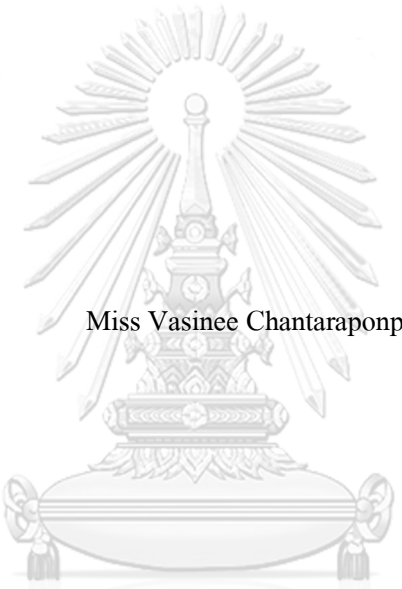
2022

Demand forecasting and inventory management for an automotive tire distributor in Northeast Thailand

Vasinee Chantaraponpun
Faculty of Engineering

Demand forecasting and inventory management for an automotive tire distributor in Northeast Thailand

Miss Vasinee Chantaraponpun



A Thesis Submitted in Partial Fulfillment of the Requirements

for the Degree of Master of Engineering in Engineering Management

(CU-Warwick)

FACULTY OF ENGINEERING

Chulalongkorn University

Academic Year 2022

การพยากรณ์อุปสงค์และการบริหารจัดการสินค้าคงคลังของผู้จัดจำหน่ายยางรถยนต์แห่งหนึ่งในภาคตะวันออกเฉียงเหนือของประเทศไทย

น.ส.วศินี จันทรพลพันธ์

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิศวกรรมศาสตรมหาบัณฑิต
สาขาวิชาการจัดการทางวิศวกรรม ศูนย์ระดับภูมิภาคทางวิศวกรรมระบบการผลิต
คณะวิศวกรรมศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย
ปีการศึกษา 2565

Thesis Title	Demand forecasting and inventory management for an automotive tire distributor in Northeast Thailand
By	Miss Vasinee Chantaraponpun
Field of Study	Engineering Management
Thesis Advisor	Professor PARAMES CHUTIMA, Ph.D.

Accepted by the FACULTY OF ENGINEERING, Chulalongkorn University in Partial Fulfillment of the Requirement for the Master of Engineering

..... Dean of the FACULTY OF ENGINEERING

(Professor SUPOT TEACHAVORASINSKUN, D.Eng.)

THESIS COMMITTEE

..... Chairman

(Associate Professor JEERAPAT NGAOPRASERTWONG)

..... Thesis Advisor

(Professor PARAMES CHUTIMA, Ph.D.)

..... External Examiner

(Associate Professor Chuvej Chansa-ngavej, Ph.D.)

วศินี จันทรพลพันธ์ : การพยากรณ์อุปสงค์และการบริหารจัดการสินค้าคงคลังของผู้จัดจำหน่ายยางรถยนต์แห่งหนึ่งในภาคตะวันออกเฉียงเหนือของประเทศไทย. (Demand forecasting and inventory management for an automotive tire distributor in Northeast Thailand) อ.ที่ปรึกษาหลัก : ศ.ปารเมศ ชุติมาวศ.ม.

งานวิจัยนี้มีวัตถุประสงค์เพื่อปรับปรุงการจัดการสินค้าคงคลังของบริษัทผู้จัดจำหน่ายยางรถยนต์ในภาคตะวันออกเฉียงเหนือของประเทศไทย เพื่อลดปริมาณสต็อกที่ไม่จำเป็นเป็นหลัก จากการตรวจสอบเบื้องต้น สาเหตุหลักของสินค้าล้นสต็อกคือความต้องการของลูกค้าที่ไม่แน่นอนและการขาดระบบควบคุมสินค้าคงคลังตามทฤษฎี เพื่อจัดการกับปัญหาและขอบเขตของการวิจัยได้ดีขึ้น ผลิตภัณฑ์และตัวแทนจำหน่ายย่อยที่เหมาะสมสามรายการที่มีรูปแบบความต้องการที่แตกต่างกันจะถูกเลือกเพื่อค้นหาแบบจำลองการคาดการณ์ที่เหมาะสมที่สุดสำหรับแต่ละผลิตภัณฑ์ และปรับแต่งนโยบายสินค้าคงคลังตามรูปแบบความต้องการ วิธีการแบ่งออกเป็นสองส่วนหลักคือการหาวิธีการคาดการณ์จำนวนความต้องการและนโยบายการควบคุมสินค้าคงคลังที่เหมาะสม

การพัฒนาแบบจำลองการคาดการณ์อุปสงค์ที่แม่นยำยิ่งขึ้น มีแบบจำลองการคาดการณ์หกแบบ ได้แก่ ค่าเฉลี่ยเคลื่อนที่สามเดือน การทำให้เรียบแบบเอกซ์โพเนนเชียลแบบเอกซ์โปเนนเชียลแบบเรียบแบบเอ็กซ์โปเนนเชียลแบบทวีคูณ วิธีการแบบฤดูหนาวของ Holt การถดถอยเชิงเส้น และ ARIMA ดำเนินการเพื่อเลือกแบบจำลองที่ดีที่สุดสำหรับผลิตภัณฑ์สามรายการจากสามลูกค้าและตัวแทนจำหน่าย โดยวัดจาก Mean Absolute Percentage Error (MAPE)

สำหรับผลลัพธ์ของนโยบายสินค้าคงคลังที่เหมาะสมและค่าคาดการณ์ความต้องการที่แม่นยำยิ่งขึ้น ตัวแทนจำหน่ายย่อยและบริษัทสามารถลดต้นทุนสินค้าคงคลังได้มากถึง 47% รวมถึงต้นทุนการถือครองและมูลค่าหมุนเวียนของสินค้าคงคลังเพิ่มขึ้นถึง 80% ในขณะที่จำนวนวันที่ถือครองสินค้าคงคลังลดลง นานถึง 55 วัน

สาขาวิชา การจัดการทางวิศวกรรม ลายมือชื่อนิสิต .....

ปีการศึกษา 2565 ลายมือชื่อ อ.ที่ปรึกษาหลัก .....

6372809821 : MAJOR ENGINEERING MANAGEMENT

KEYWORD: demand management, inventory management, demand forecasting, Inventory policy

Vasinee Chantaraponpun : Demand forecasting and inventory management for an automotive tire distributor in Northeast Thailand . Advisor: Prof. PARAMES CHUTIMA, Ph.D.

The objective of this research is to improve the inventory management for an automotive tire distributor company in Northeast Thailand to mainly reduce the excessive unnecessary stock. According to the initial investigations, the main causes of overstock are unstable customer demands and a lack of an inventory control system based on theory. In order to better address the issues and scope down the research area, three suitable products and sub-dealers with different demand patterns are selected to find the best-fit forecasting model for each of them and be customized the inventory policy based on the demand patterns. The methodology is divided into two main parts which are the demand forecasting model and inventory control policies for both sub-dealers and the company.

Regarding the development of more accurate demand forecasting models, there are six forecasting models which are three months moving averages, single exponential smoothing, double exponential smoothing, Holt's winter method, linear regression, and ARIMA conducted to select the best model. The study reveals that Holt's winter and ARIMA model provides the least forecasting errors as measured by Mean Absolute Percentage Error (MAPE).

According to a proper inventory policy and more accurate demand forecast value from the suitable model, sub-dealers and a company can save up to 47%, and inventory turnover increases by up to 80% while inventory holding days decreases by up to 55 days.

Field of Study: Engineering Management Student's Signature .....

Academic Year: 2022 Advisor's Signature .....

ACKNOWLEDGEMENTS

Firstly, I would like to express my special thanks of gratitude to my dissertation advisor, Prof. Parames Chutima, Ph. D who contributed his time to support and guide me through this research. Without his encouragement, suggestions, and comments, it could be challenging to finish this dissertation. Additionally, I greatly appreciate the dissertation committees' remarks and recommendations.

Additionally, I would want to express my gratitude to the studied company for allowing me to investigate and for providing the data for observation and analysis. Finally, I want to express my gratitude and appreciation to my family for always supporting and motivating me to pursue my other life goals.

Vasinee Chantaraponpun

TABLE OF CONTENTS

Page

List of tables

Page

Table of figures

Page

1. Introduction

1.1 Background of research

Demand management and inventory control are the important criteria factors that must be considered to support the supply chain performance and run a successful business. Effective demand and inventory control planning is the tool for customers ’orders forecasting with greater accuracy and improving inventory levels, resulting in cost reduction. Additionally, the inventory level has a direct effect on a company's profit and cash flow. When a company has more inventory on hand than is necessary to fulfill expected demand, this may result in several operational difficulties and financial constraints, such as high inventory holding cost, the wider storage warehouse, the capital tied up in stockpile and the slow liquidity. On the other hand, if the company carries too low stock, there is a high risk of running out of stocks and missing the customers' deals which must have negative impacts on the revenue and customer satisfaction.

Therefore, demand and inventory management are the keys to increasing the supply chain performance together with the sales growth and providing high-profit margins. A more accurate prediction based on the suitable policy and strategy can reduce safety stock levels, optimize inventory investments, and corresponding cash flow's negative effect while improving profits and the business's flexibility responds to customer demand.

