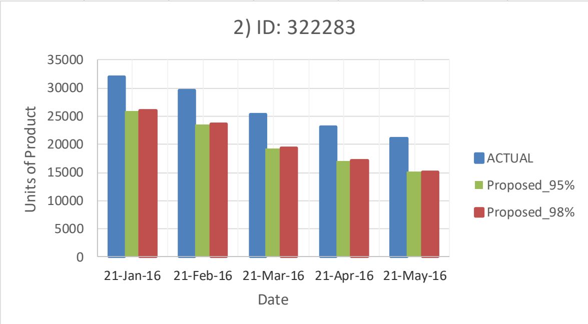


Figure 5.5 Group A - Periodic Review Policy Results for Item No. 11 – 20 (98% Service Level for Safety Stock)

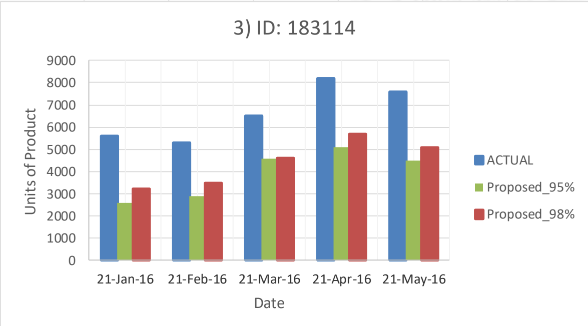
Periodic stock records on the date of the 21st of every month between January and May 2016 are reviewed and plotted. *Figure 5.6, 5.7, and 5.8* illustrate 14 items from group A that show a reduction in inventory due to the proposed policy implementation.



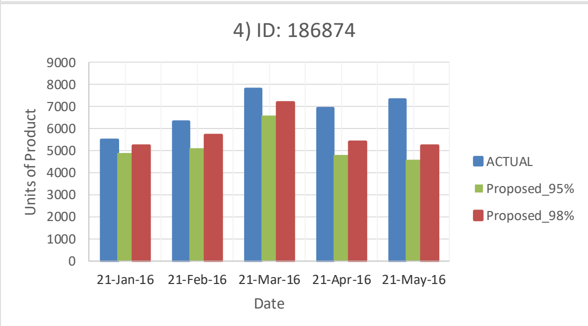
Month (2016)	Inventory Level (unit) Actual	95%Service level	98%Service level
Jan	55,500	43,500	43,500
Feb	49,000	37,000	37,000
Mar	43,800	31,800	31,800
Apr	38,500	26,500	26,500
May	41,000	16,700	16,700



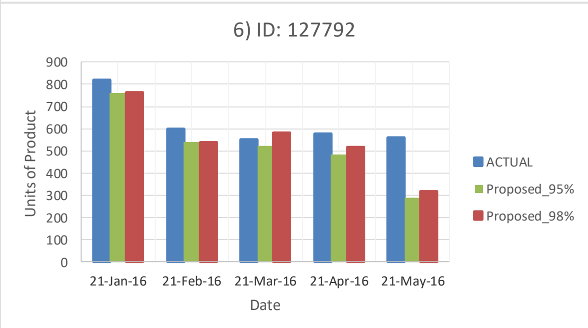
Month (2016)	Inventory Level (unit) Actual	95%Service level	98%Service level
Jan	32,000	26,000	26,000
Feb	29,600	23,600	23,600
Mar	25,300	19,300	19,300
Apr	23,100	17,100	17,100
May	21,100	15,100	15,100



Month (2016)	Inventory Level (unit) Actual	95%Service level	98%Service level
Jan	5,600	2,600	3,200
Feb	5,300	2,900	3,500
Mar	6,500	4,600	4,600
Apr	8,200	5,100	5,700
May	7,600	4,500	5,100

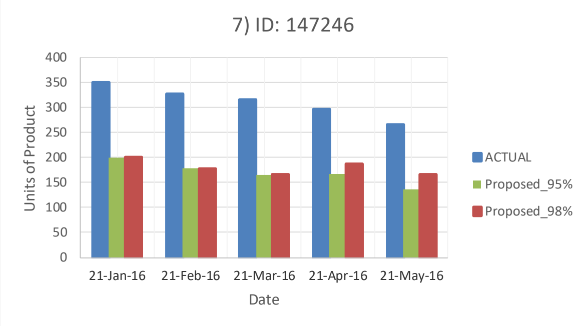


Month (2016)	Inventory Level (unit) Actual	95%Service level	98%Service level
Jan	5,500	4,900	5,200
Feb	6,300	5,100	5,700
Mar	7,800	6,600	7,200
Apr	6,900	4,800	5,400
May	7,300	4,600	5,200

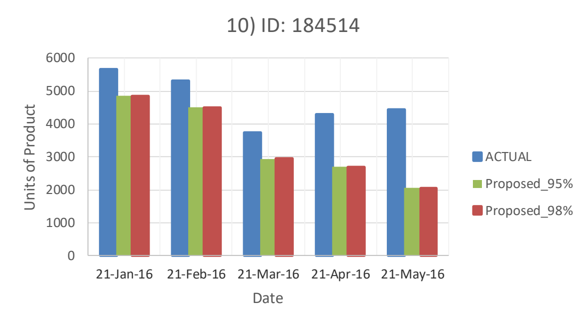


Month (2016)	Inventory Level (unit) Actual	95%Service level	98%Service level
Jan	821	761	761
Feb	599	539	539
Mar	551	521	581
Apr	575	485	515
May	558	288	318

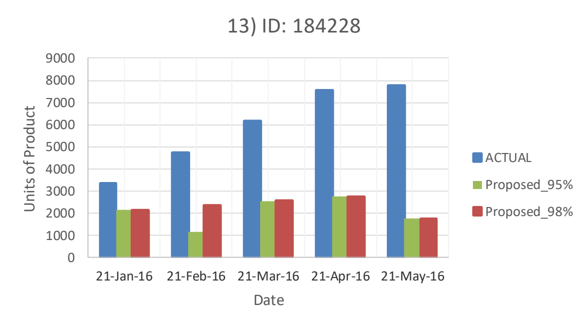
Figure 5.6 Reduction of an Inventory for Group A Items – 1/3



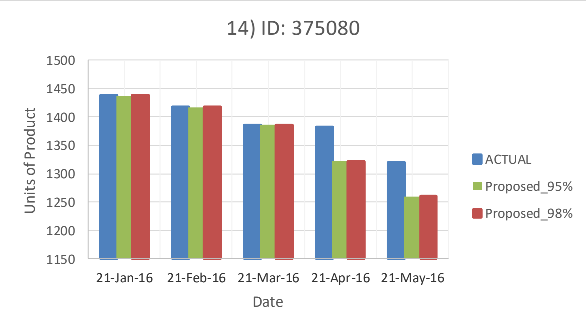
Month (2016)	Inventory Level (unit)		
	Actual	95%Service level	98%Service level
Jan	350	200	200
Feb	328	178	178
Mar	316	166	166
Apr	297	167	187
May	267	137	167



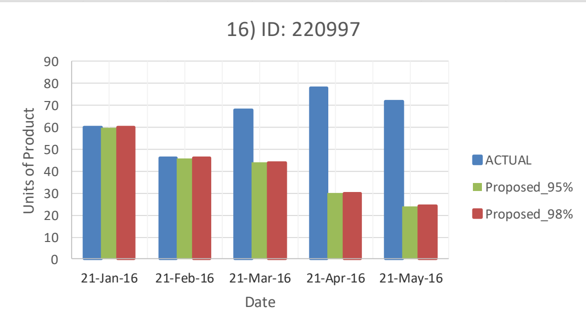
Month (2016)	Inventory Level (unit)		
	Actual	95%Service level	98%Service level
Jan	5,650	4,850	4,850
Feb	5,300	4,500	4,500
Mar	3,750	2,950	2,950
Apr	4,300	2,700	2,700
May	4,450	2,050	2,050



Month (2016)	Inventory Level (unit)		
	Actual	95%Service level	98%Service level
Jan	3,350	2,150	2,150
Feb	4,750	1,150	2,350
Mar	6,150	2,550	2,550
Apr	7,550	2,750	2,750
May	7,750	1,750	1,750

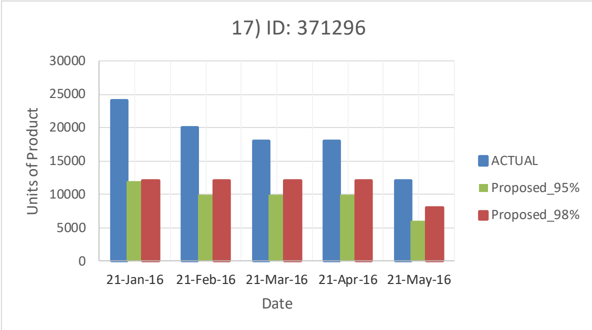


Month (2016)	Inventory Level (unit)		
	Actual	95%Service level	98%Service level
Jan	1,438	1,438	1,438
Feb	1,417	1,417	1,417
Mar	1,386	1,386	1,386
Apr	1,382	1,322	1,322
May	1,320	1,260	1,260

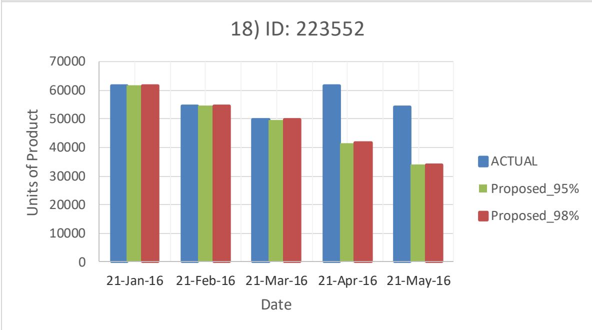


Month (2016)	Inventory Level (unit)		
	Actual	95%Service level	98%Service level
Jan	60	60	60
Feb	46	46	46
Mar	68	44	44
Apr	78	30	30
May	72	24	24

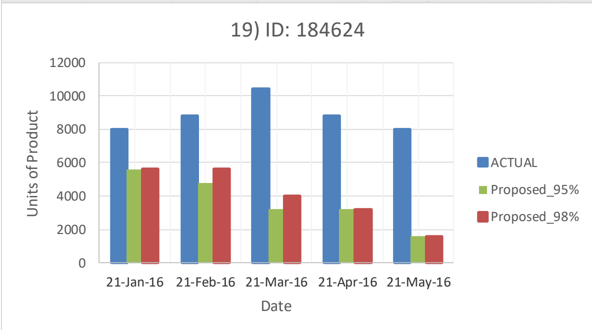
Figure 5.7 Reduction of an Inventory for Group A Items – 2/3



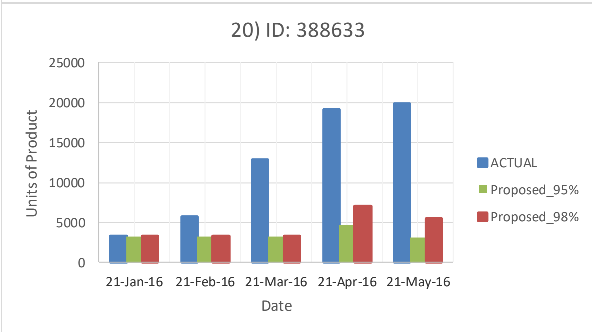
Month (2016)	Inventory Level (unit) Actual	95%Service level	98%Service level
Jan	24,000	12,000	12,000
Feb	20,000	10,000	12,000
Mar	18,000	10,000	12,000
Apr	18,000	10,000	12,000
May	12,000	6,000	8,000



Month (2016)	Inventory Level (unit) Actual	95%Service level	98%Service level
Jan	61,600	61,600	61,600
Feb	54,600	54,600	54,600
Mar	49,600	49,600	49,600
Apr	61,600	41,600	41,600
May	54,000	34,000	34,000



Month (2016)	Inventory Level (unit) Actual	95%Service level	98%Service level
Jan	8,000	5,600	5,600
Feb	8,800	4,800	5,600
Mar	10,400	3,200	4,000
Apr	8,800	3,200	3,200
May	8,000	1,600	1,600



Month (2016)	Inventory Level (unit) Actual	95%Service level	98%Service level
Jan	3,300	3,300	3,300
Feb	5,700	3,300	3,300
Mar	12,900	3,300	3,300
Apr	19,100	4,700	7,100
May	19,900	3,100	5,500

Figure 5.8 Reduction of an Inventory for Group A Items – 3/3

The inventory determined from 95% service level of safety stock is supposed to be less than the inventory determined from 98% service level of safety stock. Nevertheless, the comparisons for some items such as item number 1, 4, 16, and 18 show that the inventories of both service levels are equal. This is a result of two factors. First, the minimum order quantity makes the ordering decision the same. Second, the current inventory level is too high compared to the demand, or it is overstocked. Therefore, it results in the decision of not ordering the same items.

The other 6 items do not result in a reduction of an inventory. Three of them (Item No. 9, 11, and 15) result in the increase of inventory due to the implementation. Nevertheless, these items are ordered from a single customer who acknowledges the inventory level and shares the ordering information with the studied company. The comparisons are illustrated in *Figure 5.9.*

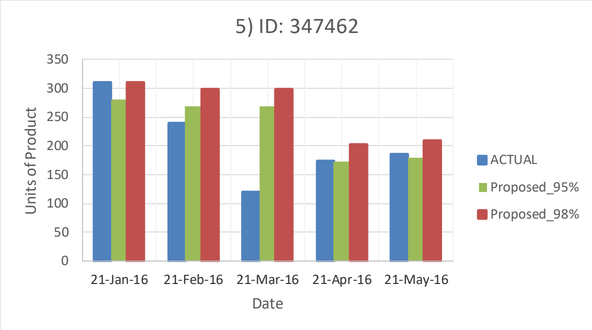
Month (2016)	Inventory Level (unit) Actual	95%Service level	98%Service level
Jan	5,400	25,100	27,100
Feb	2,700	20,600	23,000
Mar	12,600	15,900	18,200
Apr	22,500	13,800	16,200
May	26,100	18,300	20,700

Month (2016)	Inventory Level (unit) Actual	95%Service level	98%Service level
Jan	5,400	19,700	21,900
Feb	-	16,800	19,000
Mar	9,900	15,100	17,100
Apr	18,000	13,200	15,300
May	23,400	13,300	15,400

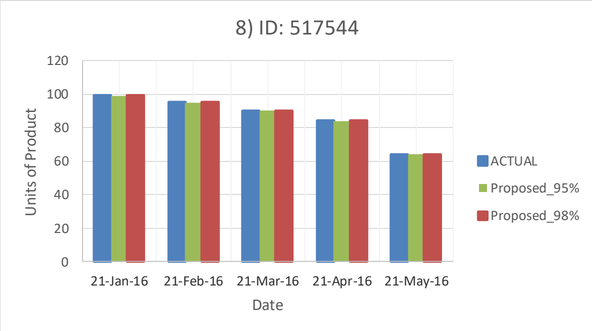
Month (2016)	Inventory Level (unit) Actual	95%Service level	98%Service level
Jan	11,050	8,650	11,050
Feb	11,050	14,650	15,850
Mar	6,650	17,450	19,850
Apr	3,050	16,250	17,450
May	3,050	17,450	19,850

Figure 5.9 Inventory Results for Group A Items with Receiving Shared Information from A Single Customer

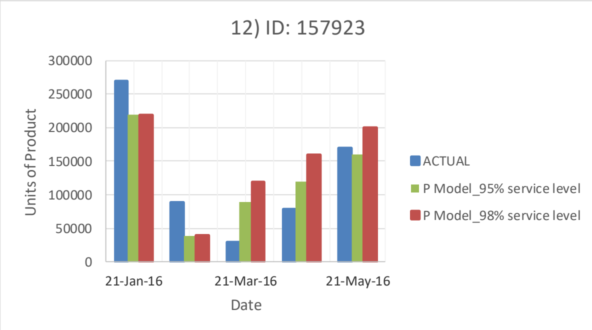
The other 3 items (No. 5, 8, and 12) are shown in *Figure 5.10*. The current operations are in the same range of the proposed policy.



Month (2016)	Inventory Level (unit) Actual	95%Service level	98%Service level
Jan	311	281	311
Feb	239	269	299
Mar	119	269	299
Apr	173	173	203
May	186	179	209



Month (2016)	Inventory Level (unit) Actual	95%Service level	98%Service level
Jan	99	99	99
Feb	95	95	95
Mar	90	90	90
Apr	84	84	84
May	64	64	64



Month (2016)	Inventory Level (unit) Actual	95%Service level	98%Service level
Jan	269,000	219,000	219,000
Feb	89,000	39,000	39,000
Mar	29,000	89,000	119,000
Apr	79,000	119,000	159,000
May	170,000	160,000	200,000

Figure 5.10 Inventory Results for Group A Items with No Inventory Reduction for Implementing the Proposed Policy

Table 5.6 illustrates the comparison of actual operations and simulation results toward three key performance indexes (KPI) identified in section 4.1. These are inventory level, inventory value and service level. The table presents the inventory level and value with daily average. The actual service level is presented in percentage. The service levels are 100% since both actual operation and proposed policy maintain inventory for serving the demand except actual operation of item no. 11 (code 307112) which experienced a stock out period during February for 15 days (shown in *Figure 5.3 and 5.5*).

The total numbers of inventory level and value by the proposed policy for both 95 and 98 percent service level are less than the actual operation.

Since, the proposed policy does not suit with the products ordered by a single customer who shares information, the summary of total inventory level and value without these items is shown to determine the real reduction of the adopted policy.

Overall, the stock level of 95% service level is less than 98% service level. Regarding the simulation results in *Figure 5.2*, *5.3*, *5.4*, *and 5.5*, there is no stock-out event for both safety stocks. Hence, the service level of 95% is suggested for the policy application since the inventory holding is less than the safety stock determined from 98% service level, and it can serve the customers' demands without any stock out event occurring nor any potential unfulfilled demand.