1.2 Thailand's Automotive Industry Overview

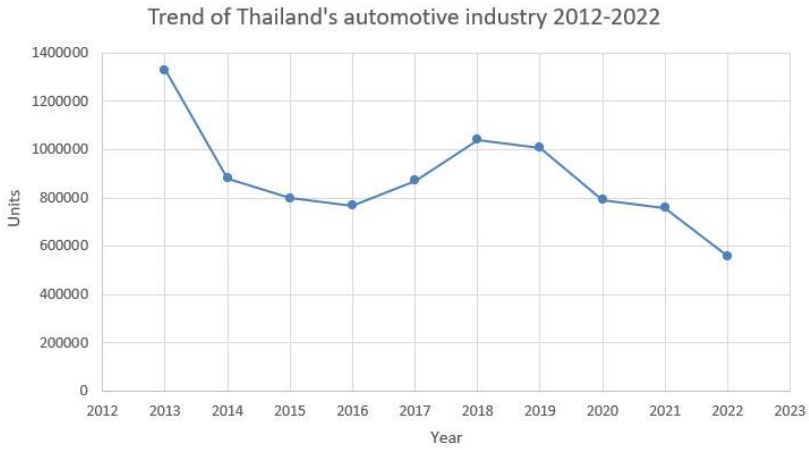


Figure 1: Trend of Thailand's automotive industry (Source from Thailand Automotive Institute)

According to the total sale from Automotive Thailand Institute, the Thailand customer demand trend in the automotive industry has been fluctuating for the past ten years, from 2013-2022, as shown in figure 1. In 2020, the sale gradually dropped down from the previous year 2020, about 21 percent, and seemed to decrease continuously. However, the Automotive Thailand Institute suggested that the automotive demand will slightly recover and increase this year,2022, by comparing the sale between the first quarter of 2021 and 2022, which raised about 19 percent.

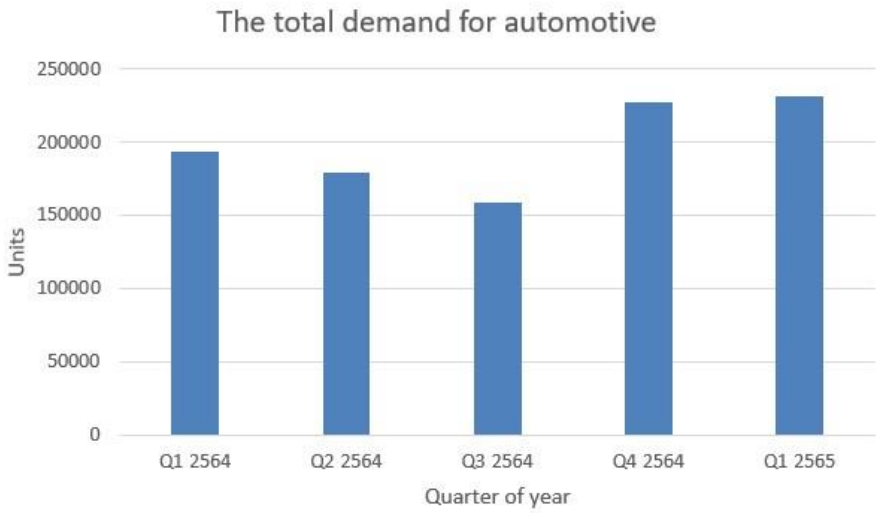


Figure 2: The total sale of automotive vehicle (Source from Thailand Automotive Institute)

Therefore, demand and inventory management are essential for a company to face this uncertain demand challenge.

1.3 Company Background

This research studies the demand side and inventory management for the distributor of automotive tires in northeast Thailand. A company established in 1998 and located at Udon Thani province with two warehouses. The employers are about 50 people with the main five departments. The authorized capital is 5,000,000 THB. A company is one of the biggest tire distributors in northeast region. The major customers are about 180 small dealers in Northeast Thailand, especially in Udon Thani and Khon kaen province.

Figure 3: Company's sedan tires warehouse (company source)

Figure 4: Company's tires truck and agriculture vehicle warehouse (company source)

1.3.1 Products and item codes

Figure 5: A company's workflow

For a company's workflow, a company predicts the demand for each product based on staff's experience and personal judgment, then orders them from the manufacturer. After that, a company stock the products in the warehouse, waiting for the customers' orders. Staff pack and deliver the products to customers when the orders are received. A company receives the products from a Thai manufacturer in Nakhon Pathom in central Thailand. The lead time is approximately 5 to 7 days depending on the situation. There are 164 stock keeping units (SKU). The company specifies the item codes to help the operator quickly identify the specification of each tire and save the time of allocating the warehouses, collecting, and ordering them. Nevertheless, this item code is set as a standard for every department. The codes are divided into three main groups depending on the vehicle type. The first one is a radial tire for a sedan with 70 items. Secondly, a radial tire for agriculture vehicles is six items, while a tire for four wheels cars and pickup trucks is 88 items. The coding identifies simply the definition as below Figure 3. Each group can be divided through the more specific detail like the dimension, diameter, and design/style of tread.

No table of figures entries found.	**Warehouse**	**Type of vehicle**
1-xx-11-xxx	Warehouse No.1	11 for Sedan
2-xx-12-xxx	Warehouse No.2	12 for Agriculture vehicles
2-xx-14-xxx	Warehouse No.2	14 for Four wheels cars and pickup trucks

Table 1: Product coding (company source)

1.4 Statement of Problem

According to the change of customers' demand, the company is facing financial issues due to the sale reduction by tying up the capital into the stockpile. Based on the previous year's financial report, a company lost the profit from unnecessary high costs in supply chain. The total sale is 66,282 items which are 114,544,040 THB, while the capital is 97,362,434 THB, and the profit is 17,181,606 excluding other additional costs, such as holding inventory and wage. The main problematic area is from holding excessive inventory. The company ordered and carried more stocks than customers demanded due to non-practical forecasting techniques. The total number of excessive stocks is 2812 items, while their value is approximately 5,691,857 THB. The inventory turnover ratio is 17.11 and the inventory conversion period is 22 days. Both values are calculated from latest financial data using the formula.

$$Inventory\ turnover\ rate = \frac{Annual\ consumed\ quantity}{Average\ number\ of\ units\ in\ stock}$$

$$Inventory\ conversion\ period = \frac{Days\ in\ year}{Inventory\ turnover\ ratio}$$

Annual sales 2021	114,544,040 THB
Capital cost	

Profit (including additional costs)	97,362,434 THB
Excessive inventory value	17,181,606 THB
Inventory turnover	5,691,857 THB
Inventory conversion period	17.11
	22 days

Table 2: The table of previous year financial data (company source)

However, a company has a pricing policy to manage this obsolete inventory. Due to the tire's life cycle, most customers prefer products with a recent manufactured date. A company encourages them by using the discount promotion.

- 20% discount from the selling price in the first quarter
- 30% discount from the selling price in the second quarter
- After that, a 40% discount from the selling price

From the company data, the sale of excess stock for three quarters is approximately 2,343,706.10 THB. which is about three million THB less than the investing cost. On the contrary, if the company sells them at the full price, the sale price will be 6,696,303 THB, earning 1,004,445 THB profit.

Cost of excess stock = 5,691,857.68 THB	
Sale with standard price	**Actual sale after a discount**
6,696,303.15 THB	2,343,706.10THB
Profit	**Loss**
+ 1,004,445.47 THB	- 3,348,151.58 THB

Table 3: The comparison sales of excess stocks (company source)

The comparison between the standard price sale and the sale after discount shows that a company unreasonably waste the money from overstock due to the existing strategy which may not be based on theoretical method. It depends on the owner experience and intuitive judgments. Therefore, this research studies demand and inventory management to improve a company's inventory level together with control uncertainty customers' demand to eliminate unnecessary cost.

1.5 Research Objectives

The research aims to improve a supply chain performance of a case study company. The specific objectives are following:

1. To improve inventory management by proposing, designing and developing the new policy to control the inventory quantity with focus of the customer demand.
2. To reduce the amount of capital tied up in product stockpile and increase the profit and the available liquidity.
3. To more accurately manage the customers' demand by investigation the best-fit forecasting models.

1.6 Research Questions

This research will investigate a variety of strategies and policies to improve a inventory level that is suited for a case study company. The following research questions will be investigated:

1. Which demand and inventory management strategies can be applied to decrease and prevent unnecessary high cost?
2. Does the customer behavior effect on a company’s supply chain performance?

3. How does a company manage and control customers' demand more efficiently?
4. What is the appropriate policy to control inventory levels?

1.7 Scope of Research

The scope of the research is to establish a demand and inventory management policy to improve the supply chain performance which is suited for the case study company, the automotive tire distributor. The historical data would be considered. The research will only focus on the redial tires for the sedan which are 70 SKUs. This type of products is the best-selling items and can be sold all the year. ABC analysis method will be applied to categorize the product inventory and identify the problematic area. Some of these products is used as the example in the inventory analysis. The study also focuses on five targeted customers to gather the information and examine their purchasing behavior. This project will focus on the customer within Udon Thani and Khon Kaen area, due to the fact that other customers in northeast area examination will be too broad and time-consuming. Some specific consumers which are the company's largest and considered to affect the great result will be selected to narrow down. The customer selection will be based on the Pareto principle. The topics of interview are about the current order strategy and policy which are related to the cycle of order, the number of products, the quantity of each product in order and the historical sales in the past two year.

To evaluate the inventory control performance, key performance indexes (KPIs) will be used to measure the proposed approach and results in the implementation phase.

1. Inventory turnover
2. Inventory holding days
3. Inventory value
4. Inventory level

1.8 Expected Outcome

According to the research approach, the expected outcomes aimed to obtain as follows:

1. A new policy for better inventory control
2. The reduction of overstock quantity and inventory cost
3. The long-term plan to manage the customers' needs and predicts the sale more correctly based on the theoretical method
4. The more effective company's performance in supply chain management

2. Literature Review

A significant amount of relevant data had to be gathered in order for this study's objective to be achieved. This will able to come up with improvements and suggestions as well as gain a complete understanding of the area of study. The information from the literature was obtained via literature searches in Google scholar, Warwick library, and Chulalongkorn library database. Some of the most used keywords were demand management, demand planning, inventory management, and inventory policy in the area of automotive industry and distributors.

2.1 Supply Chain Management

A network of related businesses which adds value to a chain of transformed inputs from their point of origin to the final goods and services desired by the specified end-users refers as supply chain. Supply chain management is the integrated management process of physical goods and information flows between suppliers and customers or among corporate departments (Nenes et al., 2010). The objective of supply chain management is to deliver the right products to customers at the right time and place, together with maintaining customer satisfaction. Supply chain management has become one of the most critical areas where businesses may gain an advantage. However, efficient supply chain management is challenging due to various factors, including rapidly growing product diversity, outsourcing, and corporate globalization

In the case that companies' supply chains are out of control if they are facing the burden of unnecessarily large inventory, poor customer service, rising expenses, and minimizing income. Businesses must revise their existing supply chains and improve them by using new techniques to prepare for any new possibilities and challenges they may encounter. It is necessary for the company to understand that different products must have different supply chains due to the different demands for successful management. Therefore, products with stable demand patterns should not use the same management approach as unstable demand products. The company cannot use one strategy to fit all products for an effective supply chain performance

2.2 Demand Management

Demand management is a supply chain strategy to find a balance between customer requirements and supplier capabilities. This method allows the supply chain to respond to customer demand and needs with minor disruptions. The method is not only forecasting. It involves coordinating demand and supply, boosting adaptability and flexibility, and lowering variability.

According to the academic (Bóna and Lénárt, 2014), a critical stage of resource planning is forecasting future demand and preparing for demand changes because it supports other planning processes like production scheduling and material requirements planning as well. Although markets are changing instantaneously nowadays, supply chains must be adaptable and practical. This might be connected to the client demand's uncertainty and higher customer expectations. An organization must prepare a plan for demand uncertainty to keep customers (Gupta and Maranas, 2003)).

2.2.1 Uncertainty demand management

In terms of uncertainty demand, (Gupta and Maranas, 2003) claimed that unpredictability must be considered while planning decisions. This relates to the fundamental objective of planning models, which is to allocate resources for the future based on historical data and current demand to make forecasts for the future. The most crucial factor to take into account is choosing the most appropriate representation of these uncertainty indicators in order to integrate uncertainties into planning processes. Due to unexpected prediction errors and rapid market changes, a demand forecast will never be precisely accurate.

To deal with the uncertain demand, there are two possible strategies that the company can use.

- Shape strategy: This is implemented by making agreements and contracts with clients. It would include an agreed quantity supply offer to the customers with a minimum/maximum amount. In exchange, they receive an offer of a price reduction on the items. The goal is to reorganize the demand distribution in order to reduce the adverse risk while achieving possible advantages (Gupta and Maranas, 2003).
- Adapter strategy: This approach does not affect the market's uncertainty level. By continuously adjusting the operations to the demand, it simply manages the overall risk response to the situation, such as profit margins and stock levels (Gupta and Maranas, 2003).

2.2.2 Demand forecasting

Because production and delivery require time to complete, forecasting demand is an essential tool for every type of business. In most cases, the number of goods that has to be manufactured, ordered, or delivered will be calculated by forecasting. To maintain the customer, every company wants to respond to the customer's needs immediately, so they stock the products. A company that can offer a faster time to provide the product to the customer will be a strong competitor among others. Accurate forecasting increases a business's capacity to plan for proper logistical operations like manufacturing up to efficiently scaled quantities and ordering raw material from suppliers up to economies of scale (Waters, 2021). More precise demand forecasts result in more effective performance and enhanced customer service. On the other hand, the poor estimation will negatively result in ineffective operations, less profit, and unsatisfactory customer service

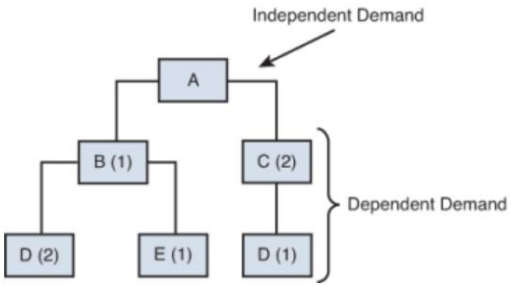


Figure 6: The relationship between dependent and independent demand (Sanders, 2013)

According to the book (Sanders, 2013), the demand can be divided into two groups. The first one is independent demand, which is for the finished goods, while demand for component components or subassemblies is dependent demand. However, these dependent and independent demands are linked together, as shown in the figure above, and the manufacturer requires to manage both of them. At the same time, a case study company is the distributor for tires, and finished goods, so the company may focus on the strategy of managing only the independent demand.

2.2.4 Pattern of demand behavior

According to the book (Mishkin, 2015), the demand can be classified into five basic patterns based on the time series. The repeated observation of consumer demands for a service or product in the sequence of occurrence is defined as a time series. Four of them display in the patterns, which are horizontal, trend, cyclical and seasonal, presented in the below figure. The other is the random or irregular pattern.

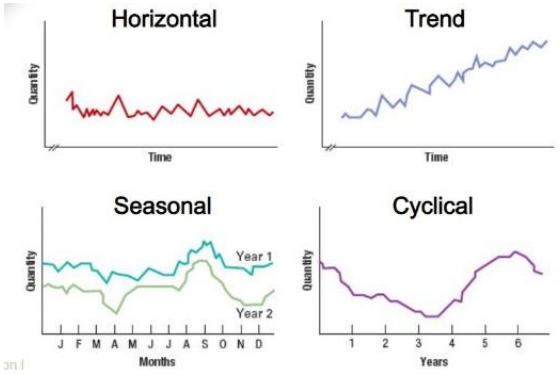


Figure 7: Patterns of demand (Mishkin, 2015)

Each type of demand behaviors is described below:

- Horizontal pattern: the fluctuation of data around the constant mean
- Trend: the consistent decrease or increase in the mean of the series over the time
- Cyclical: The gradual changes that are less predictable and occur over longer times, such as years or decades.
- Seasonal: A reoccurring pattern of demand movement, including increase and decrease depending on the time of the day, week, month, or season. The movement may behave similarly to cyclical but in a shorter period of time.
- Random: The unforecastable demand variation, which is no specific pattern. It may combine other ways together.

2.3 Inventory Management

The definition of inventory is every item and resource that a company own and holds and plans to add value to before selling (Relph and Milner, 2015). The frequent issue with inventory is the number of varieties and the required quantity. Because inventory holds a significant amount of money, the business must get a reasonable investment return.

Inventory management is the process of controlling your stock by monitoring purchase orders, delivery schedules, and shipment tracking. The goal of inventory management is to manage the flow of materials and other associated activities, involving forecasting inventories,

monitoring their availability, controlling their lead times, and allocating storage for them. According to inventory costs, which are the second-largest asset category in manufacturing organizations after investment in machinery and equipment, inventory management is crucial for effective performance and supply chain management. Between 15 and 30% of the entire asset comprises inventory (Nenes et al., 2010).

A significant portion of a small organization's budget is allocated to purchasing inventory; however, inventory management is one of the underestimated and poorly managed corporate functions. Due to poor and ineffective inventory management, many smaller firms have large amounts of capital tied up in excess stock. Therefore, Poor inventory control directly affects a business's cash flow and liquidity. Holding inventory at a specific level is essential due to variable demand, uncertain supply, and manufacturing cycle periods. Maintaining and managing a balance between inventory supply and demand is challenging. A business would want to carry sufficient stocks to meet client needs and avoid sales losses resulting from running out of stock while avoiding having excessive inventory on hand owing to the expense of keeping.

2.3.1 Types of inventories

The inventory has many forms in the manufacturing process as the above figure. There are generally four primary classifications.

- Raw materials: the materials are required to manufacture finished goods. These inventory items are parts that are currently in stock, excluding work in process and finished products.
- Work-In-Process (WIP): this type of inventory is still in the production process
- Finished good: The products are ready to be sold and delivered to the customer

- Overhaul or MRO: MRO inventory stands for Maintenance, Repair, and Operating Supplies. This type of inventory is a small detail that requires selling the finished goods, but it is not directly required to produce them.

2.3.2 Inventory turnover ratio

As tied-up capital is not a representative measure to compare against other inventories, it is challenging to utilize it when evaluating the performance of stock; therefore, the comparison of the inventory turnover ratio is a more accurate indicator because it indicates that the actual data are comparable. This inventory turnover presents the total material flow in the current period compared to the average amount of money over the previous year. The inventory turnover rate calculates how frequently the average inventory gets changed over. The equation of inventory turnover ratio shows below.

$$Inventory\ turnover\ rate = \frac{Annual\ consumed\ quantity}{Average\ number\ of\ units\ in\ stock}$$

2.3.3 Inventory Classification: ABC analysis

According to the academic journal (Boylan et al., 2008), the management of materials through the classification of relevant stock units (SKUs) to make decisions in line with the forecast and control of stock levels has been addressed as an operational concern. Managers may concentrate on the most crucial SKUs based on product categorization. By categorizing the demand for various products, stock levels can be effectively managed, improving service and lowering costs.