In summary, the application of the proposed policy and forecasting technique can decrease the inventory level for group A items except for the products which are ordered by a single customer who shares ordering information. 95% service level for safety stock determination is recommended. The assessment shows that the proposed policy can reduce daily average numbers of items by 17% and reduce the average daily inventory value by 23% compared to the current operation of the studied company.

Table 5.6 Comparison Performance Measurement for Group A Items

No.	Product ID	Average Daily Inventory Level (unit)			cost per unit (THB)	Average Daily Inventory Value (THB)			Service Level Measurement		
		Actual operation	95% Service level	98% Service level		Actual operation	95% Service level	98% Service level	Actual operation	95% Service level	98% Service level
1	250625	47,168	34,011	34,011	0.40	18,710	13,491	13,491	100%	100%	100%
2	322283	26,774	21,037	21,037	1.82	48,729	38,287	38,287	100%	100%	100%
3	183114	6,609	4,093	4,539	4.56	30,136	18,662	20,697	100%	100%	100%
4	186874	6,613	5,188	5,696	4.84	32,005	25,108	27,567	100%	100%	100%
5	347462	222	251	287	132	29,230	33,109	37,779	100%	100%	100%
6	127792	673	586	610	167	112,605	98,107	102,061	100%	100%	100%
7	147246	304	173	182	230	69,974	39,917	42,003	100%	100%	100%
8	517544	97	97	97	354	34,352	34,352	34,352	100%	100%	100%
9	293460	14,248	19,138	21,324	3.43	48,843	65,603	73,098	100%	100%	100%
10	184514	4,744	3,579	3,579	5.09	24,149	18,219	18,219	100%	100%	100%
11	307112	11,874	16,116	18,141	3.46	41,085	55,760	62,767	90%	100%	100%
12	157923	127,794	129,106	149,981	0.46	59,211	59,819	69,491	100%	100%	100%
13	184288	5,706	2,188	2,383	2.21	12,632	4,845	5,276	100%	100%	100%
14	375080	1,409	1,387	1,387	33	46,175	45,462	45,462	100%	100%	100%
15	184336	8,251	15,556	17,386	3.08	25,373	47,835	53,463	100%	100%	100%
16	220997	66	45	45	526	34,895	23,927	23,927	100%	100%	100%
17	371296	18,900	10,325	11,800	2.92	55,094	30,097	34,397	100%	100%	100%
18	223552	56,549	49,299	49,299	1.51	85,389	74,441	74,441	100%	100%	100%
19	184624	8,020	3,735	4,035	4.74	37,999	17,696	19,118	100%	100%	100%
20	388633	11,349	3,369	4,239	1.90	21,563	6,401	8,054	100%	100%	100%
Total		**357,369**	**319,279**	**350,058**		**868,147**	**751,139**	**803,949**	**100%**	**100%**	**100%**
Reduction			11%	2%			13%	7%			
Total (without item 9 ,11, and 15)		**322,996**	**268,470**	**293,207**		**752,846**	**581,940**	**614,622**			
Reduction			17%	9%			23%	18%			

5.1.3 Sensitivity Analysis for the Weight Factor

Sensitivity analysis for the weight factor (alpha) affecting to the overall performance is performed in this section since the methodology of the alpha selection in section 5.1.1 neglects the variance of demand size, error, and value. All studied items are considered equal. Moreover, the overall performance of the policy adoption can be evaluated.

The weight factors of 0.1, 0.2, and 0.3 are selected for the study. Items which are ordered by single customers who share demand information are not included in the analysis. Safety Stock is determined at 95% service level for all cases.

Table 5.7 Results for Weight Factors Sensitivity Analysis

Total (without item 9 ,11, and 15)	**Actual**	**Weight Factor**		
		0.1	**0.2**	**0.3**
Total Average Daily Inventory (units)	322,996	240,795	268,470	276,554
Reduction		*25%*	*17%*	*14%*
Total Average Daily Value (THB)	752,846	585,475	581,940	575,088
Reduction		*22%*	*23%*	*24%*
Actual Service Level	100%	100%	100%	100%

The results illustrated in *Table 5.7* show that an alpha of 0.1 can reduce the most units of items, while alpha of 0.3 can reduce the most value of stock. All cases can provide 100% actual service level.

The opposite results are because of the ignorance of the item unit value during forecasting technique selection. It is possible that the items with large units tend to be fitted with weight factor of 0.1, but its unit cost is low. However, the difference between three weight factors in in terms of value are considered marginal. The 11% difference of inventory level for weight factor of 0.1 and 0.3 cannot be accurately verified that which one is better as the volume of product or required space is not considered in this analysis. Nevertheless, the result implies that the using alpha of 0.1 and 0.3 impacts to the different sets of items.

5.2 GROUP B INVENTORY

Twenty (20) items out of the fifty four (54) items in group B are randomly selected to be tested for the study evaluation. The selection will cover a range of 8 to 11 months demand occurring.

5.2.1 Forecasting Approach Evaluation

Regarding *Table 4.7*, three forecasting techniques, Naïve, 3 months moving average, and simple exponential smoothing will be simulated and have their average errors of MASE, MAD, and MSE for month 4 to 12 compared.

The implementation steps are similar to group A. The weight factor (smoothing factor) for simple exponential smoothing approach will be assessed toward three forecasting-error indicators (MASE, MAD, and MSE) by using the solver function in Microsoft excel.

Table 5.8 shows the weight factors that give the minimum error for each indicator. The average and median of the optimum weight factors are in a range of 0.2. Hence, 0.2 will be selected for the forecasting method analysis for simple exponential smoothing.

Table 5.8 Group B Items - Weight Factors Analysis for Exponential Smoothing Technique

Alpha for Simple Exponential Smoothing Method (Group B)							
No. of month showing demand	No.	Code	Group Check	Seq. Order	Optimum Weight Factor (alpha)		
					MASE	MAD	MSE
11	1	401079	B	64	0.19	0.19	0.29
	2	226689	B	65	0.17	0.17	0.10
	3	330746	B	66	0.10	0.10	0.10
	4	121633	B	68	0.11	0.11	0.11
	5	109427	B	69	0.10	0.10	0.10
	6	325384	B	72	0.10	0.10	0.10
	7	404367	B	76	0.28	0.28	0.41
10	8	429581	B	79	0.46	0.46	0.86
	9	382116	B	80	0.12	0.12	0.13
	10	230136	B	84	0.19	0.19	0.30
	11	325388	B	87	0.38	0.38	0.53
9	12	RO-028	B	91	0.33	0.33	0.32
	13	159145	B	93	0.44	0.44	0.28
	14	270040	B	101	0.25	0.25	0.10
	15	184275	B	103	0.44	0.44	0.30
	16	121680	B	104	0.10	0.10	0.12
8	17	380616	B	105	0.10	0.10	0.10
	18	416437	B	106	0.10	0.10	0.10
	19	326936	B	112	0.49	0.49	0.59
	20	416445	B	113	0.14	0.14	0.10
		Average			**0.23**	**0.23**	**0.25**
		Median			**0.18**	**0.18**	**0.12**

Then, the average values from the specified error techniques are determined for the three forecasting methods as shown in *Table 5.9, 5.10, and 5.11*. The approach that results in the minimum error is named on the right column of the table.

The comparison of the least error forecasting techniques with the least error from the three forecasting indicators is shown in *Table 5.12*. The table presents that simple exponential smoothing approach with fixed alpha at 0.2 appears to be a technique which gives the most accurate results for the selected data from all three indicators.

Table 5.9 Average MASE for Group B Items and the Minimum Error Forecasting Approach

MASE / month (4 - 12)						**Approach Resulting Minimum Error**
No.	Code	Seq. Order	Naïve	3 Months Moving Average	Exponential Smoothing (Alpha = 0.2)	
1	401079	64	1.00	0.729	0.731	3 Months Moving Avg
2	226689	65	1.00	0.772	0.683	ES (Alpha = 0.2)
3	330746	66	1.00	0.754	0.595	ES (Alpha = 0.2)
4	121633	68	1.00	0.814	0.631	ES (Alpha = 0.2)
5	109427	69	1.00	0.965	0.847	ES (Alpha = 0.2)
6	325384	72	1.00	0.751	0.660	ES (Alpha = 0.2)
7	404367	76	1.00	0.730	0.783	3 Months Moving Avg
8	429581	79	1.00	1.333	1.712	Naïve
9	382116	80	1.00	0.669	0.659	ES (Alpha = 0.2)
10	230136	84	1.00	0.808	0.693	ES (Alpha = 0.2)
11	325388	87	1.00	0.944	1.067	3 Months Moving Avg
12	RO-028	91	1.00	0.738	0.789	3 Months Moving Avg
13	159145	93	1.00	0.728	0.856	3 Months Moving Avg
14	270040	101	1.00	0.725	0.598	ES (Alpha = 0.2)
15	184275	103	1.00	0.833	1.054	3 Months Moving Avg
16	121680	104	1.00	0.833	0.725	ES (Alpha = 0.2)
17	380616	105	1.00	0.715	0.714	ES (Alpha = 0.2)
18	416437	106	1.00	0.706	0.685	ES (Alpha = 0.2)
19	326936	112	1.00	0.867	1.034	3 Months Moving Avg
20	416445	113	1.00	0.677	0.609	ES (Alpha = 0.2)

Table 5.10 Average MAD for Group B Items and the Minimum Error Forecasting Approach

MAD / month (4 - 12)						**Approach Resulting Minimum Error**
No.	Code	Seq. Order	Naïve	3 Months Moving Average	Exponential Smoothing (Alpha = 0.2)	
1	401079	64	7.11	5.19	5.20	3 Months Moving Avg
2	226689	65	1900	1467	1298	ES (Alpha = 0.2)
3	330746	66	1056	796	628	ES (Alpha = 0.2)
4	121633	68	856	696	540	ES (Alpha = 0.2)
5	109427	69	12667	12222	10735	ES (Alpha = 0.2)
6	325384	72	1889	1419	1246	ES (Alpha = 0.2)
7	404367	76	4122	3011	3229	3 Months Moving Avg
8	429581	79	67	89	114	Naïve
9	382116	80	1878	1256	1237	ES (Alpha = 0.2)
10	230136	84	789	637	547	ES (Alpha = 0.2)
11	325388	87	600	567	640	3 Months Moving Avg
12	RO-028	91	311	230	245	3 Months Moving Avg
13	159145	93	6.0	4.4	5.1	3 Months Moving Avg
14	270040	101	38	27	23	ES (Alpha = 0.2)
15	184275	103	178	148	187	3 Months Moving Avg
16	121680	104	133	111	97	ES (Alpha = 0.2)
17	380616	105	390	279	279	ES (Alpha = 0.2)
18	416437	106	17.0	12.0	11.7	ES (Alpha = 0.2)
19	326936	112	111	96	115	3 Months Moving Avg
20	416445	113	11.1	7.5	6.8	ES (Alpha = 0.2)

Table 5.11 Average MSE for Group B Items and the Minimum Error Forecasting Approach

MSE / month (4 - 12)						**Approach Resulting Minimum Error**
No.	Code	Seq. Order	Naïve	3 Months Moving Average	Exponential Smoothing (Alpha = 0.2)	
1	401079	64	83	59	65	3 Months Moving Avg
2	226689	65	6,981,667	3,819,568	3,601,666	ES (Alpha = 0.2)
3	330746	66	1,638,889	867,284	629,098	ES (Alpha = 0.2)
4	121633	68	1,603,333	898,519	762,726	ES (Alpha = 0.2)
5	109427	69	223,555,556	174,469,136	130,043,835	ES (Alpha = 0.2)
6	325384	72	3,913,333	2,616,667	1,918,210	ES (Alpha = 0.2)
7	404367	76	23,763,333	15,534,444	19,413,909	3 Months Moving Avg
8	429581	79	6,667	12,531	20,961	Naïve
9	382116	80	5,302,778	2,228,086	2,139,355	ES (Alpha = 0.2)
10	230136	84	905,000	576,667	599,177	3 Months Moving Avg
11	325388	87	540,000	470,000	645,536	3 Months Moving Avg
12	RO-028	91	137,778	79,753	79,020	ES (Alpha = 0.2)
13	159145	93	59	31	30	ES (Alpha = 0.2)
14	270040	101	2,378	1,314	1,009	ES (Alpha = 0.2)
15	184275	103	71,111	35,556	39,459	3 Months Moving Avg
16	121680	104	40,000	20,000	17,799	ES (Alpha = 0.2)
17	380616	105	285,569	154,966	120,653	ES (Alpha = 0.2)
18	416437	106	389	194	170	ES (Alpha = 0.2)
19	326936	112	14,444	11,975	17,810	3 Months Moving Avg
20	416445	113	168	81	73	ES (Alpha = 0.2)

Table 5.12 Group B - Comparison of Forecasting Approach Resulting Minimum Error for Each Indicator

No.	Code	Approach Resulting Minimum Average Error		
		MASE	**MAD**	**MSE**
1	401079	3 Months Moving Avg	3 Months Moving Avg	3 Months Moving Avg
2	226689	ES (Alpha = 0.2)	ES (Alpha = 0.2)	ES (Alpha = 0.2)
3	330746	ES (Alpha = 0.2)	ES (Alpha = 0.2)	ES (Alpha = 0.2)
4	121633	ES (Alpha = 0.2)	ES (Alpha = 0.2)	ES (Alpha = 0.2)
5	109427	ES (Alpha = 0.2)	ES (Alpha = 0.2)	ES (Alpha = 0.2)
6	325384	ES (Alpha = 0.2)	ES (Alpha = 0.2)	ES (Alpha = 0.2)
7	404367	3 Months Moving Avg	3 Months Moving Avg	3 Months Moving Avg
8	429581	Naïve	Naïve	Naïve
9	382116	ES (Alpha = 0.2)	ES (Alpha = 0.2)	ES (Alpha = 0.2)
10	230136	ES (Alpha = 0.2)	ES (Alpha = 0.2)	3 Months Moving Avg
11	325388	3 Months Moving Avg	3 Months Moving Avg	3 Months Moving Avg
12	RO-028	3 Months Moving Avg	3 Months Moving Avg	ES (Alpha = 0.2)
13	159145	3 Months Moving Avg	3 Months Moving Avg	ES (Alpha = 0.2)
14	270040	ES (Alpha = 0.2)	ES (Alpha = 0.2)	ES (Alpha = 0.2)
15	184275	3 Months Moving Avg	3 Months Moving Avg	3 Months Moving Avg
16	121680	ES (Alpha = 0.2)	ES (Alpha = 0.2)	ES (Alpha = 0.2)
17	380616	ES (Alpha = 0.2)	ES (Alpha = 0.2)	ES (Alpha = 0.2)
18	416437	ES (Alpha = 0.2)	ES (Alpha = 0.2)	ES (Alpha = 0.2)
19	326936	3 Months Moving Avg	3 Months Moving Avg	3 Months Moving Avg
20	416445	ES (Alpha = 0.2)	ES (Alpha = 0.2)	ES (Alpha = 0.2)
Naïve		1	1	1
3 Months Moving Avg		7	7	6
ES (Alpha = 0.2)		12	12	13

In conclusion, simple exponential smoothing with alpha 0.2 will be selected for the demand estimation applied to the periodic simulation review in the next section.

5.2.2 Periodic Review Policy Simulation Results

The periodic review simulation is applied to 20 items from group B. Basis and assumption refers to section 4.2.8. 95% and 98% service level are sensitively determined for safety stock. The comparison results of actual inventory level are illustrated in *Figure 5.11 and 5.12* for 95% service level, and *Figure 5.13 and 5.14* for 98% service level. The actual inventory levels from January to May 2016 are shown in blue bold lines, and the proposed policy results are shown in red dash lines.