A company generally maintains an inventory of various raw materials and components to satisfy manufacturing demands. Inventory categorization is a crucial application and one of the most common inventory management methods. According to Pareto's principle, a small proportion of products account for a high proportion of value. This value can consist of total sales, earnings, or any suitable parameter. This value can consist of total sales, profits, or any

proper parameter. Approximately 10% to 20% of the inventory's items contribute 70% to 80% of its value. This group is classified as class A in the inventory class. The B class is a standard value product with around thirty percent of total items and thirty-five percent of the total. Lastly, the C class is considered about fifty percent of whole items and accounted for ten percent of the total value.

The quantity of each product type is multiplied by its unit price to determine the overall inventory value. The relationship between the value and ABC classification is shown below figure.

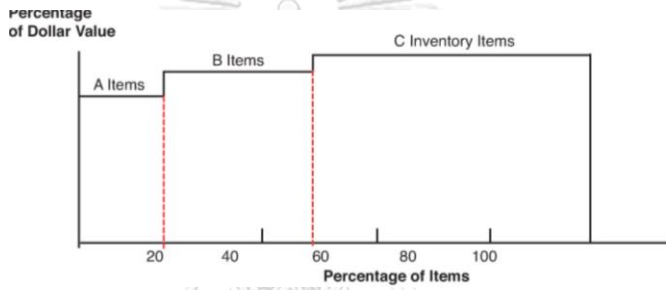


Figure 8: Relation of value to percentage of ABC Classification (Sanders, 2013)

The standard ABC categorization can be performed using a multi-criteria approach, which identifies the items based on a range of values. By using a variety of classification methods, it may also be categorized as a multi-criteria technique. The most valuable things are organized as A-items as they require a higher level of servicing (Syntetos et al., 2009). Class A products, representing the most significant part of the value, should be subject to the strictest and closest control, followed by classes B and C, respectively (Balaji and Kumar, 2014).

The benefits of ABC analysis are various. Firstly, the method ensures that such products, which have a significant investment, are under closer and better management. Secondly, the holding inventory cost is lower. Thirdly, the inventory turnover rate is maintained at a high level. Finally, products in c class can be flexible controlled by adding sufficient buffer stock.

2.3.4 The cost related to inventory management

One of the essential factors in making an inventory decision is the cost. The costs involved in inventory management are listed below.

- Ordering cost**:** The cost of placing an order is a variable cost that relies on the number of orders. Typically, ordering costs include all expenditures directly associated with the ordering process(Jonsson and Mattsson, 2008). To calculate Economic Order Quantities (EOQ), ordering costs must be defined because each item has a distinct ordering cost. Averaging the ordering costs for each inventory item will simplify that. Two methods—top-down and bottom-up—are described to determine the ordering cost. A top-down strategy will divide the total number of sales orders by the total amount of variable ordering expenses, such as the overall cost and time spent on material planning, the purchase process, and order management. In contrast, the evaluation for the bottom-up method should be distributed over a longer time (Jonsson and Mattsson, 2008).

$$Top - down = \frac{Total\ amount\ of\ variable\ ordering\ costs}{Number\ of\ orders}$$

$$Bottom - up = Hoyly\ rate \times Time\ per\ order$$

- Inventory holding cost: The expenses a business must pay for keeping goods on hand are referred to as inventory holding costs. Taxes, insurance, staff expenses, depreciation, the cost of maintaining assets in storage, replacing perishable products, and opportunity costs are just a few examples of the various carrying costs that a business may face. The key element of the holding cost and a challenging concept to define is the capital cost associated with inventory
- Shortage cost: When the amount of the product needed exceeds the amount of stock on hand, a charge known as a shortage is incurred. 15% of the purchase price is typically calculated to be the shortage cost.

- Total inventory cost: the sum of inventory holding cost (IHC), shortage cost (SC), and ordering cost (OC) together.

$$Total\ inventory\ cost = Ordering\ cost + Inventory\ holding\ cost\ + Shortage\ cost$$

2.4 Inventory Control Policy

There are two main goals for inventory control. By preventing understocking, the initial goal is to optimize the quality of client service. Understocking results in production bottlenecks, delayed delivery, backlog orders, loss of sales, and low customer satisfaction. The second goal of inventory control is to increase production or purchasing efficiency by lowering the price of offering adequate levels of customer service.

According to the reviewed thesis (Nerdnoi, 2014), ABC analysis-based policies applied to each inventory category use the Pareto analysis of sales imbalance. Therefore, it indicates that each item should have a different handling or management policy corresponding to its categorization. Nerdnoi (2014) suggested that the items in A class must be tightly controlled, accurately forecasted, and should not out of stock. Therefore, the reorder point is more frequent than other items in other classes. In contrast, the reorder point of items in the C class is longer than in the other two classes. Reordering of C-item inventory should only be done after an actual withdrawal has taken place.

2.4.1 Continuous review policy

The inventory level is continuously inspected under the continuous review policy. The order may be placed instantly whenever the inventory level reaches the reorder point. Practically, the inventory quantity will be evaluated straight away following each withdrawal from inventory.The two-bins method is one of the continuous review policies. The reorder point of the two-bins concept is the point that the first bin runs out of stock. The new order will be placed at

this point, and the second bin will fulfill the products in the first bin. A second bin always has enough stock level to meet the demands until the new order arrives to avoid the out-of-stock.

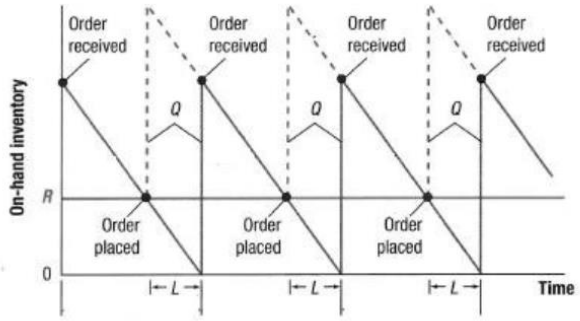


Figure 9: Reorder point of the continuous policy (Vaz and Mansori, 2017)

2.4.2 Periodic review policy

A standard inventory system where the amount of inventory is checked on a regular schedule and a decision is made on how much to order to boost the inventory level to a specific amount. The number of placed orders is equal to the different number of target inventory levels and the actual inventory level.

2.5 Inventory Management Method With Optimal Order Quantity

2.5.1 Economic order quantity (EOQ)

The economic order quantity (EOQ) technique is the way to find the number of items that should be ordered and shipped in each lot by determining the amount that minimizes the overall cost of buying and keeping inventory. The standard EOQ model works well for the company with stable demand and steady. The order fulfillment quantity is received at once, and the lead time for processing orders is constant. The model is an inventory system with a continuous order cycle. A replacement order will be placed if the inventory level reaches the reorder point. The quantity that will result in the lowest carrying cost and ordering cost is the economic order quantity. To achieve the ideal level, the balance between these expenses, which work in opposition to one

another, must be considered. The average amount of inventory will increase as the size of the order increases. Still, fewer orders will need to be completed, lowering the ordering cost and raising the carrying cost. The best integration of these two related costs is the ideal order quantity. The perfect order quantity is determined by the interaction between the holding and ordering costs.

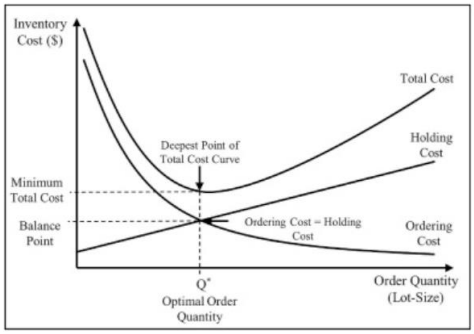


Figure 10: The total inventory cost curve (Tasdemir and Hiziroglu, 2019)

Therefore, only two costs, total yearly ordering costs and the total annual holding cost, need to be taken into consideration for the EOQ model.

$$Annual\ ordering\ cost = \frac{(Annual\ demand / Order\ quantity)}{Cost\ per\ order}$$

$$Annual\ holding\ cost = \left(\frac{Order\ quantity}{2}\right) \times Holding\ cost\ per\ unit\ per\ year$$

The economic order quantity shows

$$Ordering\ cost = Holding\ cost$$

$$The\ optimal\ value\ of\ order\ quantity = \sqrt{\frac{2(Annual\ demand)(Cost\ per\ order)}{Holding\ cost}}$$

2.5.2 Service level

Customer satisfaction levels influence how quickly a manufacturing business can fulfill orders. Many companies must make a difficult trade-off between maintaining low inventory levels and achieving high customer satisfaction via delivery on time shown in below figure.

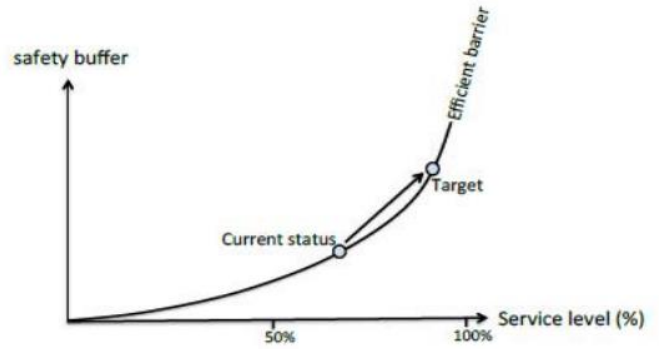


Figure 11: The trade-off of the service level and safety stock (Nerdnoi, 2014)

Shivsharan (2012) means that the cycle service and fill rate are the service indicator to monitor and track inventory and measure the performance of customer demand response (Shivsharan, 2012). The cycle service represents the possibility that no supply will run out within the period. The fraction of demand that can be met by available stock is the fill rate. Both equations are present below.

$$Cycle\ service = 1 - \frac{Number\ of\ shortage\ inventory\ cycle}{Total\ number\ of\ inventory\ cycle}$$

$$Fill\ rate = \frac{Number\ of\ demand\ \ delivered\ directly\ from\ inventory}{Total\ demand}$$

In conclusion, cycle service is easier to monitor and estimate, whereas fill rate results in a somewhat substantially lower service level than what should be.

2.5.3 Safety stock and reorder point

Safety stock was implemented into supply networks to avoid numerous supply chain risks, such as fluctuating consumer demand (Shivsharan, 2012). The safety stock is used as a buffer on the production side to help protect the manufacturing plan and timeline from fluctuation. On the supply side, suppliers might occasionally be unreliable regarding lead time and volume (Farahani, 2011).

There are three standard methods to determine the safety stock level. The first approach is time supply which sets the safety stock at the supply. The second one is a supply ordering cost which is lower the ordering cost and holding inventory. Lastly, the service level approach reduces cost but still maintains customer satisfaction.

Due to the uncertain and complicated variables, Cetin et al. (2004) developed a safety stock formulation for analysis to minimize the number of stochastic variables and uncertainty lead time.

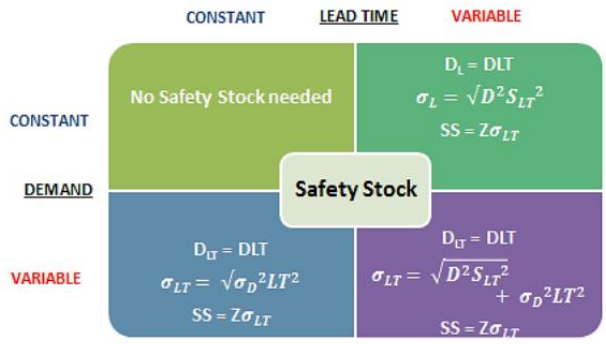


Figure 12: The formulation of safety stock (Nerdnoi, 2014)

SS = safety stock

σ_d = Standard deviation in demand per period

LT = Average lead time

D = Demand in average

D_{Lt} = Demand during lead time

S_{Lt} = Standard deviation in lead time

σ_{Lt} = Standard deviation of demand during lead time

CSL = Cycle service level

K = Safety factor

The demand for a product within a certain lead time and the previously estimated safety stock are used to estimate the reorder point. Applying this technique may ensure that items are available while awaiting the delivery of new ones. The formulation of reorder point presents below.

$$ROP = SS + DL$$

ROP = Reorder point SS = Safety stock

DL = Demand during a period

2.6 Planning Demand Uncertainty Through Customer Differentiation

Customer relationship management has become a key topic in the academic and operating area because the company can receive different values from each customer. According to the literary journal (Reinartz et al., 2004), it stated that while there are advantages to managing consumers in various ways, businesses must also take into consideration that establishing more relationships is not necessarily better; instead, it is crucial to create solid bonds with the proper clients. Organizations must be aware of consumer behavior and profitability to develop individual client relationships successfully. Moreover, the organization must consider additional aspects when evaluating the customer apart from profit (Gordon, 2003).

Ulaga and Eggert (2006) explored that the cost is expensive for the company to provide the same service to every customer. The service differentiation for a proper customer can provide a better solution than the financial issue. A situation where the company may acquire a vital supplier status with some targeted consumers, and so the client becomes more dependent on that specific supplier, can be created by creating a customized service. Independent of the industry is more critical in today's economic environment to differentiate beyond only offering unique products and competitive prices to customers. For instance, value creation may be a creative method of providing an extra service that other businesses would not be able to provide (Ulaga and Eggert, 2006).

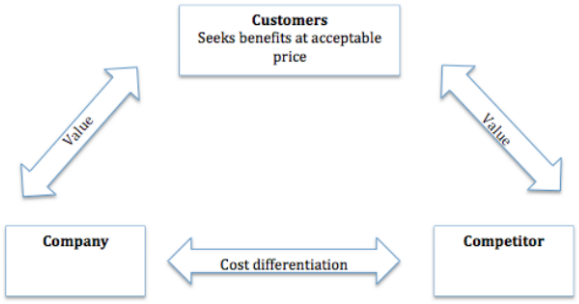


Figure 13: The customer value creation through cost differentiation (Martin, 2005)

The above figure presents the customer value creation using a cost differentiation strategy. The capability of a company to set itself apart from its competitors is the source of competitive advantage. The cost advantage results in a reduced cost for the particular product, and the value benefit results in offering products or services (Martin, 2005) . Additionally, Ulaga and Eggert (2006) suggested that the superior customer is the long-term plan for value creation apart from providing cost reduction or additional benefits. In the present market, the company is facing the challenge that customers choose to use several suppliers in steads of creating a solid relationship with the main one.

As a result, supply networks tend to become more complicated. Two interesting methods are to boost customer value and supply chain performance for all businesses.

2.6.1 Vendor Management Inventory (VMI)

Vendor management inventory (VMI) is a method for optimizing supply chain planning activities. It benefits organizations, especially small and medium-sized, that could benefit from improved customer collaboration. The primary concept of VMI is that the supplier, rather than the client, has control over stock management. The provider will advantage from the ability to readily monitor and modify distribution strategy in response to customer demand changes. Online supplier is a way to reduce the complexity by accessing the online data system to observe the inventory level and other customers' requirements. Then, the supplier can deliver the products based on that data.

2.6.2 Collaborative Planning Forecasting and Replenishment (CPFR)

This strategy is the tool to overcome the lack of sight and information on actual consumer demand by boosting supply through joint planning, joint decision-making, joint forecast development, and a new replenishment method. According to this technique, companies want to manage inventory by sharing information about and replenishing items along the supply chain. When the suppliers notify that the stock levels are too low, they restock their customers' inventory rather than wait for an order (Seifert, 2003).

CPFR is a valuable and popular method because it provides more accurate forecast data for the company. The estimated data will be more effective when the customer and supply cooperate and share the information. The supplier can create a more efficient plan to respond to the customer's needs. Therefore, this approach can address issues with keeping large amounts of inventory to ensure product availability, problems with numerous forecasts created within the same business and the impact of promotions on the development of the sales forecast.

CPFR provides several advantages to the company.

- cost reduction
- quickly way to observe real-time information
- more accurate information

- increase in customer service
- faster inventory turns
- inventory holdings cost reduction
- excessive stock reduction

Maharaj (2017) suggested that communication and real-time data are the main factors of poor demand management. Demand management requires the collaboration of every department involved in the supply chain. Synchronization is a key to balancing demand and supply (Maharaj, 2017).

2.7 Related Researches

Section	Year	Author	Contribution
Demand management	1999	Cachon	This study investigates stochastic demand fluctuation in a model with a single supplier and several retailers. The researcher finds the total inventory cost can reduce by lowering supplier demand variance with scheduled ordering policies. (Cachon, 1999)
Demand management	2012	Hung lau	In the downstream of a retail supply chain, this research intends to investigate the operation of demand management in achieving a balance between distribution efficiency and consumer responsiveness. The finding reveals that demand management techniques, such as customer segmentation and pricing differentiation, can increase the supply chain's overall distribution performance while

			responding to fulfill actual customer needs. Other approaches, such as vendor-managed inventory, can help aggregate demand with a less negative impact on customer service. These adjustments require a thorough comprehension of customer requirements, the company's supply capabilities, and corresponding organizational strategy, leadership, and culture changes (Hung Lau, 2012).
Demand management	2015	Murray	This study improves standard and advanced forecasting techniques to solve the unavailable collaborative information issue by clustering customers based on their demand behavior. Since it is impractical to build specific customer forecasts, we may design a manageable number of forecast models and use them for each consumer class (Murray et al., 2015).
Demand management	2017	Maharaj	A researcher applied information sharing and collaborative forecasting within the organization to manage various demand orders on the underlying Just-In-time approach in a case study of the stationery distributor. The study aims to minimize resources and costs. This study found that although real-time data are updated through the communication between departments involved in the supply chain, rapidly changing market trends are still challenging. Demand synchronization plays a vital

			role in balancing demand and supply (Maharaj, 2017).
Demand management	2017	Nulden	This study aims to identify the causes of excessive stock from a distributor perspective and indicate the proper area that should be improved to increase the company's supply chain performance. A researcher suggests that the categorization should be based on the substitution group due to the SKU's uncertain monthly demand. ROP, ROQ, and demand forecasting for the A category should be regularly examined to minimize the risk of overstock (Nuldén, 2017).
Inventory management and demand forecasting	2015	Lu Chang	This research aims to optimize the order amount from the customers' demand by developing a decision support system with an optimal multivariate forecast model. The finding reveals a multivariate forecast model performs better than traditional forecasting techniques, smooth exponential, and a moving average model to predict the actual demand, helping a company more effectively manage the order (Lai and Chang, 2015).
Inventory management	2018	Rizkya	The goal of this study is to determine the optimal inventory system policy. By using low inventory costs and ordering costs, the optimal inventory system can identify order quantity to satisfy consumer demand. A continuous and periodic