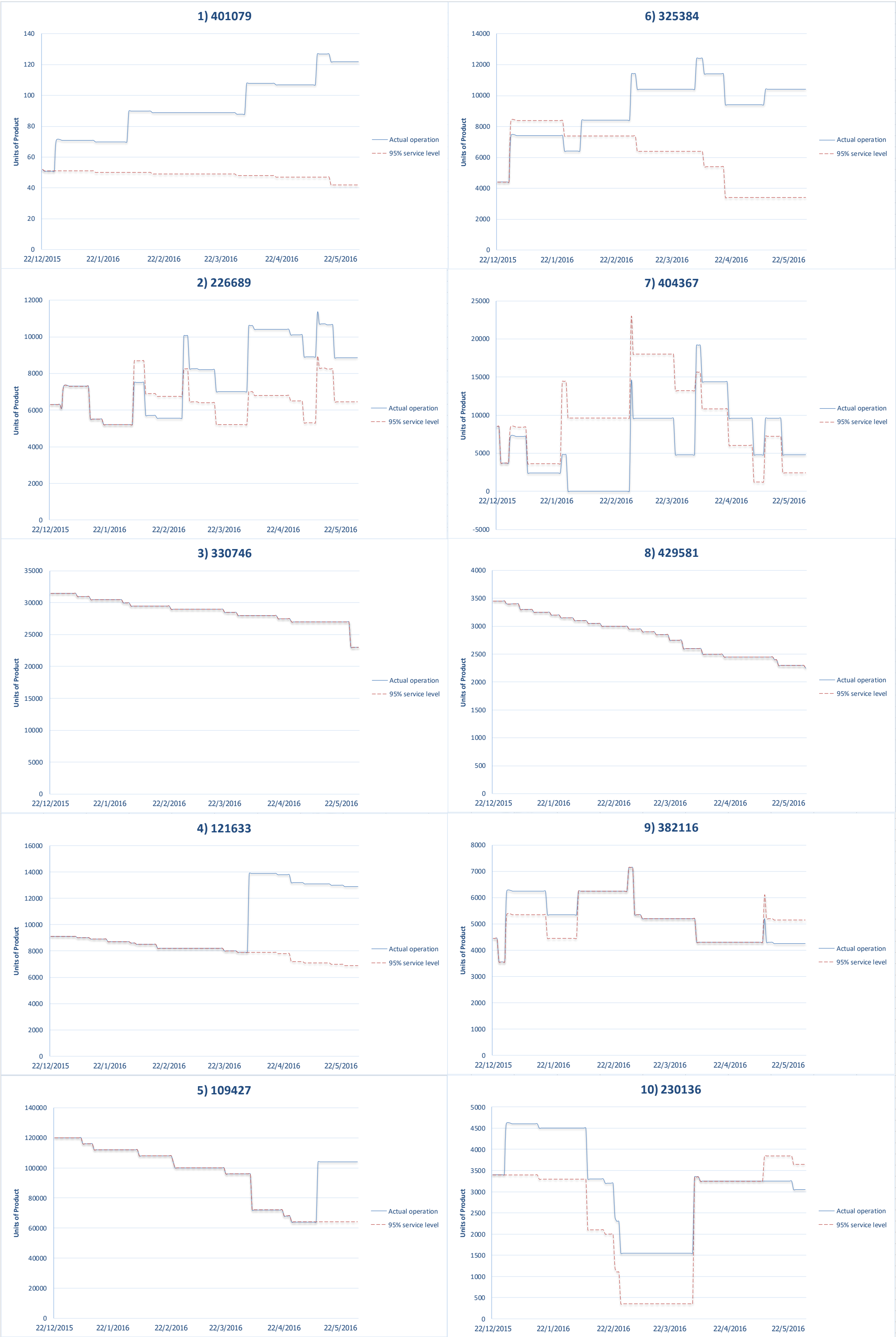


Figure 5.11 Group B - Periodic Review Policy Results for Item No. 1 – 10 (95% Service Level for Safety Stock)

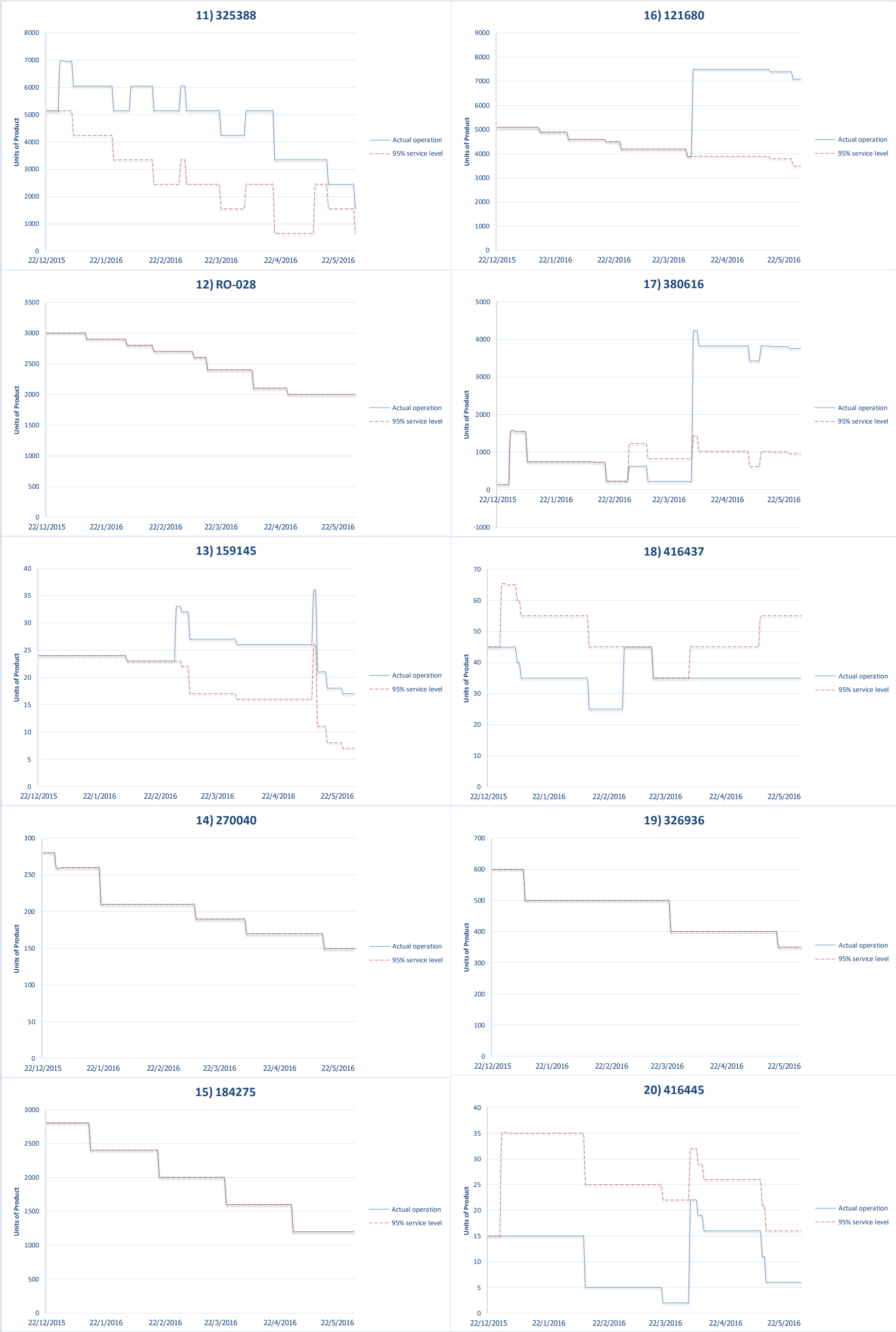


Figure 5.12 Group B - Periodic Review Policy Results for Item No. 11 – 20 (95% Service Level for Safety Stock)

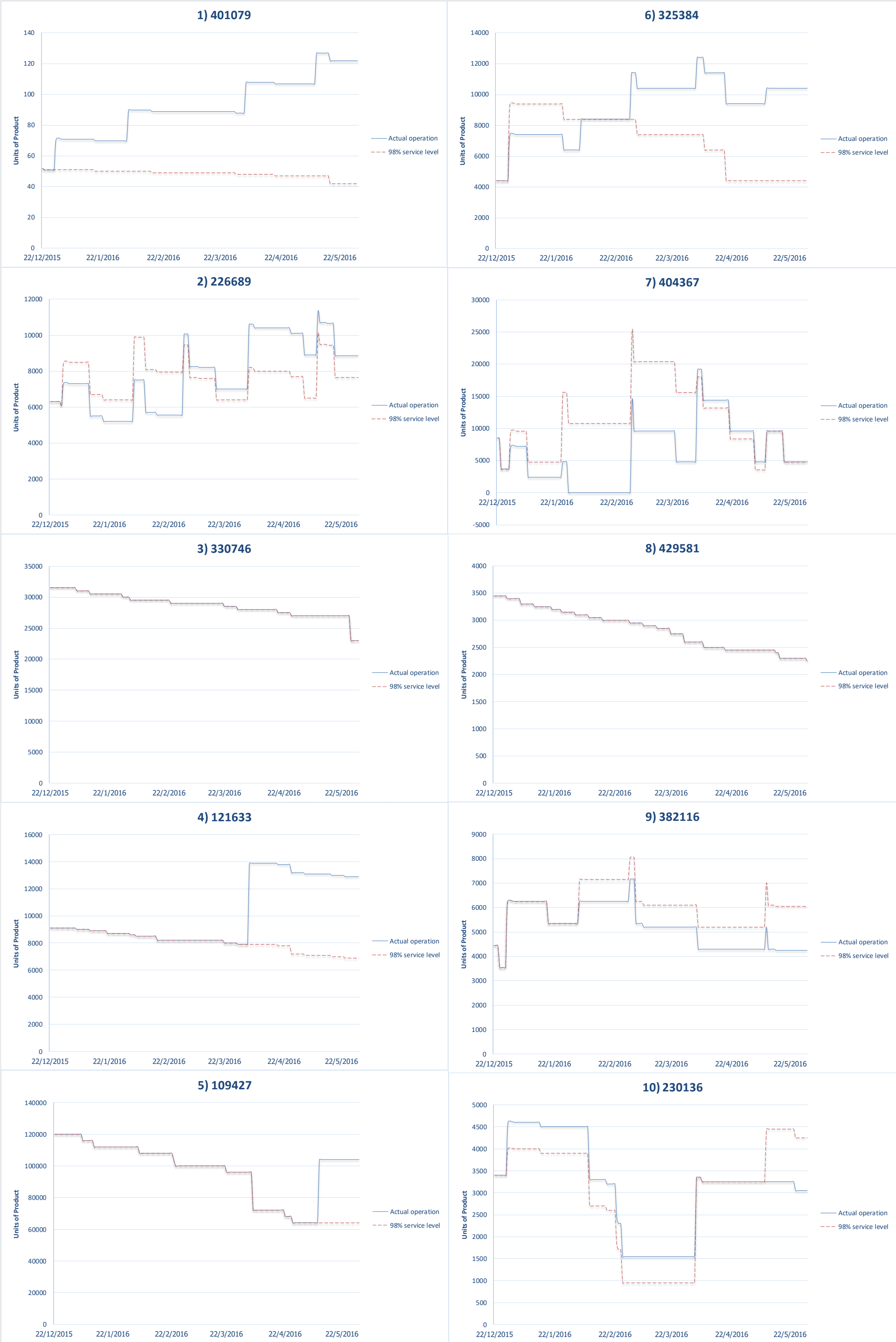


Figure 5.13 Group B - Periodic Review Policy Results for Item No. 1 – 10 (98% Service Level for Safety Stock)

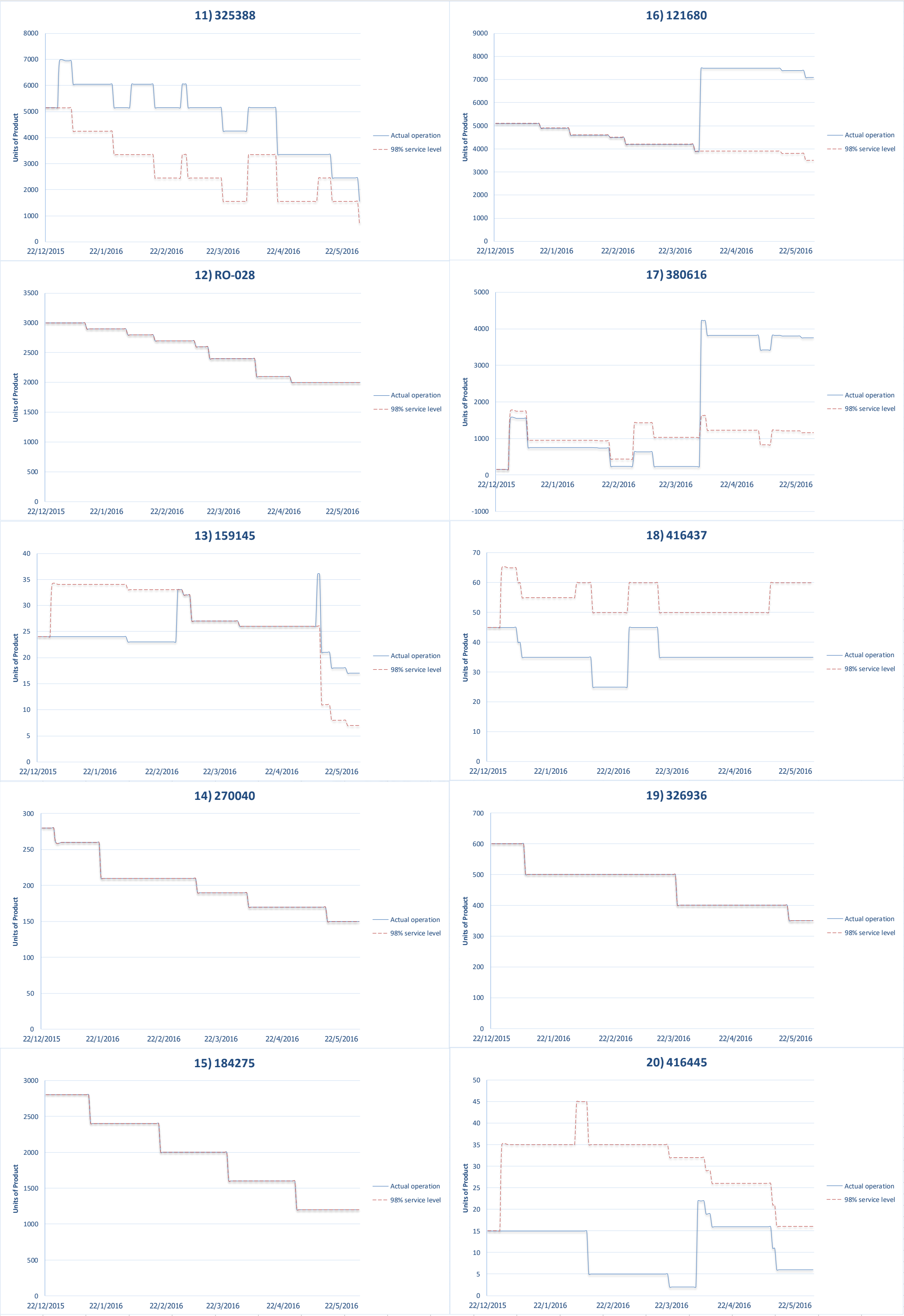
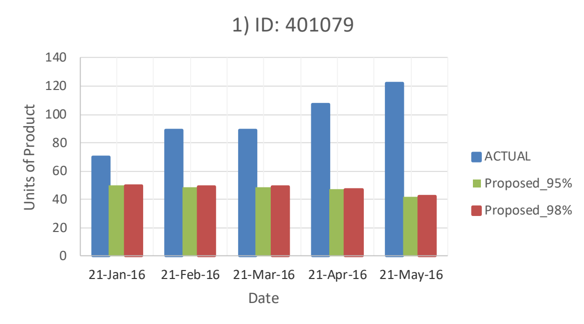
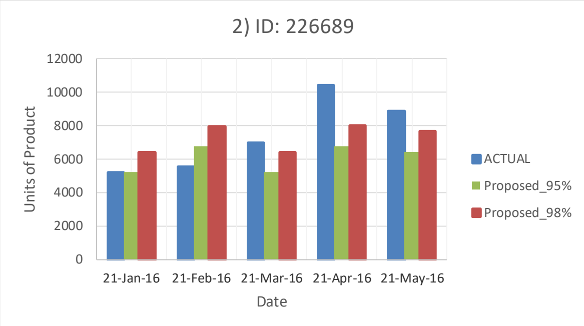


Figure 5.14 Group B - Periodic Review Policy Results for Item No. 11 – 20 (98% Service Level for Safety Stock)

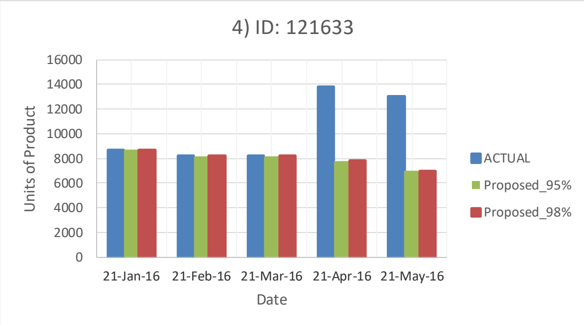
Periodic stock records on the date of the 21st of every month between January and May 2016 are reviewed and plotted. *Figure 5.15, and 5.16* illustrate 9 items in group B that show a reduction of an inventory due to the proposed policy implementation.