			review policy was performed to discover an inventory system policy that can deal with overstock with dynamic probabilistic demand characteristics. The results show that the continuous review strategy reduces inventory costs in the automotive sector (Rizkya et al., 2018).
Inventory management	2018	Riza, Hardi Purba and Muklisin	The researcher aims to reduce the total inventory cost and meet the customer demand of a company in the automotive industry by applying a standard economic order quantity to two products. The finding is that total inventory cost with the EOQ method is lower than the order based on company policy. The limitation of this research is that the proposed strategy is suited for constant demand and a company with fewer product variables (Rizkya et al., 2018).
Inventory management	2020	Ramos	The research is about inventory management of spare parts in the automotive sector using lean practices in a synergistic manner. One of the most difficult challenges in effectively managing these products is controlling the stock level due to the demand uncertainty and infrequent characteristics. This issue is the main challenge for a distributor who wants to maintain the service level by holding a large stock. The research overcomes the problem by implementing the most suitable inventory policy for

			each SKU ategory. The methodology achieved total inventory cost reduction and greater order fulfillment. This study focused only on the company's inventory as a single link in the supply chain (Ramos et al., 2020).
Inventory management	2021	Anjani and Nizar	In this research, the four forecasting methods, single exponential smoothing, double exponential smoothing, trend analysis regression, and moving average, are performed through Minitab software to identify the optimal stock level for a medical device distributor. The result presents that trend regression analysis is the lowest error value (Anjani and Nizar, 2021).

Chapter 3. Research Methodology

3.1 Research Design

The methodology of this study is divided into two main parts. The first part is about the demand forecasting model to more accurately predict the demand for each SKU of each customer and demand analysis to characterize the demand pattern, while the second part is about the policy to manage the inventory depends on the prediction and demand pattern based on the first part.

3.1.1 Demand Forecasting Model and Demand Analysis

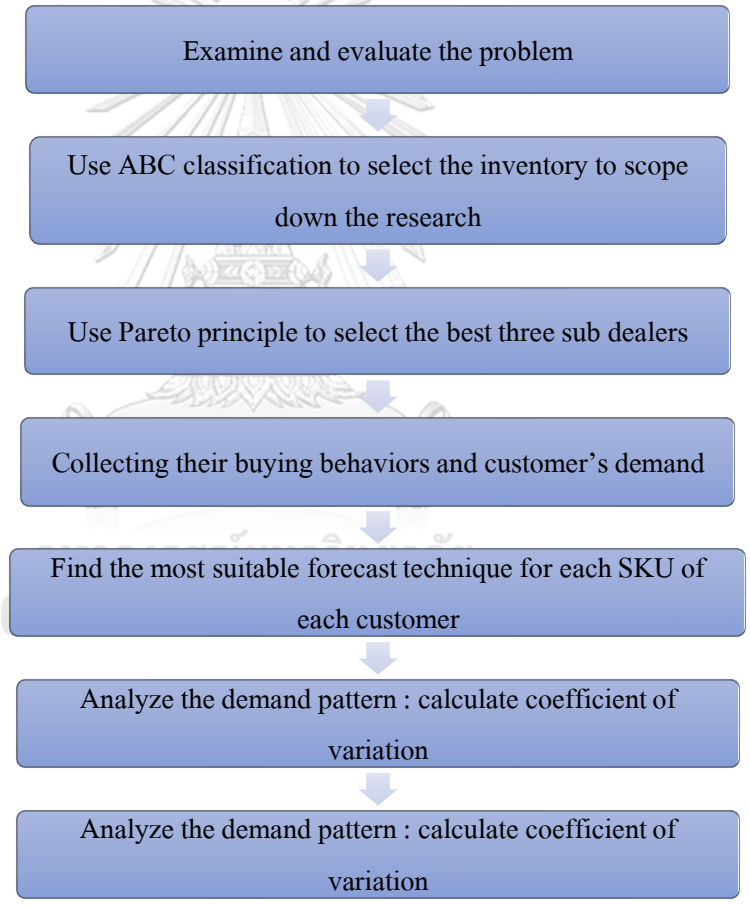


Figure 14: The flowchart of first part methodology

The methodology begins with understanding the problem and evaluate the root-cause then the proper products and customers who are sub dealers are selected to scope down the research area and get the effective results. After collecting the data, the best-fit forecasting

techniques are investigated for each customers' SKU to get the most acerated demand predicting values. The final step of this part is analyzing and characterizing the demand pattern based on the variation.

3.1.2 Inventory Control Policy

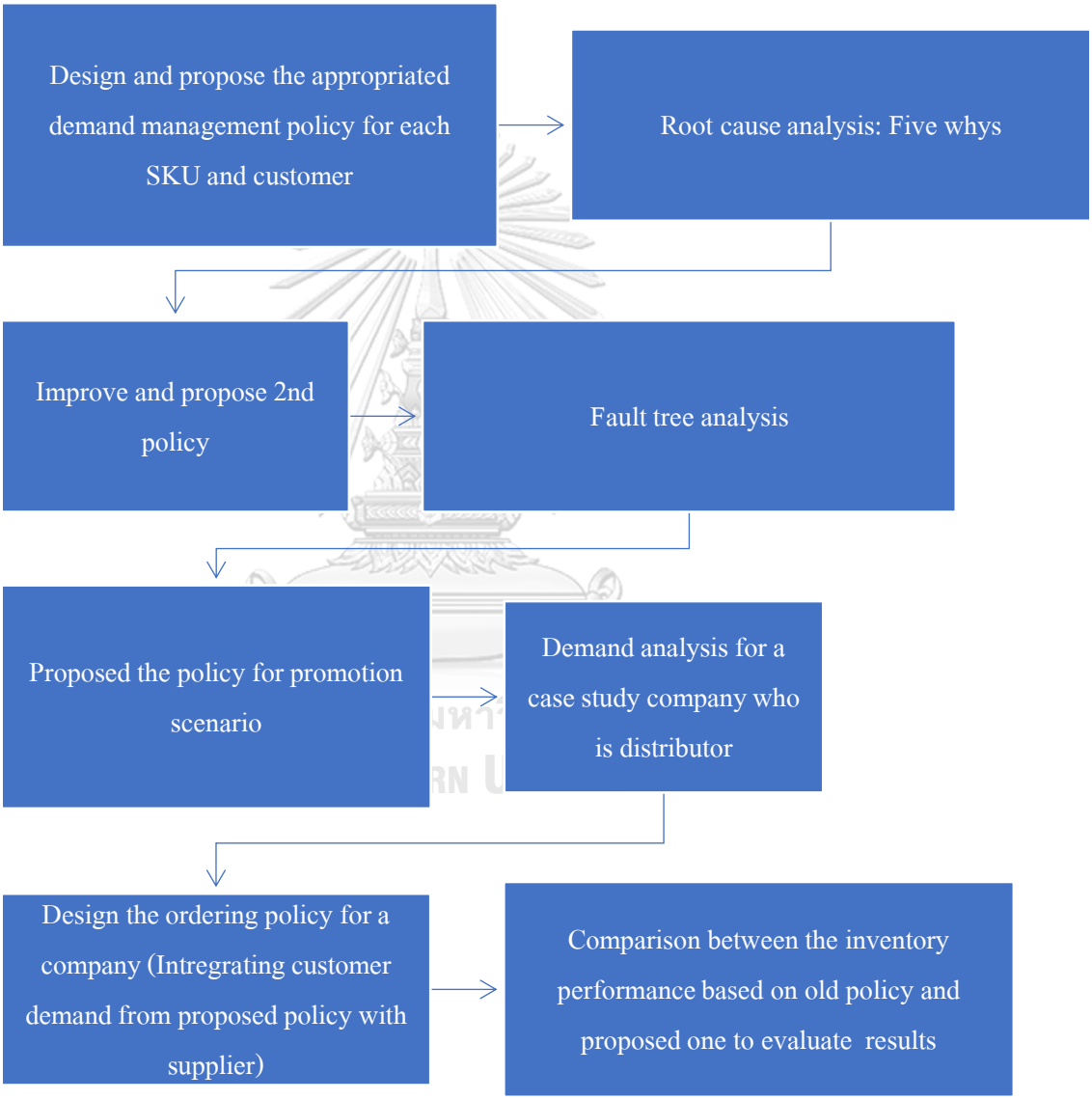


Figure 15: the flowchart of second part methodology

In this section, the policies are separated into two parts due to the below diagram. The first one is the inventory policy for a company's customers who are sub dealers and the second

one is the policy for a case study company who is a distributor. Each part consists of the policies for two scenarios which are the policy without promotion period and the policy with promotion period. The policy mainly depends on the demand patterns and forecast value from the first methodology.