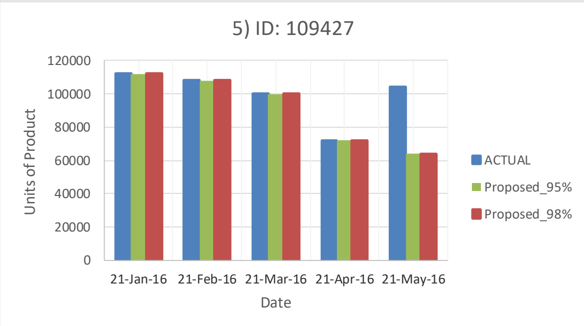
Month (2016)	Inventory Level (unit) Actual	95%Service level	98%Service level
Jan	70	50	50
Feb	89	49	49
Mar	89	49	49
Apr	107	47	47
May	122	42	42



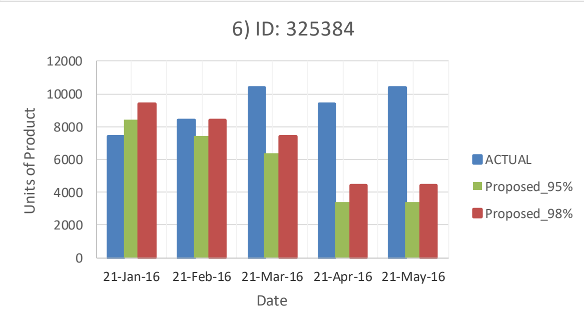
Month (2016)	Inventory Level (unit) Actual	95%Service level	98%Service level
Jan	5,200	5,200	6,400
Feb	5,550	6,750	7,950
Mar	7,000	5,200	6,400
Apr	10,400	6,800	8,000
May	8,850	6,450	7,650



Month (2016)	Inventory Level (unit) Actual	95%Service level	98%Service level
Jan	8,700	8,700	8,700
Feb	8,200	8,200	8,200
Mar	8,200	8,200	8,200
Apr	13,800	7,800	7,800
May	13,000	7,000	7,000

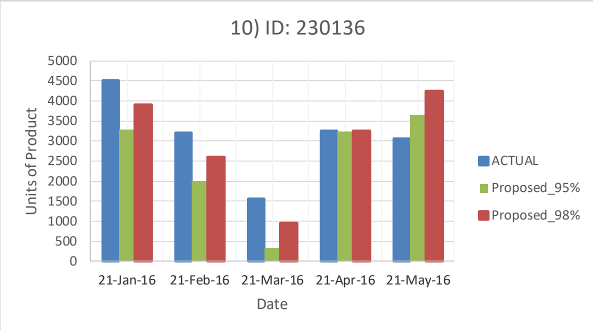


Month (2016)	Inventory Level (unit) Actual	95%Service level	98%Service level
Jan	112,000	112,000	112,000
Feb	108,000	108,000	108,000
Mar	100,000	100,000	100,000
Apr	72,000	72,000	72,000
May	104,000	64,000	64,000

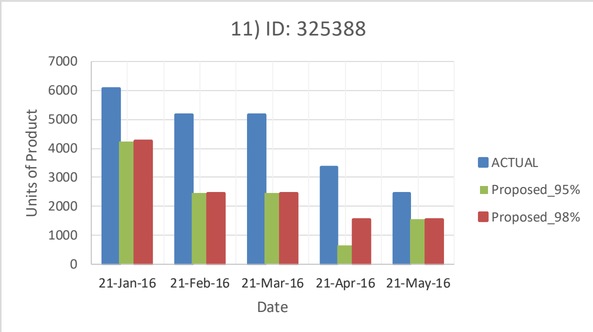


Month (2016)	Inventory Level (unit) Actual	95%Service level	98%Service level
Jan	7,400	8,400	9,400
Feb	8,400	7,400	8,400
Mar	10,400	6,400	7,400
Apr	9,400	3,400	4,400
May	10,400	3,400	4,400

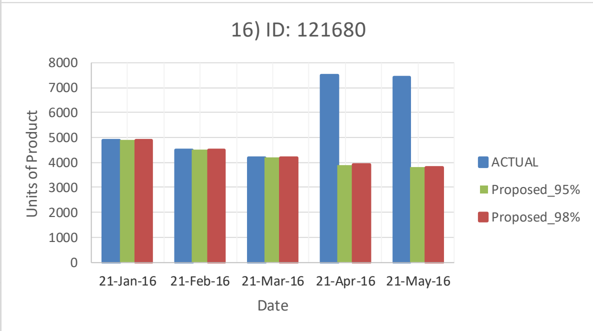
Figure 5.15 Reduction of an Inventory for Group B Items – 1/2



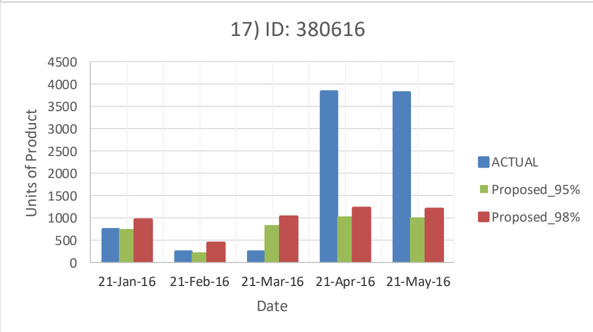
Month (2016)	Inventory Level (unit) Actual	95%Service level	98%Service level
Jan	4,500	3,300	3,900
Feb	3,200	2,000	2,600
Mar	1,550	350	950
Apr	3,250	3,250	3,250
May	3,050	3,650	4,250



Month (2016)	Inventory Level (unit) Actual	95%Service level	98%Service level
Jan	6,050	4,250	4,250
Feb	5,150	2,450	2,450
Mar	5,150	2,450	2,450
Apr	3,350	650	1,550
May	2,450	1,550	1,550



Month (2016)	Inventory Level (unit) Actual	95%Service level	98%Service level
Jan	4,900	4,900	4,900
Feb	4,500	4,500	4,500
Mar	4,200	4,200	4,200
Apr	7,500	3,900	3,900
May	7,400	3,800	3,800



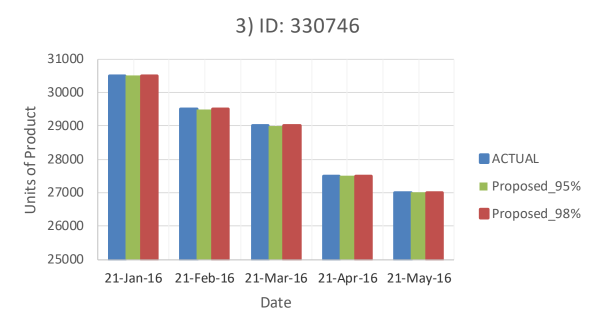
Month (2016)	Inventory Level (unit) Actual	95%Service level	98%Service level
Jan	749	749	949
Feb	234	234	434
Mar	230	830	1,030
Apr	3,826	1,026	1,226
May	3,808	1,008	1,208

Figure 5.16 Reduction of an Inventory for Group B Items – 2/2

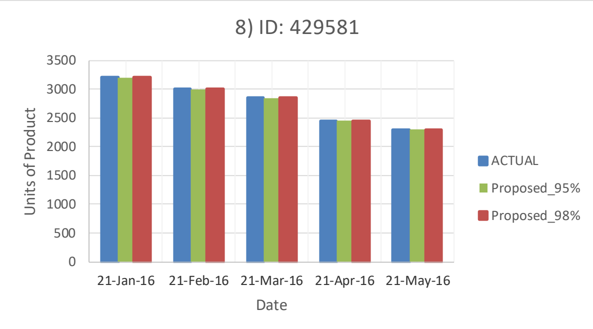
The other 11 items in Group B can be divided into 2 groups. First, there are 8 items that the actual operations stay in the same range as the proposed policy. They are illustrated in *Figure 5.17, and 5.18*. As previously mentioned for group A items, implementation results, which inventories for two service levels are equal, are because of MOQ (minimum order quantity) and current overstocked levels.

The last 3 items shown in *Figure 5.19* are the items that the proposed policy has given an increase of inventory level. It is because the studied company manages them lower than the proposed service level.

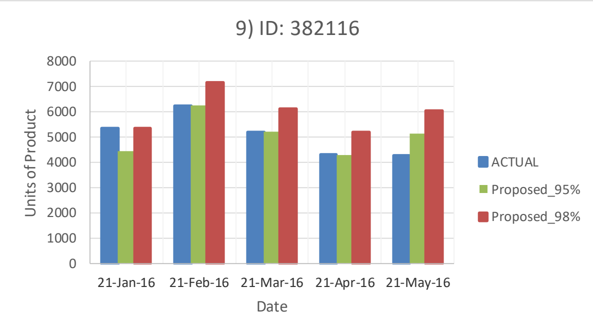
However, the actual operation for item number 7 (Code 404367) has experienced a stock-out during the study period as shown in *Figure 5.11 and 5.13.* It implies that even the proposed policy does not decrease the inventory level, but it helps ensuring appropriate stock level from the safety stock determination.



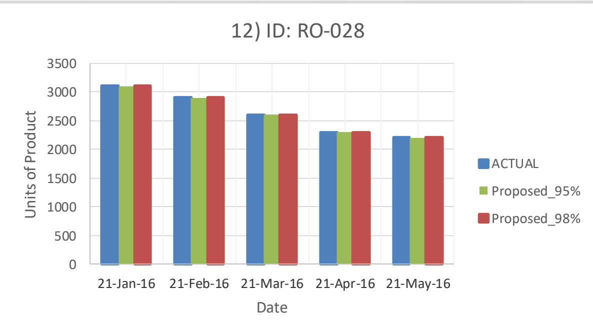
	Inventory Level (unit)		
Month (2016)	Actual	95%Service level	98%Service level
Jan	30,500	30,500	30,500
Feb	29,500	29,500	29,500
Mar	29,000	29,000	29,000
Apr	27,500	27,500	27,500
May	27,000	27,000	27,000



	Inventory Level (unit)		
Month (2016)	Actual	95%Service level	98%Service level
Jan	3,200	3,200	3,200
Feb	3,000	3,000	3,000
Mar	2,850	2,850	2,850
Apr	2,450	2,450	2,450
May	2,300	2,300	2,300

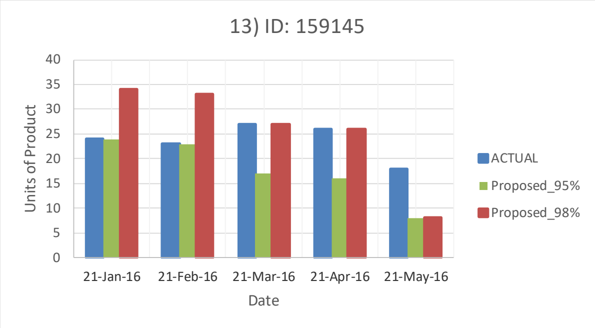


	Inventory Level (unit)		
Month (2016)	Actual	95%Service level	98%Service level
Jan	5,350	4,450	5,350
Feb	6,250	6,250	7,150
Mar	5,200	5,200	6,100
Apr	4,300	4,300	5,200
May	4,250	5,150	6,050

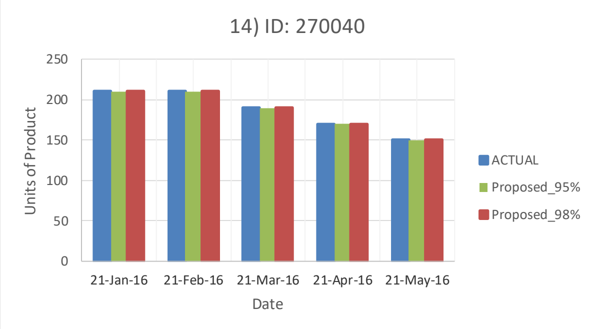


	Inventory Level (unit)		
Month (2016)	Actual	95%Service level	98%Service level
Jan	3,100	3,100	3,100
Feb	2,900	2,900	2,900
Mar	2,600	2,600	2,600
Apr	2,300	2,300	2,300
May	2,200	2,200	2,200

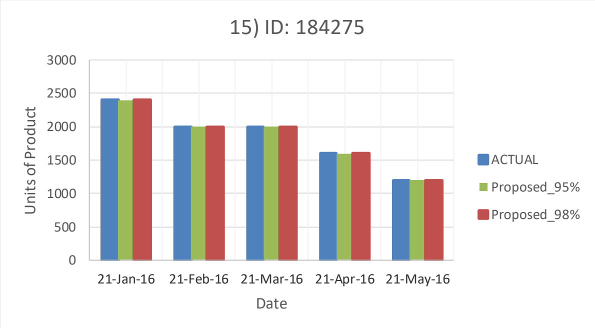
Figure 5.17 Inventory Results for Group B Items with No Inventory Reduction for Implementing the Proposed Policy – 1/2



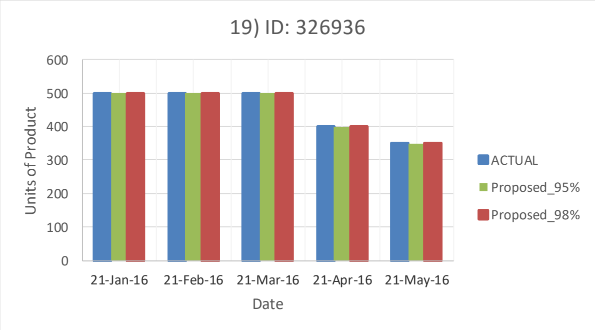
	Inventory Level (unit)		
Month (2016)	Actual	95%Service level	98%Service level
Jan	24	24	34
Feb	23	23	33
Mar	27	17	27
Apr	26	16	26
May	18	8	8



	Inventory Level (unit)		
Month (2016)	Actual	95%Service level	98%Service level
Jan	210	210	210
Feb	210	210	210
Mar	190	190	190
Apr	170	170	170
May	150	150	150

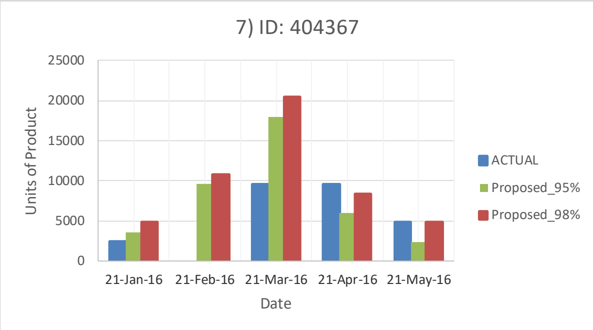


	Inventory Level (unit)		
Month (2016)	Actual	95%Service level	98%Service level
Jan	2,400	2,400	2,400
Feb	2,000	2,000	2,000
Mar	2,000	2,000	2,000
Apr	1,600	1,600	1,600
May	1,200	1,200	1,200

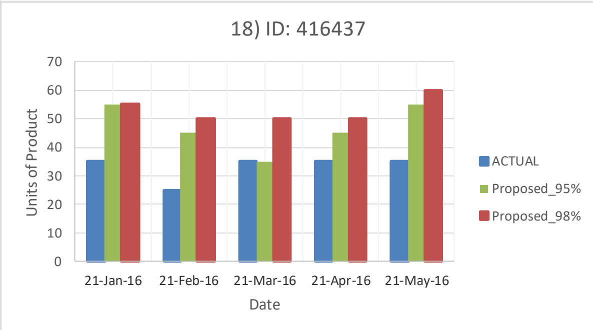


	Inventory Level (unit)		
Month (2016)	Actual	95%Service level	98%Service level
Jan	500	500	500
Feb	500	500	500
Mar	500	500	500
Apr	400	400	400
May	350	350	350

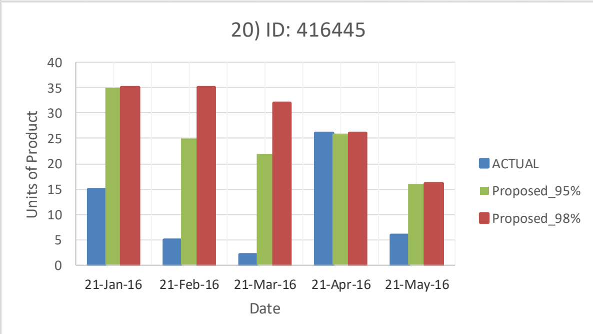
Figure 5.18 Inventory Results for Group B Items with No Inventory Reduction for Implementing the Proposed Policy – 2/2



	Inventory Level (unit)		
Month (2016)	Actual	95%Service level	98%Service level
Jan	2,400	3,600	4,800
Feb	-	9,600	10,800
Mar	9,600	18,000	20,400
Apr	9,600	6,000	8,400
May	4,800	2,400	4,800



	Inventory Level (unit)		
Month (2016)	Actual	95%Service level	98%Service level
Jan	35	55	55
Feb	25	45	50
Mar	35	35	50
Apr	35	45	50
May	35	55	60



	Inventory Level (unit)		
Month (2016)	Actual	95%Service level	98%Service level
Jan	15	35	35
Feb	5	25	35
Mar	2	22	32
Apr	26	26	26
May	6	16	16

Figure 5.19 Inventory Results for Group B Items with Inventory Increase for Implementing the Proposed Policy

Table 5.13 illustrates the comparison of actual operation and simulation results toward three key performance indexes (KPI) identified in section 4.1. The actual operation for item number 7 results a period of no stock. The percentage of time (calculated in numbers of day) is determined and shown as a service level in the table.

Overall, the stock level of 95% service level is smaller than 98% service level. Regarding the simulation results in *Figure 5.11, 5.12, 5.13, and 5.14*, there is no stock out event for both safety stocks. Hence, the service level of 95% is suggested for the policy application because inventory holding is less than the safety stock determined from 98% service level, and it can serve the customers' demands without any unfulfilled event.

In summary, the application of the proposed policy and forecasting technique can decrease the average inventory level for group B items by 7% and average inventory value by 19% at 95% service level for safety stock component compared to the current operation. The actual operation experienced a stock out period for item number 7. The proposed policy results in no stock out period, thus it shows 100% for all items.

Table 5.13 Comparison Performance Measurement for Group B Items

No.	Product ID	Average Daily Inventory Level (unit)			cost per unit (THB)	Average Daily Inventory Value (THB)			Service Level Measurement		
		Actual operation	95% Service level	98% Service level		Actual operation	95% Service level	98% Service level	Actual operation	95% Service level	98% Service level
1	401079	92	48	48	110.23	10,168	5,332	5,332	100%	100%	100%
2	226689	7,803	6,475	7,623	2.96	23,081	19,154	22,548	100%	100%	100%
3	330746	28,731	28,731	28,731	0.76	21,836	21,836	21,836	100%	100%	100%
4	121633	10,259	8,084	8,084	1.83	18,775	14,794	14,794	100%	100%	100%
5	109427	98,225	92,725	92,725	0.22	21,610	20,400	20,400	100%	100%	100%
6	325384	9,106	6,000	6,956	3.60	32,767	21,590	25,031	100%	100%	100%
7	404367	6,147	9,139	10,977	1.84	11,328	16,843	20,229	78%	100%	100%
8	429581	2,833	2,833	2,833	1.65	4,674	4,674	4,674	100%	100%	100%
9	382116	5,175	5,102	5,963	4.78	24,747	24,397	28,513	100%	100%	100%
10	230136	3,152	2,522	2,961	4.89	15,397	12,319	14,463	100%	100%	100%
11	325388	4,537	2,624	2,827	4.15	18,827	10,891	11,732	100%	100%	100%
12	RO-028	2,496	2,496	2,496	8.70	21,705	21,705	21,705	100%	100%	100%
13	159145	25	19	27	951.94	23,418	17,944	25,738	100%	100%	100%
14	270040	200	200	200	14.28	2,856	2,856	2,856	100%	100%	100%
15	184275	1,943	1,943	1,943	1.32	2,564	2,564	2,564	100%	100%	100%
16	121680	5,619	4,314	4,314	1.95	10,966	8,419	8,419	100%	100%	100%
17	380616	1,737	849	1,041	28.87	50,151	24,526	30,048	100%	100%	100%
18	416437	36	48	54	107.88	3,850	5,212	5,839	100%	100%	100%
19	326936	462	462	462	12.44	5,748	5,748	5,748	100%	100%	100%
20	416445	11	26	30	116.02	1,239	3,038	3,473	100%	100%	100%
	Total	**188,588**	**174,642**	**180,295**		**325,705**	**264,241**	**295,940**	**99%**	**100%**	**100%**
Reduction			7%	4%			19%	9%			

5.3 GROUP C INVENTORY

Twenty (20) items of seventy two (72) items in group C are randomly tested for the evaluation study. The selection will cover a range of 2 to 7 months of occurring demands. The items which have only 1 demand data are not selected for the study as they are considered inadequate information for the analysis.