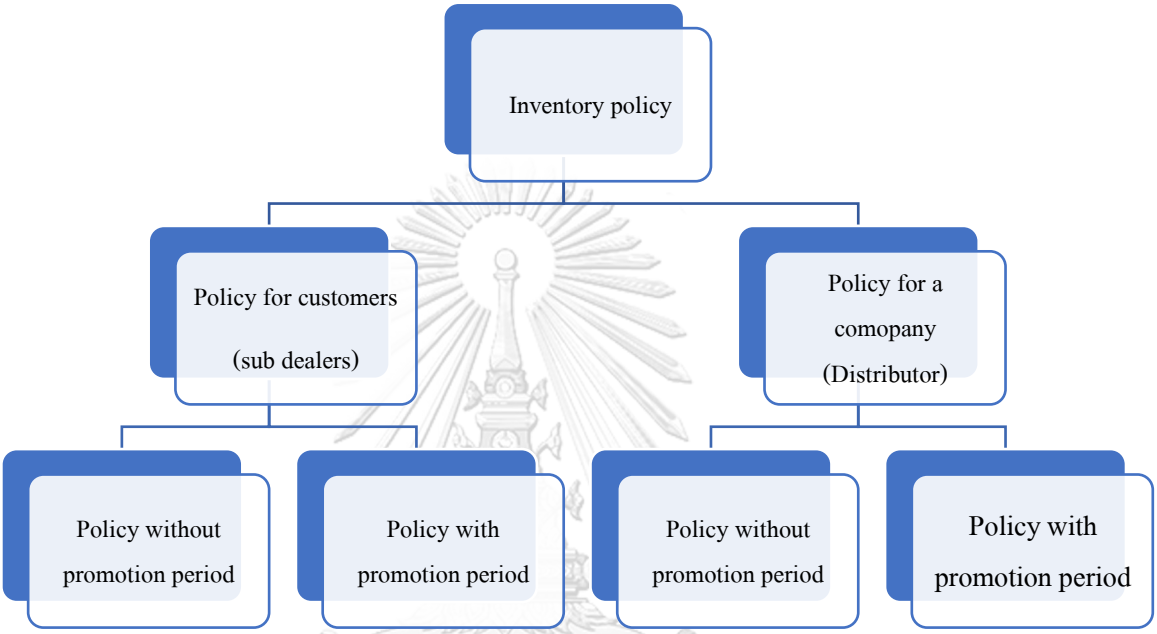


Figure 16: The diagram of overview policy

3.1 Study Company Case

A proper visit and main interview will be done with the case study firm in order to thoroughly understand the viewpoint and outlook of the research. Expected results and study purpose will be examined and taken into account in this stage, along with the company's background data, information, and insights from internal staff, as well as specific problems, concerns, and limitations of the research. After that, the problem statement for the study case and the research goals will be defined clearly.

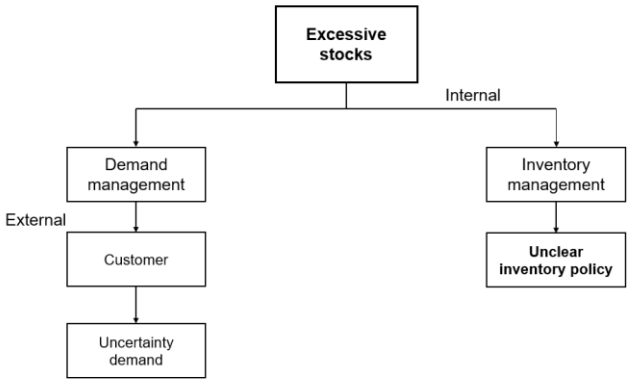


Figure 17: Categorization of primary problem

To define the current phase of existing problem in Chapter 1, an above diagram is a tool to identify and organize the possible cause of the excessive stock issue. The data used to create the diagram is based on the discussion with the company's manager and employers about the problem's real cause. The causes of overstock are mainly separated into two areas which are demand management and inventory management shown in above figure (Figure 15). For demand management, the customer's uncertainty demand is the main factor because of a lack of relationships, communication, and customer demand and behavior management policy. On the other hand, in terms of the internal factor, the existing inventory policy relies on the personal experience and intuitive judgments of the company owner, which is not based on a theoretical method. They may anticipate customer orders and add up the demand without forecast techniques and tools.

Therefore, this research will solve the problem based on these two factors by starting from observing the customer behavior of the key clients to manage and analyze their purchasing patterns, then customizing a suitable policy for each of them, which will benefit both sides.

3.2 Review the customers and customer clustering

Review and study of all the regular customers are also essential to segment the customers into three classes using the monthly sale volume as the main criteria. This step helps to

understand the perspectives of existing clients and makes it easy to select the best three sub-dealers who are considered to affect the great result.

Group of customers	Number	% Sale cumulative
Class A	43	0-80%
Class B	37	81%-95%
Class C	53	96%-100%

Table 4: The number of customers in each class based on Pareto's principle

Based on the Pareto principle, there are 133 customers in total, 43 customers who has the highest annual sale volume in the A class, 37 customers in Class B and 53 customers in Class C. The three sub-dealers who well cooperate to give information and can affect the great result will be selected from the first class who has the sale cumulative percentage up to 80%.

Table 5: Pareto principle for customer selection

No.	Name	Sale (THB)	Sale cumulative (THB)	% Sale cumulative	% No. of customer
1	Customer A	29,638,109.57	29,638,109.57	27.42%	0.67%
2	Customer B	5,181,367.66	34,819,477.23	32.21%	1.33%

Based on the calculation through the excel program, the total sale cumulative is 108,094,443.27 THB which is 100% of sale cumulative percentage. Therefore, the top three costumers which are Customer A, Customer B and Customer C are selected. The sale cumulative of these three customers is 36.69%.

3.3 Collecting data

The three targeted customer will be selected to observe the specific purchasing behavior of each customer and to predict the market trend by collecting historical sales from 2021 - 2022. Additionally, the researchers will conduct customer interviews with the managers of a customer company to acquire a complete understanding of the case firm's operations and to gather

insightful input from the customers. The interview will proceed through both an online meeting platform and face-to-face, depending on the situation and the interviewee's preference. It will take approximately 30 minutes. At least 24 hours before the scheduled interview appointment, each interviewee will get a notification of the research's scope and a consent form. The interview topic will be related to the current ordering strategy and policy of each sub-dealer which covers the period of order and delivery, the quantity of each product and the number of items in each SKU.

Table 6: The example table of data

Customer	Product (SKU)	Demand per month		Time interval	
		Average/order	Standard deviation	Average (Day)	Standard deviation
A	SKU 158	63	17.99	30	0.75
	SKU42	92	48.87	30	0.29
	SKU163	48	32.20	30	0.58
B	SKU158	10	4.67	17	7.20
	SKU42	18	9.97	15	0.29
	SKU163	12	12.05	15	0.39
C	SKU158	9	8.88	30	0.29
	SKU42	13	8.87	30	0.58
	SKU163	10	4.20	30	0.75

3.4 Demand Forecasting

This analysis part of this study is based on the gathered data and a theoretical framework. To find the best-fit solutions, the following identified approaches will be evaluated and given a weighting.

3.4.1 Demand forecasting method

In this research, there are six forecast techniques which are three months moving average, Single exponential smoothing, Double exponential, Holt winter’s method, Linear regression and ARIMA to be used to find the best fit model to conduct the demand forecast for

each SKU of each customer. Moreover, the demand and historical sale data are collected from 2021-2022.

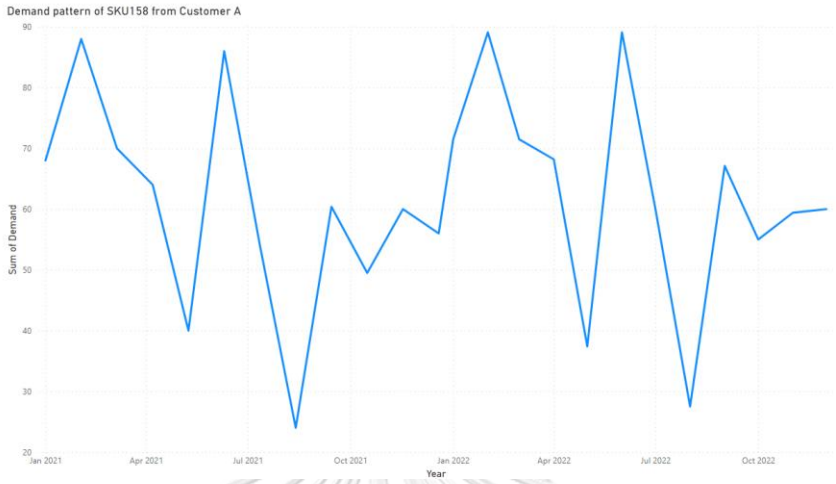


Figure 18: Demand pattern of Customer A's SKU158

SKU 158 from customer A is selected to be example to show the calculation for each forecasting model. Due to the characteristic of tire, the demand pattern is seasonal and unstable through each quarter of the year. Historical sale data for year 2022 are shown in the below table.

Table 7: Historical demand from year 2022 of Customer A's SKU158

Month (Year 2022)	Demand (units)
Jan-2022	72
Feb-2022	89
Mar-2022	72
Apr-2022	68
May-2022	37
Jun-2022	89
Jul-2022	60
Aug-2022	28
Sep-2022	67
Oct-2022	55
Nov-2022	59
Dec-2022	60

3.4.1.1 Moving Average

A company selected to use moving average technique to forecast demand by using period as three months. The calculation formula is

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

Where n = number of periods and Di =demand in period i

Moving Average with 3 months

Based on the historical data in the previous table, the demand forecasting value on April 2022 by using 3 months moving average can be calculated as:

$$\text{Forecast Demand (April 2022)} = \frac{\text{D(Jan 2022)+D(Feb 2022)+D(Mar 2022)}}{3} = \frac{72+89+72}{3} = 77$$

3.4.1.2 Single exponential smoothing

Single exponential smoothing is run by Minitab software to find the forecasting value. The α value is 0.00054 from software's trial-and-error to find the minimum error of forecasting.