5.3.1 Forecasting Approach Evaluation

Following *Table 4.7*, four forecasting techniques, Naïve, 3 months moving average, simple exponential smoothing, and Croston's method will be simulated and have the average errors of MASE, MAD, and MSE compared, for month 4 to 12 for group C items.

The implementation steps are similar to group A and B. The weight factor (smoothing factor) for simple exponential smoothing approach and Croston's method will be assessed toward three forecasting-error indicators (MASE, MAD, and MSE) by using a solver function in Microsoft excel.

Table 5.14 shows the weight factors for simple exponential smoothing technique that give the minimum error for each indicator. *Table 5.15* shows the weight factors for Croston's method that give the minimum error for each indicator as well. The average and median of the optimum weight factors for both forecasting approaches are in a range of 0.2. Hence, 0.2 will be used for for the forecasting method analysis for both simple exponential smoothing and Croston's method.

Table 5.14 Group C Items - Weight Factors Analysis for Exponential Smoothing Technique

Alpha for Simple Exponential Smoothing Method (Group C)							
No. of month showing demand	No.	Code	Group Check	Seq. Order	Optimum Weight Factor (alpha)		
					MASE	MAD	MSE
7	1	394672	C	114	0.13	0.13	0.27
	2	426079	C	115	0.12	0.12	0.21
	3	432733	C	119	0.44	0.44	0.34
6	4	130512	C	122	0.10	0.10	0.13
	5	233171	C	123	0.10	0.10	0.19
	6	272858	C	124	0.10	0.10	0.10
	7	434565	C	126	0.21	0.21	0.41
	8	349794	C	130	0.28	0.28	0.26
	9	245447	C	131	0.10	0.10	0.20
	10	168944	C	133	0.21	0.21	0.35
5	11	206151	C	138	0.10	0.10	0.14
	12	20781	C	140	0.10	0.10	0.10
	13	452049	C	141	0.10	0.10	0.20
	14	118512	C	143	0.10	0.10	0.10
4	15	445067	C	145	0.29	0.29	0.13
	16	517354	C	149	0.57	0.57	0.18
3	17	332086	C	155	0.68	0.68	0.42
	18	411564	C	161	0.10	0.10	0.10
2	19	214557	C	166	0.10	0.10	0.10
	20	382191	C	171	0.10	0.10	0.10
		Average			**0.20**	**0.20**	**0.20**
		Median			**0.10**	**0.10**	**0.18**

Table 5.15 Group C Items - Weight Factors Analysis for Croston's Method

Alpha for Croston Method (Group C)							
No. of month showing demand	No.	Code	Group Check	Seq. Order	Optimum Weight Factor (alpha)		
					MASE	MAD	MSE
7	1	394672	C	64	0.10	0.10	0.10
	2	426079	C	65	0.10	0.10	0.10
	3	432733	C	66	0.25	0.25	0.10
6	4	130512	C	68	0.12	0.12	0.10
	5	233171	C	69	0.10	0.10	0.10
	6	272858	C	72	0.10	0.10	0.13
	7	434565	C	76	0.10	0.10	0.10
	8	349794	C	79	0.10	0.10	0.10
	9	245447	C	80	0.10	0.10	0.10
	10	168944	C	84	0.47	0.47	0.90
5	11	206151	C	87	0.69	0.69	0.51
	12	20781	C	91	0.50	0.50	0.19
	13	452049	C	93	0.10	0.10	0.10
	14	118512	C	101	0.10	0.10	0.10
4	15	445067	C	103	0.10	0.10	0.10
	16	517354	C	104	0.10	0.10	0.89
3	17	332086	C	105	0.13	0.13	0.13
	18	411564	C	106	0.10	0.10	0.10
2	19	214557	C	112	0.90	0.90	0.90
	20	382191	C	113	0.90	0.90	0.90
		Average			**0.26**	**0.26**	**0.29**
		Median			**0.10**	**0.10**	**0.10**

Then, the average value from specified error techniques is determined for four forecasting methods as shown in *Table 5.16, 5.17, and 5.18.* The approach that results with the minimum error is named on the right column of the table.

The comparison of the least error forecasting techniques with the least error amongt the three forecasting indicators is shown in *Table 5.19*. The table presents that Croston's method with fixed alpha at 0.2 appears to be a technique which results in the most accuracy for the selected data from all three indicators.

Table 5.16 Average MASE for Group C Items and the Minimum Error Forecasting Approach

MASE / month (4 - 12)							Approach Resulting Minimum Error
No.	Code	Seq. Order	Naïve	3 Months Moving Average	Exponential Smoothing (Alpha = 0.2)	Croston Method (Alpha = 0.2)	
1	394672	114	1.00	0.769	0.729	0.692	Croston (Alpha = 0.2)
2	426079	115	1.00	0.850	0.713	0.673	Croston (Alpha = 0.2)
3	432733	119	1.00	0.879	1.040	1.023	3 Months Moving Avg
4	130512	122	1.00	0.719	0.689	0.600	Croston (Alpha = 0.2)
5	233171	123	1.00	1.091	0.911	0.958	ES (Alpha = 0.2)
6	272858	124	1.00	0.754	0.747	0.747	Croston (Alpha = 0.2)
7	434565	126	1.00	1.000	0.901	0.827	Croston (Alpha = 0.2)
8	349794	130	1.00	0.833	0.940	0.777	Croston (Alpha = 0.2)
9	245447	131	1.00	0.667	0.575	0.500	Croston (Alpha = 0.2)
10	168944	133	1.00	0.701	0.669	0.696	ES (Alpha = 0.2)
11	206151	138	1.00	0.952	0.683	0.889	ES (Alpha = 0.2)
12	20781	140	1.00	0.667	0.661	0.638	Croston (Alpha = 0.2)
13	452049	141	1.00	1.000	1.008	0.922	Croston (Alpha = 0.2)
14	118512	143	1.00	0.948	0.768	0.723	Croston (Alpha = 0.2)
15	445067	145	1.00	0.958	0.967	0.870	Croston (Alpha = 0.2)
16	517354	149	1.00	1.000	1.045	0.941	Croston (Alpha = 0.2)
17	332086	155	1.00	0.833	1.313	1.311	3 Months Moving Avg
18	411564	161	1.00	0.762	0.724	0.791	ES (Alpha = 0.2)
19	214557	166	1.00	1.000	0.778	1.287	ES (Alpha = 0.2)
20	382191	171	1.00	1.333	1.076	1.964	Naïve

Table 5.17 Average MASE for Group C Items and the Minimum Error Forecasting Approach

MAD / month (4 - 12)							Approach Resulting Minimum Error
No.	Code	Seq. Order	Naïve	3 Months Moving Average	Exponential Smoothing (Alpha = 0.2)	Croston Method (Alpha = 0.2)	
1	394672	114	5.78	4.44	4.21	3.85	Croston (Alpha = 0.2)
2	426079	115	544	463	388	360	Croston (Alpha = 0.2)
3	432733	119	3.67	3.22	3.81	3.92	3 Months Moving Avg
4	130512	122	45	32	31	25	Croston (Alpha = 0.2)
5	233171	123	2,639	2,880	2,403	2,472	ES (Alpha = 0.2)
6	272858	124	84	64	63	56	Croston (Alpha = 0.2)
7	434565	126	444	444	400	349	Croston (Alpha = 0.2)
8	349794	130	26,667	22,222	25,070	20,396	Croston (Alpha = 0.2)
9	245447	131	2,000	1,333	1,151	1,000	Croston (Alpha = 0.2)
10	168944	133	50	35	34	31	Croston (Alpha = 0.2)
11	206151	138	62	59	43	52	ES (Alpha = 0.2)
12	20781	140	11,667	7,778	7,715	7,440	Croston (Alpha = 0.2)
13	452049	141	278	278	280	253	Croston (Alpha = 0.2)
14	118512	143	1,000	948	768	654	Croston (Alpha = 0.2)
15	445067	145	4.44	4.26	4.30	3.76	Croston (Alpha = 0.2)
16	517354	149	6.44	6.44	6.73	6.02	Croston (Alpha = 0.2)
17	332086	155	511	426	671	674	3 Months Moving Avg
18	411564	161	156	119	113	122	ES (Alpha = 0.2)
19	214557	166	267	267	207	264	ES (Alpha = 0.2)
20	382191	171	133	178	143	214	Naïve

Table 5.18 Average MSE for Group C Items and the Minimum Error Forecasting Approach

MSE / month (4 - 12)							Approach Resulting Minimum Error
No.	Code	Seq. Order	Naïve	3 Months Moving Average	Exponential Smoothing (Alpha = 0.2)	Croston Method (Alpha = 0.2)	
1	394672	114	60	42	39	34	Croston (Alpha = 0.2)
2	426079	115	502,778	345,432	328,476	295,906	Croston (Alpha = 0.2)
3	432733	119	42	22	26	24	3 Months Moving Avg
4	130512	122	3,350	2,087	2,035	1,863	Croston (Alpha = 0.2)
5	233171	123	12,201,389	9,701,389	7,453,501	6,652,139	Croston (Alpha = 0.2)
6	272858	124	12,067	5,926	5,068	5,142	ES (Alpha = 0.2)
7	434565	126	333,333	222,222	236,915	182,058	Croston (Alpha = 0.2)
8	349794	130	1,066,666,667	572,839,506	680,512,706	431,961,287	Croston (Alpha = 0.2)
9	245447	131	4,000,000	1,777,778	1,421,167	1,000,000	Croston (Alpha = 0.2)
10	168944	133	4,975	3,349	3,489	3,403	3 Months Moving Avg
11	206151	138	7,289	4,217	2,581	3,207	ES (Alpha = 0.2)
12	20781	140	175,000,000	66,666,667	72,194,653	55,778,398	Croston (Alpha = 0.2)
13	452049	141	138,889	95,679	79,214	66,420	Croston (Alpha = 0.2)
14	118512	143	3,273,333	2,139,753	1,731,422	1,583,539	Croston (Alpha = 0.2)
15	445067	145	44	26	22	18	Croston (Alpha = 0.2)
16	517354	149	134	90	70	59	Croston (Alpha = 0.2)
17	332086	155	677,778	422,099	532,424	507,454	3 Months Moving Avg
18	411564	161	44,444	18,519	18,944	17,011	Croston (Alpha = 0.2)
19	214557	166	213,333	118,519	77,137	119,488	ES (Alpha = 0.2)
20	382191	171	80,000	62,222	43,188	70,408	ES (Alpha = 0.2)

Table 5.19: Group C - Comparison of Forecasting Approach Resulting Minimum Error for Each Indicator

No.	Code	Approach Resulting Minimum Average Error		
		MASE	**MAD**	**MSE**
1	394672	Croston (Alpha = 0.2)	Croston (Alpha = 0.2)	Croston (Alpha = 0.2)
2	426079	Croston (Alpha = 0.2)	Croston (Alpha = 0.2)	Croston (Alpha = 0.2)
3	432733	3 Months Moving Avg	3 Months Moving Avg	3 Months Moving Avg
4	130512	Croston (Alpha = 0.2)	Croston (Alpha = 0.2)	Croston (Alpha = 0.2)
5	233171	ES (Alpha = 0.2)	ES (Alpha = 0.2)	Croston (Alpha = 0.2)
6	272858	Croston (Alpha = 0.2)	Croston (Alpha = 0.2)	ES (Alpha = 0.2)
7	434565	Croston (Alpha = 0.2)	Croston (Alpha = 0.2)	Croston (Alpha = 0.2)
8	349794	Croston (Alpha = 0.2)	Croston (Alpha = 0.2)	Croston (Alpha = 0.2)
9	245447	Croston (Alpha = 0.2)	Croston (Alpha = 0.2)	Croston (Alpha = 0.2)
10	168944	ES (Alpha = 0.2)	Croston (Alpha = 0.2)	3 Months Moving Avg
11	206151	ES (Alpha = 0.2)	ES (Alpha = 0.2)	ES (Alpha = 0.2)
12	20781	Croston (Alpha = 0.2)	Croston (Alpha = 0.2)	Croston (Alpha = 0.2)
13	452049	Croston (Alpha = 0.2)	Croston (Alpha = 0.2)	Croston (Alpha = 0.2)
14	118512	Croston (Alpha = 0.2)	Croston (Alpha = 0.2)	Croston (Alpha = 0.2)
15	445067	Croston (Alpha = 0.2)	Croston (Alpha = 0.2)	Croston (Alpha = 0.2)
16	517354	Croston (Alpha = 0.2)	Croston (Alpha = 0.2)	Croston (Alpha = 0.2)
17	332086	3 Months Moving Avg	3 Months Moving Avg	3 Months Moving Avg
18	411564	ES (Alpha = 0.2)	ES (Alpha = 0.2)	Croston (Alpha = 0.2)
19	214557	ES (Alpha = 0.2)	ES (Alpha = 0.2)	ES (Alpha = 0.2)
20	382191	Naïve	Naïve	ES (Alpha = 0.2)
Naïve		1	1	0
3 Months Moving Avg		2	2	3
ES (Alpha = 0.2)		5	4	4
Croston (Alpha = 0.2)		12	13	13

In conclusion, Croston's method with alpha 0.2 will be selected for demand estimation, and will be applied to the periodic simulation review in the next section.

5.3.2 Periodic Review Policy Simulation Results

According to *Table 4.5*, inventory holding value for group C items was the highest, but they generated the least revenue proportion, only 20% (2 million THB) of the total order value (11.9 THB). Therefore, group C is less important to the company than group A and B.

As previous sections, 95 % service level for safety stock is encouraged for group A and B items. It is not reasonable to study group C for 98% service level, as its lower critical. Thus, sensitivity of service level for group C will be 90 and 95%.

The periodic review simulation is applied for 20 items in group C. Basis and assumption refer to section 4.2.8. 90% and 95% service level are sensitively determined for safety stock. The comparison results of actual inventory level are illustrated in *Figure 5.20 and 5.21* for 90% service level, and *Figure 5.22 and 5.23* for 95% service level. The actual inventory levels from January to May 2016 are shown in blue bold lines, and the proposed policy results are shown in red dash lines.

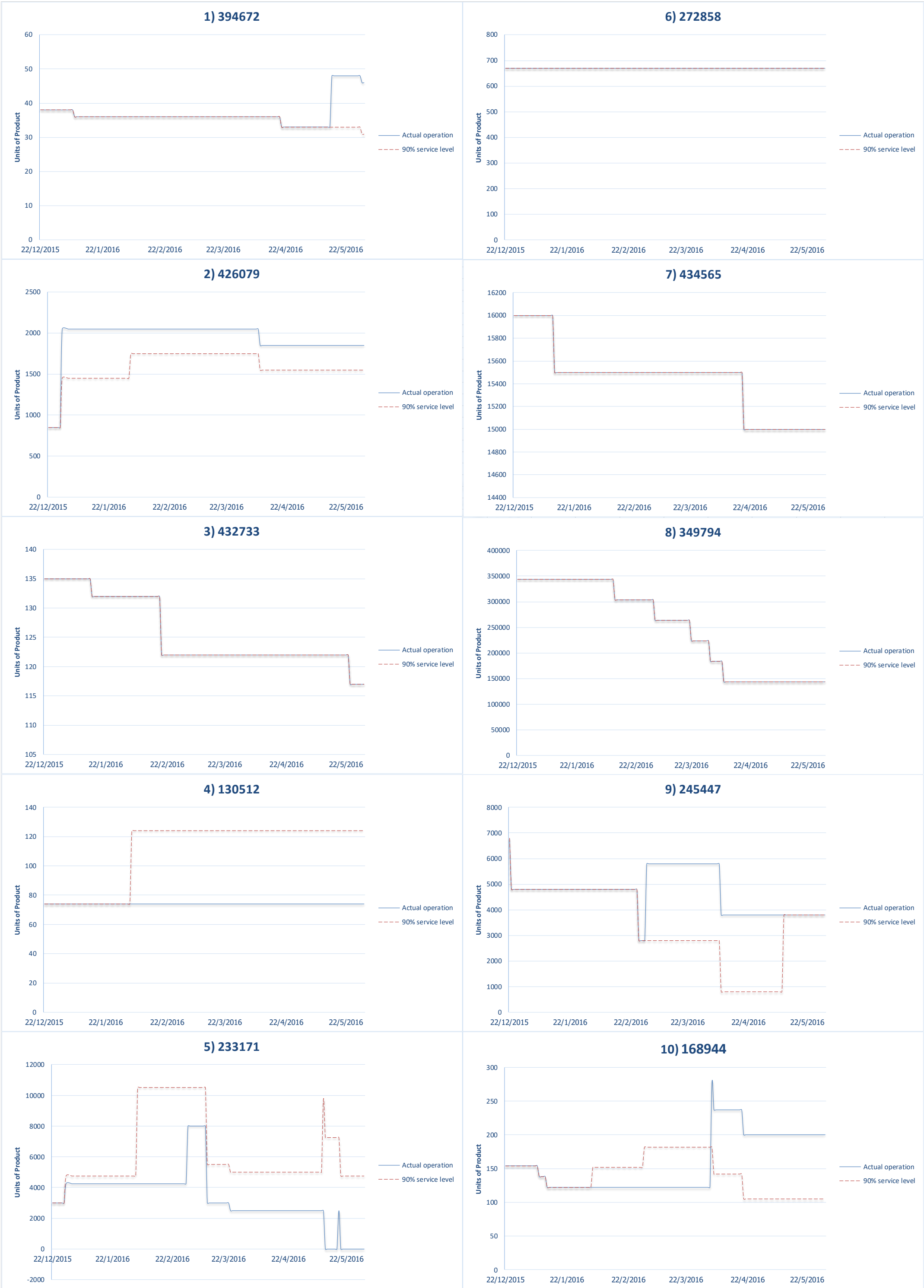


Figure 5.20 Group C - Periodic Review Policy Results for Item No. 1 – 10 (90% Service Level for Safety Stock)

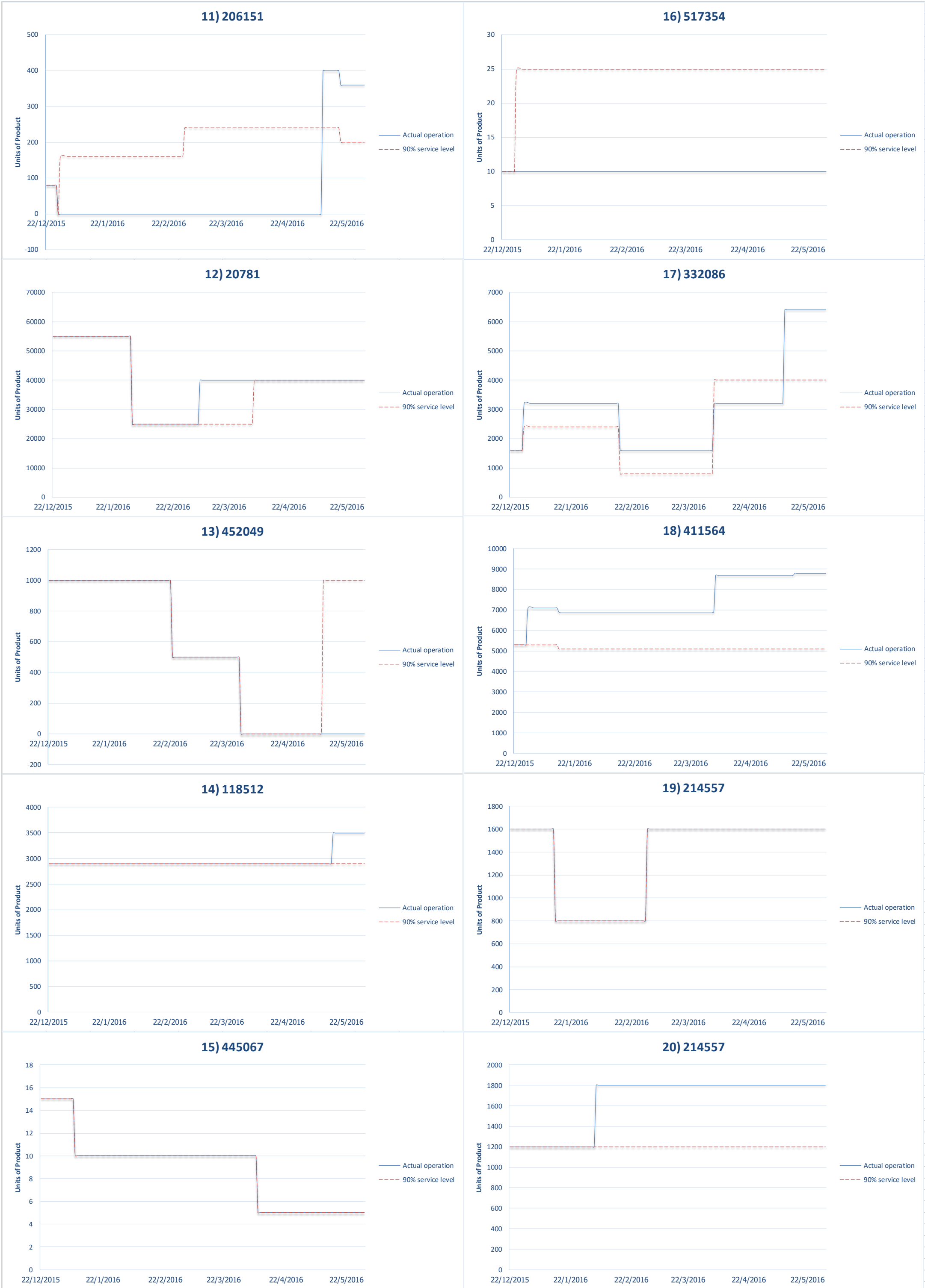


Figure 5.21 Group C - Periodic Review Policy Results for Item No. 11 – 20 (90% Service Level for Safety Stock)

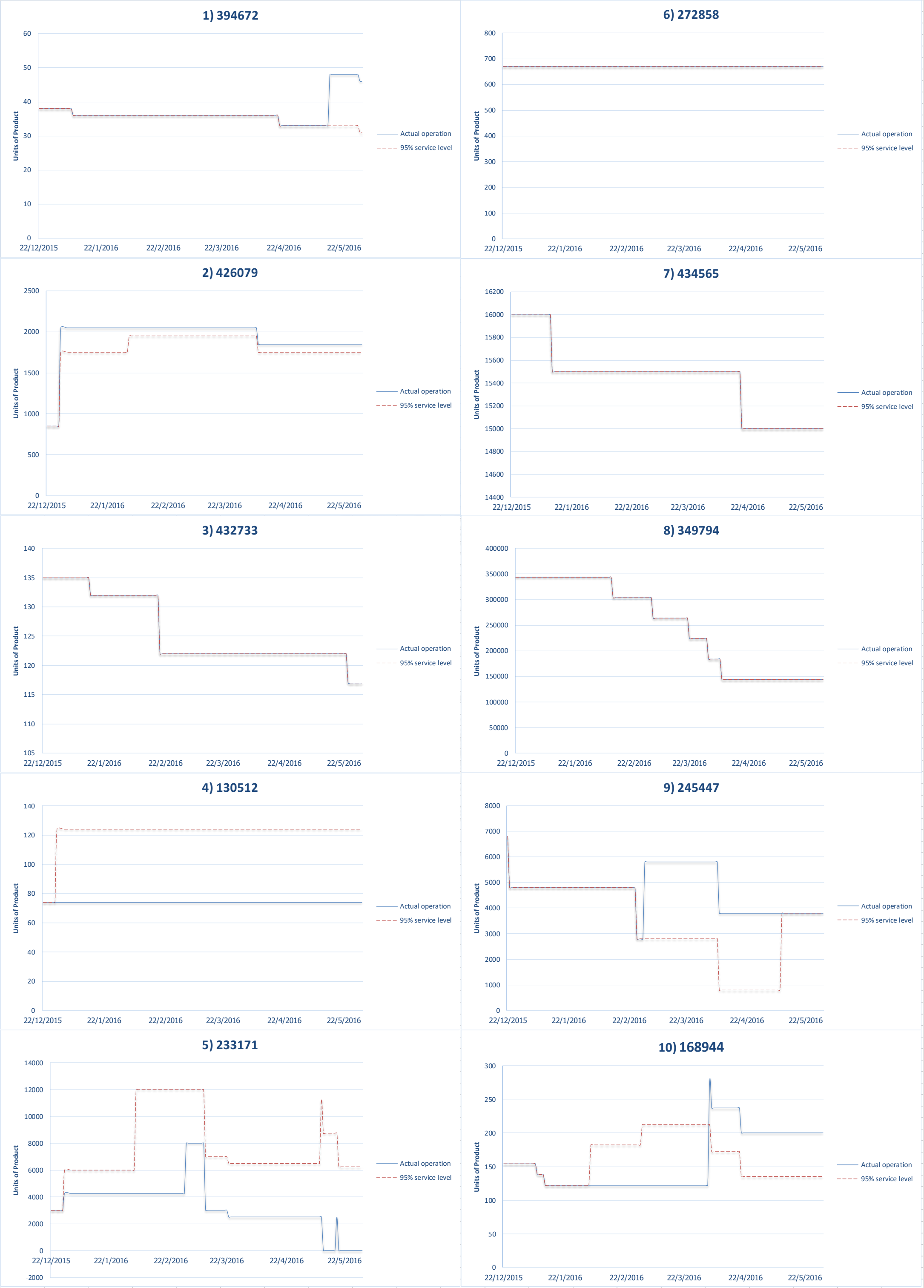


Figure 5.22 Group C - Periodic Review Policy Results for Item No. 1 – 10 (95% Service Level for Safety Stock)

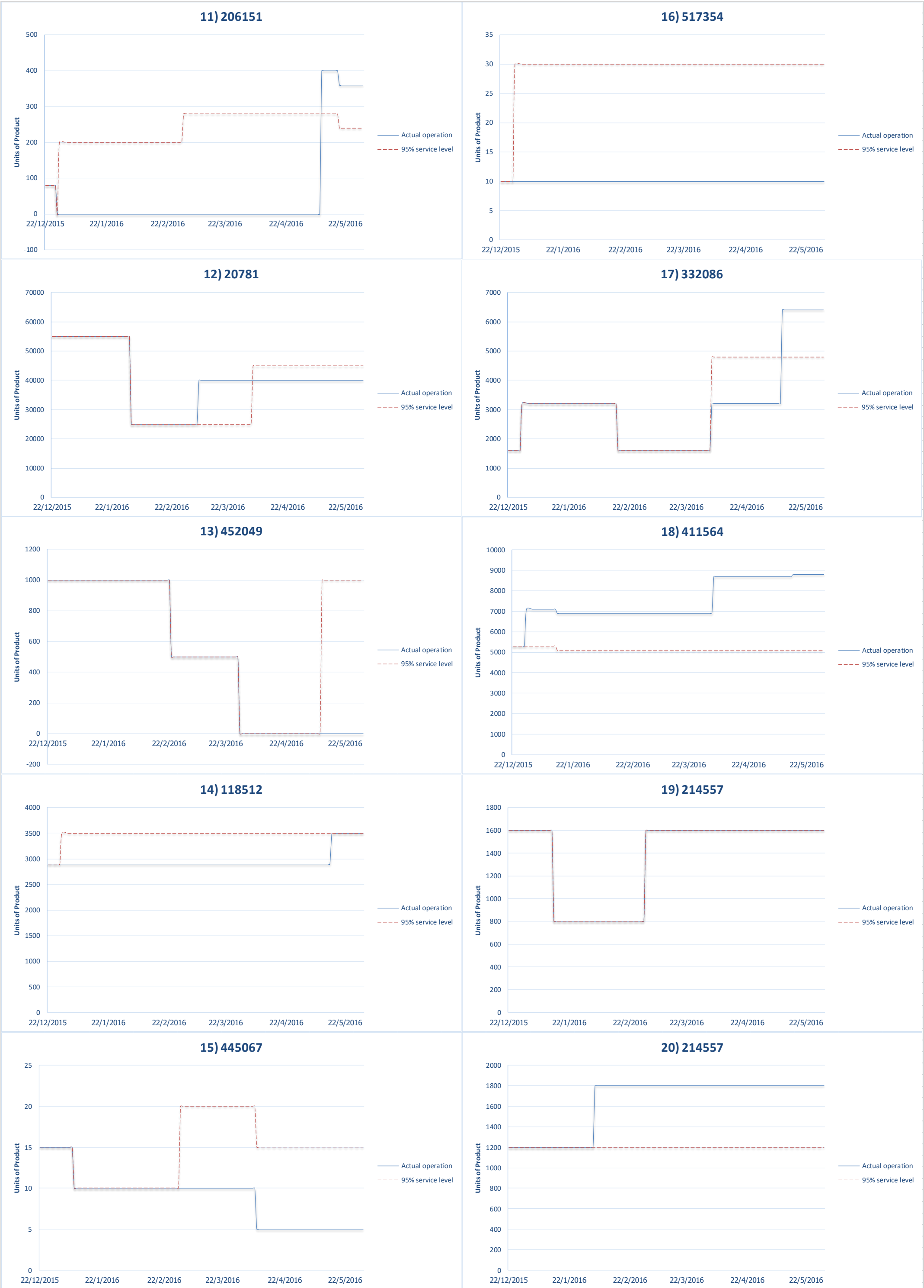
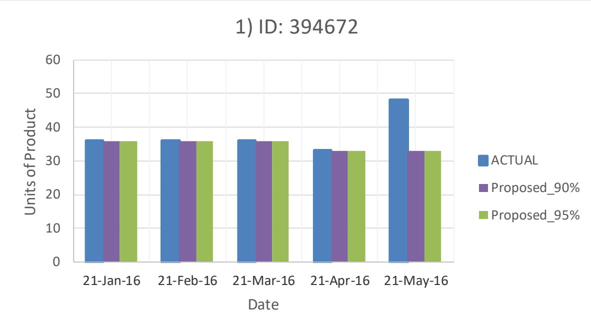
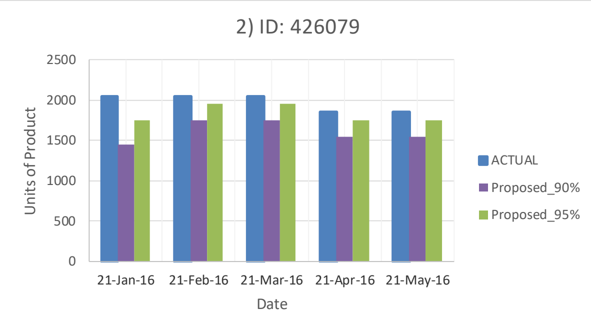


Figure 5.23 Group C - Periodic Review Policy Results for Item No. 11 – 20
(95% Service Level for Safety Stock)

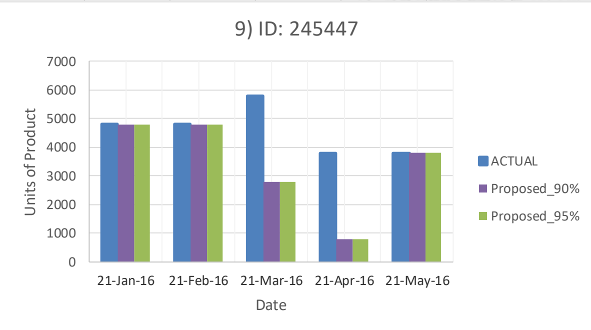
Periodic stock records on the date of the 21st of every month between January and May 2016 are reviewed and plotted. Six items in group C show an inventory reduction due to implementation of the proposed policy as illustrated in *Figure 5.24, and 5.25.*



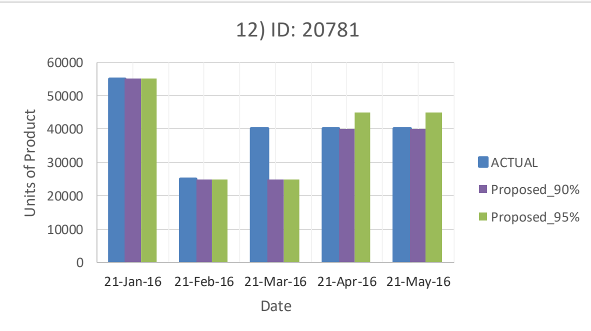
Month (2016)	Inventory Level (unit) Actual	90%Service level	95%Service level
Jan	36	36	36
Feb	36	36	36
Mar	36	36	36
Apr	33	33	33
May	48	33	33



Month (2016)	Inventory Level (unit) Actual	90%Service level	95%Service level
Jan	2,050	1,450	1,750
Feb	2,050	1,750	1,950
Mar	2,050	1,750	1,950
Apr	1,850	1,550	1,750
May	1,850	1,550	1,750

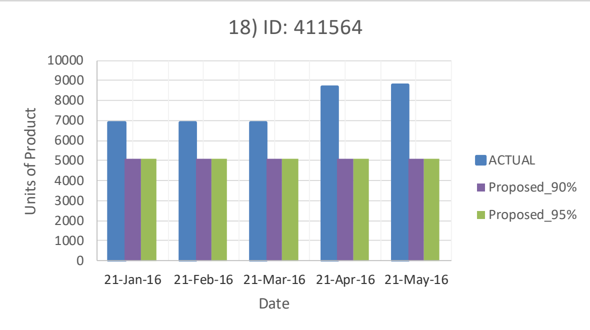


Month (2016)	Inventory Level (unit) Actual	90%Service level	95%Service level
Jan	4,800	4,800	4,800
Feb	4,800	4,800	4,800
Mar	5,800	2,800	2,800
Apr	3,800	800	800
May	3,800	3,800	3,800

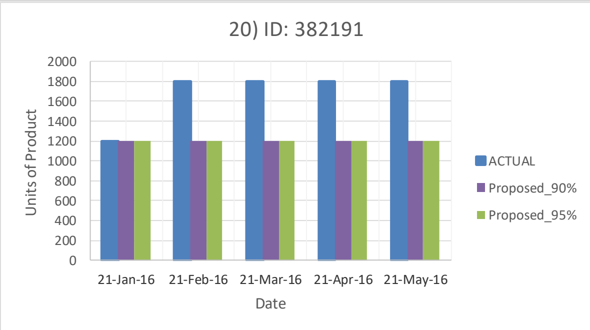


Month (2016)	Inventory Level (unit) Actual	90%Service level	95%Service level
Jan	55,000	55,000	55,000
Feb	25,000	25,000	25,000
Mar	40,000	25,000	25,000
Apr	40,000	40,000	45,000
May	40,000	40,000	45,000

Figure 5.24 Reduction of an Inventory for Group C Items – 1/2



Month (2016)	Inventory Level (unit) Actual	90%Service level	95%Service level
Jan	6,900	5,100	5,100
Feb	6,900	5,100	5,100
Mar	6,900	5,100	5,100
Apr	8,700	5,100	5,100
May	8,800	5,100	5,100



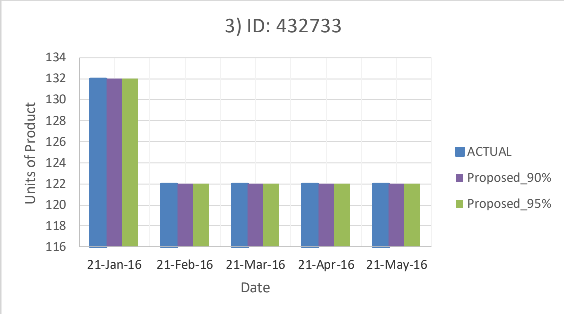
Month (2016)	Inventory Level (unit) Actual	90%Service level	95%Service level
Jan	1,200	1,200	1,200
Feb	1,800	1,200	1,200
Mar	1,800	1,200	1,200
Apr	1,800	1,200	1,200
May	1,800	1,200	1,200

Figure 5.25 Reduction of an Inventory for Group C Items – 2/2

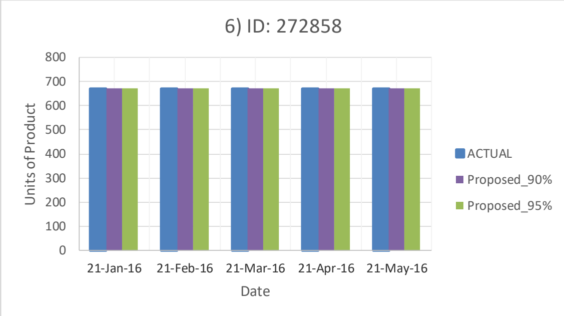
The other 14 items of Group C can be divided into 2 groups. First, there are 9 items that the current operations are in the same range of the proposed policy. They are illustrated in *Figure 5.26, and 5.27*. Most SKUs assessment results are equal to the actual operation except for Item number 14 (Code 118512) and 15 (Code 445067). Their inventory level, shown in *Figure 5.27*, are equal to service level of 90% for safety stock determination.

The last 5 items shown in *Figure 5.28* are the items that resulted in an increase of inventory level with the proposed policy. It is because the studied company manages them lower than the proposed service level. In addition, two of them (Item No. 5 and 16) are ordered by a single customer who acknowledges the inventory level and shares the ordering information with the studied company

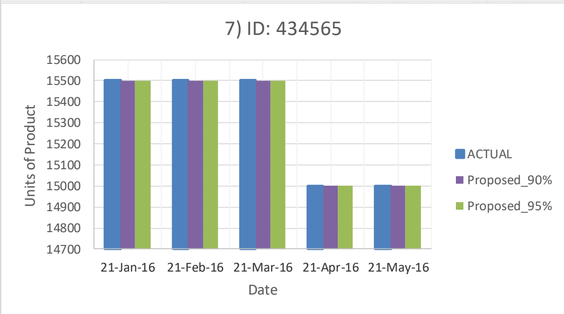
However, with the actual operation for item number 5 (Code 233171), 11 (Code 206151), and 13 (Code 452049) experienced stock-outs during the study period as shown in *Figure 5.20, 5.21, 5.22 and 5.23*. It implies that even if the proposed policy does not decrease their inventory levels, it still helps ensuring appropriate stock levels from the safety stock expectation.



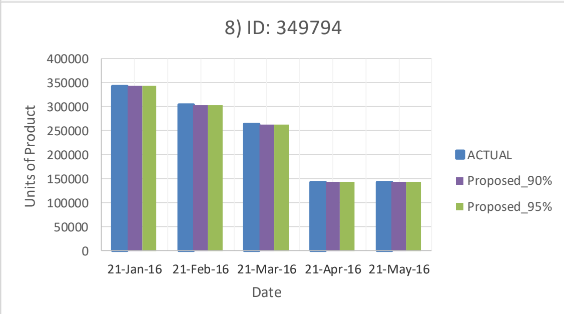
Month (2016)	Inventory Level (unit)		
	Actual	90%Service level	95%Service level
Jan	132	132	132
Feb	122	122	122
Mar	122	122	122
Apr	122	122	122
May	122	122	122



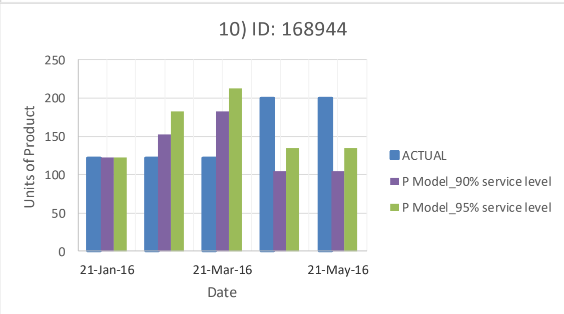
Month (2016)	Inventory Level (unit)		
	Actual	90%Service level	95%Service level
Jan	670	670	670
Feb	670	670	670
Mar	670	670	670
Apr	670	670	670
May	670	670	670



Month (2016)	Inventory Level (unit)		
	Actual	90%Service level	95%Service level
Jan	15,500	15,500	15,500
Feb	15,500	15,500	15,500
Mar	15,500	15,500	15,500
Apr	15,000	15,000	15,000
May	15,000	15,000	15,000

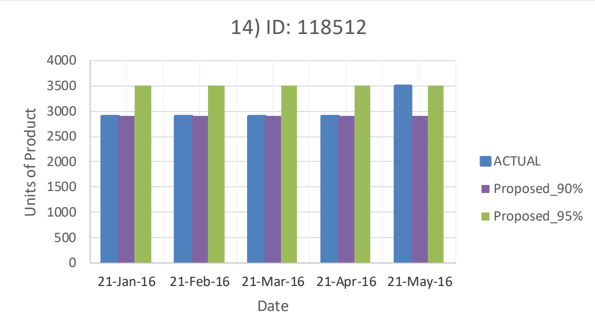


Month (2016)	Inventory Level (unit)		
	Actual	90%Service level	95%Service level
Jan	343,900	343,900	343,900
Feb	303,900	303,900	303,900
Mar	263,900	263,900	263,900
Apr	143,900	143,900	143,900
May	143,900	143,900	143,900

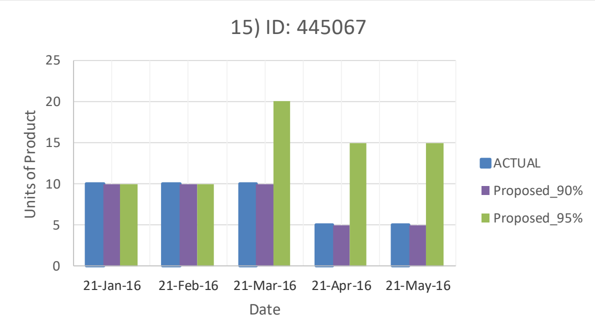


Month (2016)	Inventory Level (unit)		
	Actual	90%Service level	95%Service level
Jan	122	122	122
Feb	122	152	182
Mar	122	182	212
Apr	200	105	135
May	200	105	135

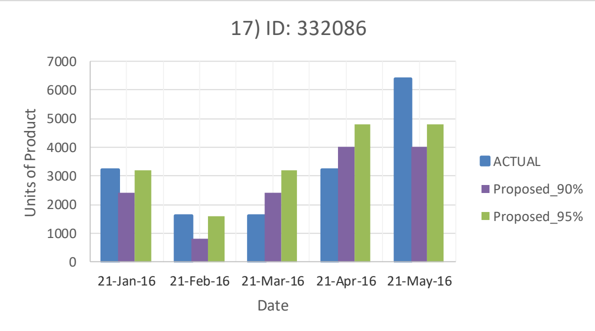
Figure 5.26 Inventory Results for Group C Items with No Inventory Reduction for Implementing the Proposed Policy – 1/2



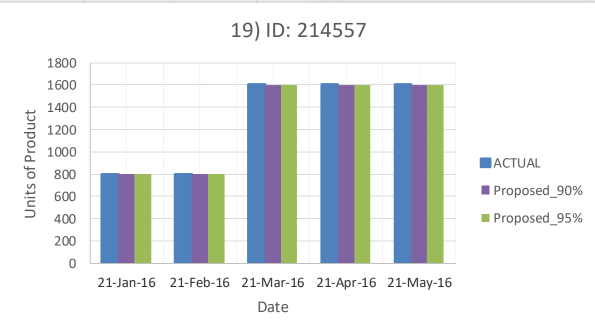
Month (2016)	Inventory Level (unit) Actual	90%Service level	95%Service level
Jan	2,900	2,900	3,500
Feb	2,900	2,900	3,500
Mar	2,900	2,900	3,500
Apr	2,900	2,900	3,500
May	3,500	2,900	3,500



Month (2016)	Inventory Level (unit) Actual	90%Service level	95%Service level
Jan	10	10	10
Feb	10	10	10
Mar	10	10	20
Apr	5	5	15
May	5	5	15

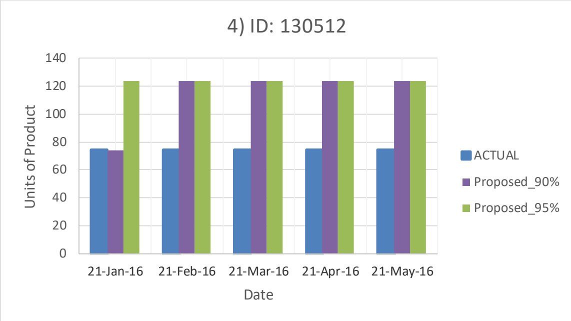


Month (2016)	Inventory Level (unit) Actual	90%Service level	95%Service level
Jan	3,200	2,400	3,200
Feb	1,600	800	1,600
Mar	1,600	2,400	3,200
Apr	3,200	4,000	4,800
May	6,400	4,000	4,800

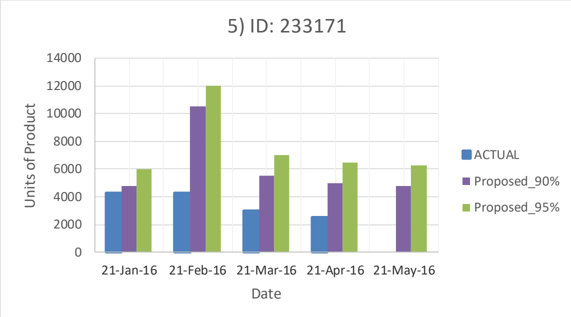


Month (2016)	Inventory Level (unit) Actual	90%Service level	95%Service level
Jan	800	800	800
Feb	800	800	800
Mar	1,600	1,600	1,600
Apr	1,600	1,600	1,600
May	1,600	1,600	1,600

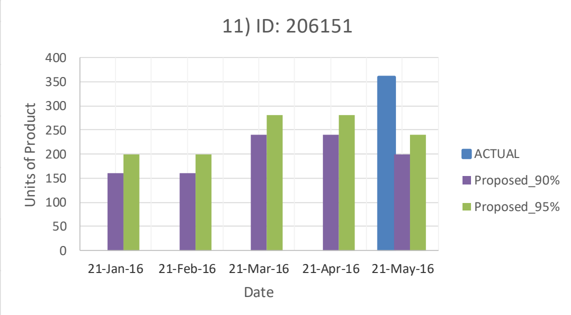
Figure 5.27 Inventory Results for Group C Items with No Inventory Reduction for Implementing the Proposed Policy – 2/2



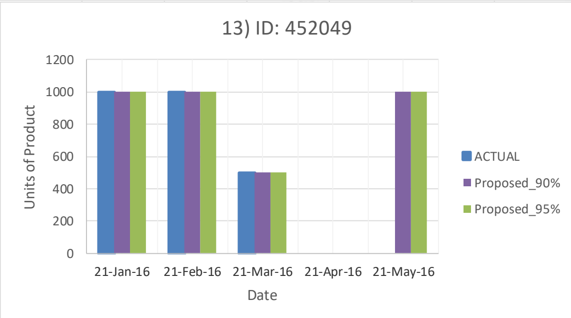
Month (2016)	Inventory Level (unit) Actual	90%Service level	95%Service level
Jan	74	74	124
Feb	74	124	124
Mar	74	124	124
Apr	74	124	124
May	74	124	124



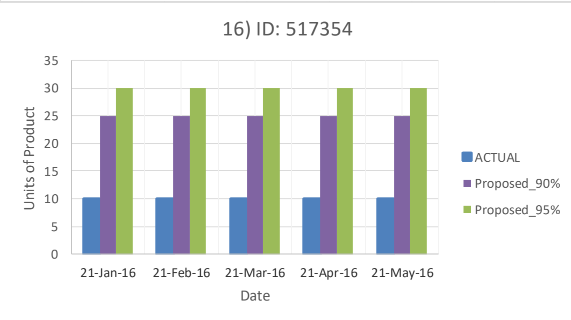
Month (2016)	Inventory Level (unit) Actual	90%Service level	95%Service level
Jan	4,250	4,750	6,000
Feb	4,250	10,500	12,000
Mar	3,000	5,500	7,000
Apr	2,500	5,000	6,500
May	-	4,750	6,250



Month (2016)	Inventory Level (unit) Actual	90%Service level	95%Service level
Jan	-	160	200
Feb	-	160	200
Mar	-	240	280
Apr	-	240	280
May	360	200	240



Month (2016)	Inventory Level (unit) Actual	90%Service level	95%Service level
Jan	1,000	1,000	1,000
Feb	1,000	1,000	1,000
Mar	500	500	500
Apr	-	-	-
May	-	1,000	1,000



Month (2016)	Inventory Level (unit) Actual	90%Service level	95%Service level
Jan	10	25	30
Feb	10	25	30
Mar	10	25	30
Apr	10	25	30
May	10	25	30

Figure 5.28 Inventory Results for Group B Items with Inventory Increase for Implementing the Proposed Policy

Table 5.20 illustrates the comparison of the actual operation and simulation results toward the three key performance indexes (KPI) identified in section 4.1. The actual operation for item number 5, 11, and 13 results in a period of no stock. The percentage of time (calculated in numbers of day) is determined and shown as a service level in the table.

Since, the proposed policy does not suit with the products ordered by a single customer who shares information, the summary of total inventory levels and values without these items is shown to determine the real reduction of the adopted policy.

Without consideration of items ordered by single customers who share the demand, it can be seen from *Table 5.20* that there is no a reduction of total inventory unit and value. The suggestions for the future improvement can be service level adjustment or inventory system adjustment such as order up to level policy.

Unfortunately, group C items verification is considered as an ineffective result, due to the limited historical data of 12 months and the comparison period of 5 months. The information of intermittent demands in group C may be inadequate for accurate evaluation.

In summary, the application of proposed policy and forecasting technique for group C items cannot be concluded. The proposed policy improves the inventory performance for some items but it is considered inadequate data because of studied period for the intermittent demand assessment.

Table 5.20 Comparison Performance Measurement for Group C Items

No.	Product ID	Average Daily Inventory Level (unit)			cost per unit (THB)	Average Daily Inventory Value (THB)			Service Level Measurement		
		Actual operation	90% Service level	95% Service level		Actual operation	90% Service level	95% Service level	Actual operation	90% Service level	95% Service level
1	394672	37	35	35	1,190	44,003	42,106	42,106	100%	100%	100%
2	426079	1,930	1,581	1,793	3.04	5,874	4,812	5,457	100%	100%	100%
3	432733	126	126	126	65.45	8,228	8,228	8,228	100%	100%	100%
4	130512	74	111	122	528.75	39,128	58,626	64,409	100%	100%	100%
5	233171	3,258	6,255	7,634	28.54	92,978	178,509	217,885	87%	100%	100%
6	272858	670	670	670	10.10	6,770	6,770	6,770	100%	100%	100%
7	434565	15,425	15,425	15,425	0.38	5,850	5,850	5,850	100%	100%	100%
8	349794	247,150	247,150	247,150	1.19	294,520	294,520	294,520	100%	100%	100%
9	245447	4,663	3,350	3,350	1.81	8,432	6,059	6,059	100%	100%	100%
10	168944	158	141	163	535.57	84,419	75,415	87,264	100%	100%	100%
11	206151	55	199	237	46.39	2,540	9,219	10,993	14%	100%	100%
12	20781	40,375	37,750	39,563	1.17	47,149	44,084	46,200	100%	100%	100%
13	452049	491	628	628	1.21	592	833	833	58%	72%	72%
14	118512	2,964	2,900	3,474	3.57	10,569	10,341	12,387	100%	100%	100%
15	445067	9	9	15	121.55	1,067	1,067	1,766	100%	100%	100%
16	517354	10	24	29	4,917	49,170	119,698	143,208	100%	100%	100%
17	332086	3,090	2,465	3,230	2.11	6,520	5,201	6,815	100%	100%	100%
18	411564	7,511	5,126	5,126	1.72	12,948	8,838	8,838	100%	100%	100%
19	214557	1,365	1,365	1,365	4.44	6,061	6,061	6,061	100%	100%	100%
20	382191	1,643	1,200	1,200	2.98	4,897	3,578	3,578	100%	100%	100%
	Total	**331,001**	**326,510**	**331,335**		**731,715**	**889,815**	**979,228**	**93%**	**99%**	**99%**
Reduction			1%	0%			-22%	-34%			
Total (without item 5 and 16)		**327,733**	**320,231**	**323,671**		**589,567**	**591,608**	**618,135**	**93%**	**98%**	**98%**
Reduction			2%	1%			0%	-5%			

5.4 TOTAL ANNUAL COST

According to section 2.6, the total ordering inventory cost is a combination of ***Annual purchase cost, Annual ordering cost***, and ***Annual holding cost***. The existing periodic review is by monthly, while the proposed interval is the same. Hence, the annual ordering cost which is associated costs of order replacement is considered the same.

The proposed methodology for group A and B items can reduce the inventory holding level which relates to the annual purchase cost and annual inventory holding cost. Therefore, the decrease of inventory level from the proposed policy results in a reduction of the total ordering inventory cost of the studied company.

Total annual cost = Annual purchase cost + Annual ordering cost + Annual holding cost

5.5 CHAPTER SUMMARY

The summary of results and assessment is illustrated in *Table 5.21*. Forecasting technique of simple exponential smoothing (weight factor 0.2) is suggested for group A and B items as the forecasting error analysis. Implementation for group A and B items shows an improvement of the operational performance. 95% Service level for safety stock determination is advised since it can decrease the inventory levels while maintaining 100% of the measured service levels.

For group C items, the Croston's method results with the least average errors. Unfortunately, implementation of the periodic review policy does not show an overall improvement. It is considered that effective solutions for group C cannot be determined, due to inadequate historical data and limited assessment period.

Table 5.21 Summary for Assessment Results

Group	Forecasting Approach	Inventory System	Service level for safety stock	Results	Exception
A	Simple Exponential Smoothing (Alpha = 0.2)	Monthly periodic review policy	95%	17% reduction of inventory units and 23 % reduction of inventory value	Items which purchased by a single customer who shares inventory information
B				7% reduction of inventory units and 19 % reduction of inventory value	
C	Croston Method (Alpha = 0.2)	Inadequate data to propose the effective policy			

Items ordered by a single customer who shares demand information and acknowledges the inventory level of the studied company do not show any improvements with the policy implementation. It can be concluded that the shared information from customer is very beneficial for the inventory management. The studied company can keep 'just enough' inventory level for these items.

Finally, the inventory levels for different service levels (95% and 98%) can be equal as two main factors. First, the minimum order quantity impacts the ordering decision likewise. Second, the current inventory level is too high compared to the demand, therefore it is overstocked. Then, the decision of not ordering stays the same.

Chapter 6
CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSIONS

The main objectives for the research are to propose new inventory policies in order to reduce the inventory level and improve internal operations in the studied company for Japanese products. This research is conducted by reviewing related theories and tools for inventory and warehouse management. Then, the evaluations of existing operations and process are performed including characteristics of inventory moving in 12 months of 2015 for 738 SKUs. Five groups are defined; 1) Non-moving stock 2) No sales last 6 months 3) Short-period stock 4) New product stock and 5) Remaining185 SKUs. Strategic managements for first four groups are proposed in Chapter 3.

Inventory for the remaining 185 SKUs are classified by using ABC Patero. Multi-criteria are considered for sequencing the importance of products. The continuity of demand is considered the most important, since it can divide groups of continuous and intermittent demand items. Moreover, 107 items which are ordered by single customers are verified. The result shows a mix of both continuous and intermittent demands for these items.

Demand patterns for all groups are assessed. Coefficient of Variation (CV) is applied to evaluate the level of data variation. Group A and B items result in low variance, while group C items result in high variance.

As identified groups of inventory and evaluation of demand pattern, forecasting approaches and error indicators, and inventory system are proposed. Periodic review policy is proposed for all groups because of high transportation costs. In addition, work flow and steps for ordering process, warehouse flow and warehouse checking process with warehouse documentations are also proposed in order to improve internal communications and system management. The communications for all procedures are importantly needed. The interpretation of roles and responsibilities shall be consistent. Arrangement of meeting is suggested in order to clarify and improve the company.

Implementation results in Chapter 5 show a reduction of inventory for Group A and B items. Simple exponential smoothing with alpha of 0.2 is recommended for forecasting. Monthly periodic review system is considered reasonable. Service level of 95% is advised for safety stock determination.

Unfortunately, group C items which are a group of intermittent demands with high variation do not result in an improvement. Effective evaluation and assessment cannot be precisely performed as limited historical data and assessment period. However, Croston's method with alpha of 0.2 shows the most accurate forecasting.

Items which are ordered by a single customer who shares information and acknowledge the stock level do not show a reduction of inventory. The communication between the studied company and customers results in the effective inventory level management.

Finally, assessment of proposed policies for group A and B items results in a reduction of inventory levels, which is linked to holding cost and ordering cost. Therefore, total cost of inventory can be decreased by the proposed policies implementation.

6.2 RECOMMENDATIONS AND CONCERNS

A mix of inventory value for Proposed ABC Pareto

Four criteria which are the continuity of monthly demand, the number of order, the value of sales, and the inventory value are considered for ABC analysis. The continuity of demand is considered of the highest importance, and the inventory value is weighted as the least important from the four factors. This judgement results in a mix items of inventory value in three groups.

During the assessment phase, all items are evaluated equally. The obvious consequences are illustrated in section 5.1.3 (Sensitivity analysis for the weight factor) that the units with high inventory value greatly influence the overall inventory performance. For instance; weight factor of 0.1 gives the least average error, and results in the least inventoried units. However, weight factor of 0.3 can reduce more inventory value with higher inventory level. Hence, the future researches are suggested to prioritize the high inventory value for each group for the evaluation.

Items which are ordered by a single customer who shares the demand information

Items ordered by a single customer who shares demand information and acknowledge the inventory level of the studied company do not show an improvement with the policy implementation. This suggests that effective communication with customers, especially for items ordered by a single customer, result in a better performance for inventory management.

Regarding high proportion of items ordered by a single customer (107 of 185 SKUs), working closely with the customer should be the key for strategic management.

Repetitions of forecasting

The implementation results that simple exponential smoothing technique, with recommended smoothing factor, clearly provides an improvement for inventory management. However, one absolute method should not be identified for the studied company to use indefinitely. It is crucial to understand the nature of a product's life cycle, external factors such as customer change and any special events. Repetition of information verification for appropriate forecasting technique should be performed every suitable period of time, such as every 6 or 12 months.

Limitation of quantitative forecasting technique

The quantitative forecasting technique is based on statistic of historical data. Uncontrolled factors such as natural disaster, and political event which affect the sales of the company should be considered in conjunction with the quantitative technique. These factors cannot be predicted but they need to be considered in order to perform future forecasts, since the environment is in constant change. Straightforward decision from quantitative technique based on historical data will result in large errors.

Limitation of the historical data

The historical data for the demand pattern verification and forecasting technique analysis is only 12 months. A longer historical data is required especially for the intermittent demand units in group C. It can be seen from the research that trends, cycles and seasonal orders cannot be captured with a 12 months record.

Forecasting technique selection

The methodology for the forecasting technique selection and alpha selection for simple exponential smoothing method are based on the fact that each studied item have equal weights. The variance of demand error, optimum weight factor, and item values are disregarded. Future studies may be required for better result accuracy.

Adjustment between the demand forecasting and the stock control system

This study examines the demand forecasting and the stock control system independently. Future study of detailed interactions between the two components should be reviewed and analysed since the most desired objective is the overall inventory performance, and not the separate components.

It can be demonstrated as in section 5.1.3 that the alpha factor of 0.1 which gives the least forecasting error does not result in the lesser inventory value. Moreover, the space requirements of item which can impact the warehouse operations are not considered for the overall perfromance comparison.

Four factors which can impact the overall performance of stock system (Syntetos and Boylan, 2008) are 1) hypothesized demand distribution 2) The forecast error variability 3) The employed safety factors and 4) the intentional bias of the estimator for the demand forecasting.

An empirical study of the interaction between the demand forecasting and the stock control on 786 SKUs of Royal Air Force parts with 27 control parameter combinations (such as service levels, lead times, and smoothing constant) was conducted by Syntetos and Boylan (Syntetos and Boylan, 2006). The results reveal that the parameter adjustments certainly improve the overall performance of stock control system.

Limitation of the simulation study

This study is performed based on the simulation and comparison of the results with the actual operation. Nevertheless, the real situation may contain other uncontrolled situations. This study results are based on the assumptions mentioned in the report. Also only 60 units (20 of each group) of 185 items are sampled for the assessment.

Moreover, 5 months comparison of the simulation results and actual operations may not be adequate especially for the intermittent demand items since the demand may not show. Then, the comparison cannot be observed.

Service Level Measuring

The period of stock out is identified for measuring the service level since the company has never recorded an unfulfilled order in the past. In reality, stock out period does not mean unfulfilled demand is occurring. It is just an indicator for potential missing opportunity for sales. Therefore, in the future, it is recommended to monitor and record the unsuccessful orders from the customers. Then, the service level can be determined from the loss of sales rather than stock out period.

Future study for bimonthly review interval for items in group B and C

Bimonthly review interval is proposed to compare with monthly review for intermittent demand items. It is expected to reduce the variance of intermittent data and result in a smaller safety stock, since these items are not frequently ordered. The comparison of coefficient of variation (CV) table is developed as shown in *Table 6.1* and *Table 6.2.* It shows that bimonthly interval reduce the variation of the data as CVs of bimonthly basis are less than CVs of monthly basis.

Table 6.1 Group B - Comparison of Coefficient of Variation (CV) for Monthly and Bimonthly Interval

No. of month showing demand	Comparison								
	No.	Code	Seq Order	Montly			Bimonthly		
				SD	Mean	CV	SD	Mean	CV
11	1	401079	64	7	7	1.05	9	13	0.70
	2	226689	65	1760	3004	0.59	1740	6008	0.29
	3	330746	66	731	1417	0.52	553	2833	0.20
	4	121633	68	692	600	1.15	877	1200	0.73
	5	109427	69	9268	14333	0.65	7364	28667	0.26
	6	325384	72	1163	2050	0.57	1461	4100	0.36
	7	404367	76	3600	5800	0.62	4891	11600	0.42
10	8	429581	79	118	229	0.52	223	458	0.49
	9	382116	80	1143	1971	0.58	1480	3942	0.38
	10	230136	84	634	879	0.72	716	1758	0.41
	11	325388	87	618	1050	0.59	1122	2100	0.53
9	12	RO-028	91	248	283	0.87	386	567	0.68
	13	159145	93	4.6	4.3	1.09	5.3	8.5	0.62
	14	270040	101	27	25	1.06	34	50	0.67
	15	184275	103	173	300	0.58	200	600	0.33
	16	121680	104	130	225	0.58	150	450	0.33
8	17	380616	105	296	246	1.20	298	492	0.61
	18	416437	106	12	11	1.03	15	23	0.69
	19	326936	112	137	150	0.91	240	300	0.80
	20	416445	113	7	6	1.17	8	12	0.70

Table 6.2 Group C - Comparison of Coefficient of Variation (CV) for Monthly and Bimonthly Interval

No. of month showing demand	Comparison								
	No.	Code	Seq Order	Montly			Bimonthly		
				SD	Mean	CV	SD	Mean	CV
7	1	394672	114	8	4	1.79	11	9	1.28
	2	426079	115	710	313	2.27	932	625	1.49
	3	432733	119	7	3	2.34	7	6	1.20
6	4	130512	122	56	21	2.66	63	42	1.51
	5	233171	123	3823	2063	1.85	2510	4125	0.61
	6	272858	124	98	46	2.14	93	92	1.02
	7	434565	128	656	375	1.75	832	750	1.11
	8	349794	130	31623	20000	1.58	30551	40000	0.76
	9	245447	131	1581	1000	1.58	0	2000	0.00
5	10	168944	133	80	33	2.44	89	66	1.35
	11	206151	138	89	40	2.21	100	80	1.25
	12	20781	140	11693	6250	1.87	7395	12500	0.59
	13	452049	141	390	208	1.87	247	417	0.59
4	14	118512	143	1639	417	3.93	1776	833	2.13
	15	445067	145	6	3	2.42	7	5	1.32
3	16	517354	149	11	3	3.37	11	7	1.76
	17	332086	155	951	325	2.93	947	650	1.46
	18	411564	161	186	67	2.80	182	133	1.36
2	19	214557	166	471	133	3.54	499	267	1.87
	20	382191	171	354	100	3.54	374	200	1.87

Then, safety stock comparisons between monthly and bimonthly review are generated for both items in group B and C as shown in *Table 6.3 and 6.4*. The interval resulting in the less safety stock is reported on the right column. The results show that safety stock of monthly and bimonthly intervals are not highly different. Bimonthly basis for 9 items in group B and 8 items in group C results less safety stock than monthly basis at the same service level of 95%. Therefore, bimonthly review interval reduces the variance of demand data and potentially decrease the inventory level.

Table 6.3 Group B - Comparison of Safety Stock for Monthly and Bimonthly Review Interval

No. of month showing demand	Safety Stock					
	No.	Code	Seq Order	95%		Less SS
				monthly	bimonthly	
11	1	401079	64	18	20	monthly
	2	226689	65	4,576	3,786	bimonthly
	3	330746	66	1,902	1,203	bimonthly
	4	121633	68	1,799	1,909	monthly
	5	109427	69	24,103	16,023	bimonthly
	6	325384	72	3,025	3,178	monthly
	7	404367	76	9,363	10,643	monthly
10	8	429581	79	307	484	monthly
	9	382116	80	2,972	3,220	monthly
	10	230136	84	1,648	1,557	bimonthly
	11	325388	87	1,608	2,442	monthly
9	12	RO-028	91	644	840	monthly
	13	159145	93	12.1	11.5	bimonthly
	14	270040	101	69	73	monthly
	15	184275	103	450	435	bimonthly
	16	121680	104	338	326	bimonthly
8	17	380616	105	769	649	bimonthly
	18	416437	106	30	34	monthly
	19	326936	112	356	522	monthly
	20	416445	113	18.2	18.2	bimonthly
Count		monthly			11	
		bimonthly			9	

Table 6.4 Group C - Comparison of Safety Stock for Monthly and Bimonthly Review Interval

No. of month showing demand	Safety Stock					
	No.	Code	Seq Order	95%		Less SS
				monthly	bimonthly	
7	1	394672	114	13	18	monthly
	2	426079	115	1,168	1,533	monthly
	3	432733	119	11.2	11.5	monthly
6	4	130512	122	91	103	monthly
	5	233171	123	6,288	4,128	bimonthly
	6	272858	124	161	153	bimonthly
	7	434565	128	1,078	1,369	monthly
	8	349794	130	52,015	50,251	bimonthly
	9	245447	131	2,601	-	bimonthly
5	10	168944	133	132	146	monthly
	11	206151	138	146	165	monthly
	12	20781	140	19,233	12,164	bimonthly
	13	452049	141	641	405	bimonthly
4	14	118512	143	2,696	2,921	monthly
	15	445067	145	10	11	monthly
3	16	517354	149	18	19	monthly
	17	332086	155	1,565	1,558	bimonthly
	18	411564	161	307	299	bimonthly
2	19	214557	166	775	821	monthly
	20	382191	171	582	615	monthly
Count		monthly			12	
		bimonthly			8	

Moreover, advantages and disadvantages for both intervals are listed and compared as illustrated in *Table 6.5*.

Table 6.5 Review Interval Comparison Analysis

	Advantage	Disadvantage
Monthly Review	1. Response to the demand faster 2. Less inventory compared to bimonthly review 3. Less used space for inventory	1. Potential high variation for safety stock from 'zero' data
Bimonthly Review	1. Potential less variation for safety stock 2. Less ordering cost (less man hour for purchasing decision)	1. Response to the demand change slower 2. Higher Inventory level 3. More used space for inventory

The proposed bimonthly review potentially generates higher stock level than a monthly review. However, preliminary determinations in *Table 6.3 and 6.4* show that the safety stock requirements for both intervals are not largely different. Moreover, bimonthly interval will make the company response to the demand slower than monthly reviews. Nonetheless, the positive side of bimonthly is less ordering cost compared to monthly interval and potentially decreases variance of intermittent demand pattern. Lastly, implementation analysis to compare inventory level is suggested for future study.

Layout for the warehouse

Warehousing layout and design is not developed in this thesis since there are other groups of items, not only Japanese products which is the focus group for this study. Nevertheless, literature review are to be performed for future study. Four typical storage assignment proposed by De Koster et al. (De Koster et al., 2007) are demonstrated as follows;

Forward-reserve allocation: Travel time for picking items is reduced. The concept is to separate two areas of stock; reserve area, and forward area. Trade-off between the amount of items placed on the forward area and replenishment period shall be carefully balanced in order to receive the maximum efficiency from spent efforts.

Storage assignment policies: typical storage managements are described;

1) Random storage – Items are randomly assigned their storage location. This technique results in a high space utilization. This policy suits for only computer-controlled environment.

2) Closet open location storage – the closet racks will be firstly filled. There is an argument that this technique is similar to the random storage.

3) Dedicated storage – It is a fixed location for storage creating a familiar route to the warehouse staff. The disadvantage is that the space is reserved for specific item even there is no stock.

4) Full-turnover storage – The storage place is assigned based on the product's turnover. The highest sales rate items are located at the easiest accessible locations. However, the disadvantage is when the demand changes the storage locations are to change accordingly which requires to reshuffle inventory.

Class-based storage: Pareto's tool used to classify items is applied for the storage assignment. Two typical ways are suggested and shown in *Figure 6.1*.

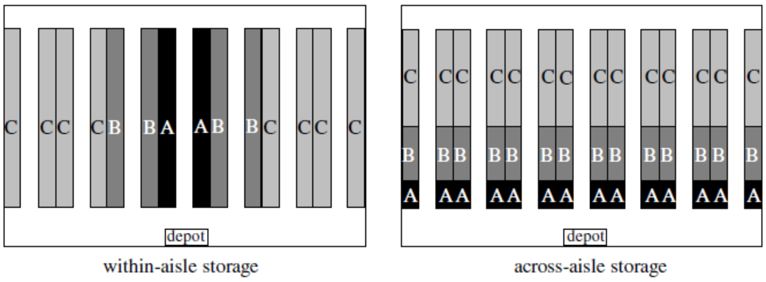


Figure 6.1: Two Common Ways for Class-based Storage Implementation
Source: (De Koster et al., 2007)

Family grouping: the concept is to group the similar items and locate them in the same area. The criteria can be item class, customer, type of product, items ordered together items and etc. However, this technique may consume more space in the warehouse compared to random storage assignment.

In addition, 5S practices consisting of sort, set, shine, standardize, and sustain are suggested for warehouse management

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APPENDIX

VITA

Miss Nutcha Joedjumnongwittayakul was born on July 3rd, 1988 in Bangkok. She graduated her Bachelor's degree in Chemical Engineering from Chulalongkorn University in 2010. After completion, Nutcha started her professional career as a Process Engineer in oil and gas industry for 4 years. Then, she decided to pursue dual Master's degree program at Regional Centre for Manufacturing Systems Engineering (RCMSE), Chulalongkorn University in cooperation with University of Warwick in United Kingdom, in major of Engineering Business Management.