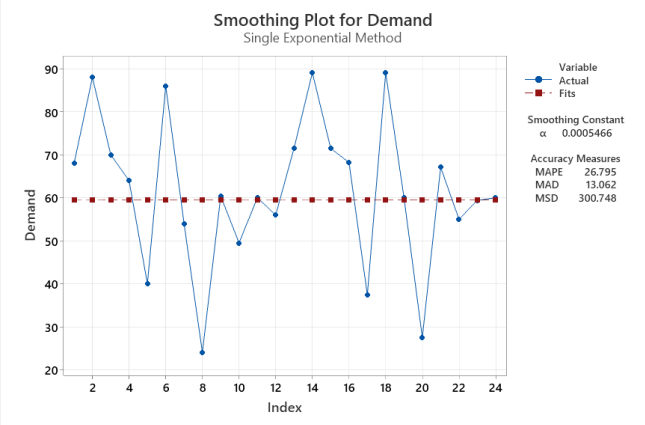


Figure 19: Demand forecasting of Customer A's SKU 158 by Single exponential smoothing

3.4.1.2 Double exponential smoothing

Double exponential smoothing is run by Minitab software to find the forecasting value. The α (level) value is 0.43 and trend value as 0.092 from software's trial-and-error to find the minimum error of forecasting.

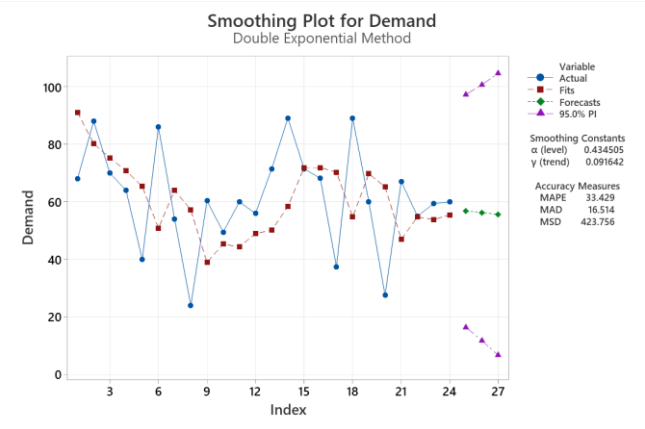


Figure 20:Demand forecasting of Customer A's SKU 158 by Double exponential smoothing

3.4.1.3 Holt winter's method

Holt winter's method is run by Minitab software to find the forecasting value. The α (level) value is 0.3, trend value is 0.2 and seasonal value is 0.2 from software's trial-and-error to find the minimum error of forecasting.

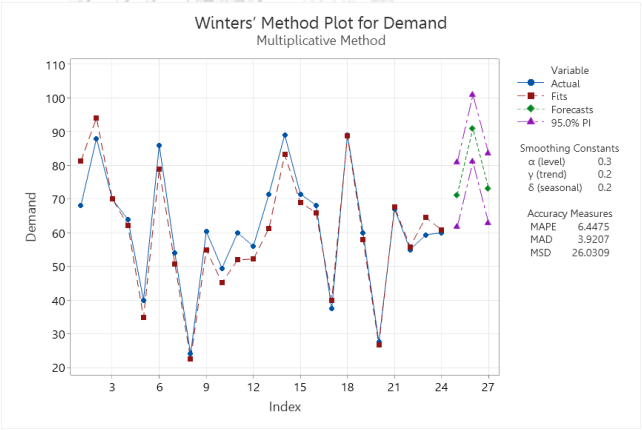


Figure 21: Demand forecasting of Customer A's SKU 158 by Holt winter's method

3.4.1.4 Linear regression analysis

Linear regression analysis is run by Minitab software to find the forecasting value. The appropriated equation is Yt = 65.66 - 0.334×t where Yt is demand forecasting value and t is month. This equation comes from the trend analysis of Minitab software.

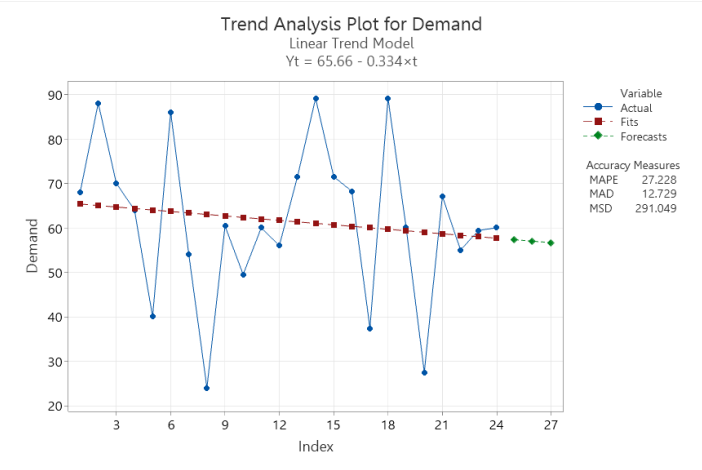


Figure 22: Demand forecasting of Customer A's SKU 158 by Linear regression analysis

3.4.1.5 ARIMA

ARIMA with seasonal is run through Minitab software to find the forecasting value by using ARIMA forecasting command. The seasonal period is 12 months. The program chooses the best-fit parameter from the minimum AICc value, a second-order estimate, which is (0,1,0) (1,0,0).

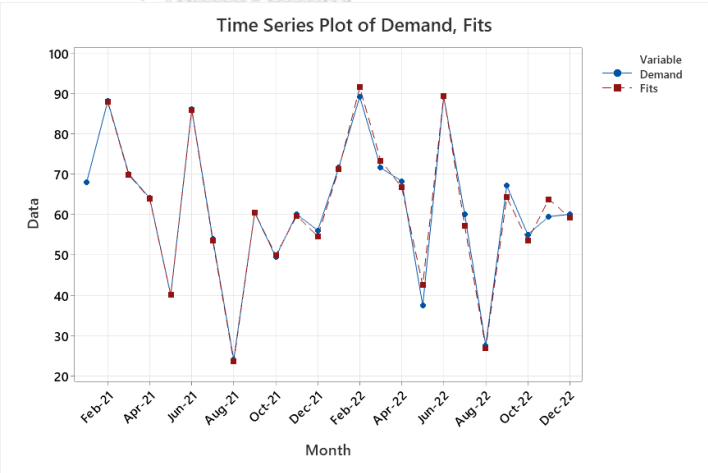


Figure 23: Demand forecasting of Customer A's SKU 158 by ARIMA

3.4.2 Forecast Accuracy

According to the fact that forecast never has 100% accuracy, the error of forecast is the difference between the actual demand and forecast demand. There are several calculation and indicators to examine the error of each forecasting model such as MAD, MSE and MAPE. In this

research, Mean Absolute Percentage Error is selected to use which is commonly and easy to interpret and explain. The formula of mean absolute percentage is

$$M = \frac{1}{n}\sum_{t=1}^{n}\left|\frac{A_t - F_t}{A_t}\right|$$

Where M = mean absolute percentage error

n = number of times the summation iteration happens

At = Actual value

Ft = Forecast value

3.4.3 Demand forecasting method selection

The best-fit forecasting model is selected by computing all above calculation methods with historical demand data of Customer A's SKU158 from 2021 to 2022 and using MAPE to be an error indicator. The monthly forecast value for year 2022 from six forecasting techniques is shown in the below table.

Table 8: Demand forecasting of Customer A's SKU158 with 6 methods and Forecasting Accuracy

Month	Demand	Moving Average 3 months	Simple Exponential Smoothing	Double Exponential Smoothing	Holt Winter's method	Linear Regression	ARIMA
Jan-2022	72	55.17	59.43	50.15	81.31	61.32	71.12
Feb-2022	89	63.50	59.43	58.29	94.77	60.99	91.40
Mar-2022	72	72.20	59.45	71.92	72.05	60.65	73.31
Apr-2022	68	77.37	59.45	71.91	65.99	60.32	66.66
May-2022	37	76.27	59.45	70.32	35.20	59.98	42.45
Jun-2022	89	59.03	59.46	54.73	82.49	59.65	89.29
July-2022	60	64.90	59.45	69.74	55.15	59.32	57.11
Aug-2022	28	62.17	59.46	65.21	25.28	58.98	26.95
Sep-2022	67	58.87	59.45	47.01	62.00	58.65	64.18
Oct-2022	55	51.53	59.45	54.73	51.25	58.31	53.54
Nov-2022	59	49.87	59.45	53.85	55.92	57.98	63.71

Dec-2022	60	60.50	59.45	55.49	57.10	57.65	59.26
MAPE (%)		35.64	26.28	33.43	6.45	27.23	**3.53**

According to the above table, the lowest mean absolute percentage error value is 3.53; therefore, the suitable forecasting model for this SKU of Customer A is ARIMA model whose parameters are (0,1,0) (1,0,0). However, the summarize of experimental for other SKUs and other customers is shown in below table.

Table 9: Demand forecasting of every SKU from three selected customers with 6 methods and Forecasting Accuracy

Name of Customer	**Product ID**	**Moving Average 3 months**	**Single Exponential**	**Double Exponential**	**Winter Method**	**Linear regression**	**ARIMA**	**Conclusion of forecasting model**
		MAPE	**MAPE**	**MAPE**	**MAPE**	**MAPE**	**MAPE**	
A	**SKU158**	35.64	26.795	33.429	6.4475	27.228	**3.531**	**ARIMA**
	SKU42	9.125	11.261	12.222	11.058	11.991	**4.0123**	**ARIMA**
	SKU163	67.365	20.975	141.3	**17.475**	60.757	30.913	**Winter**
B	**SKU158**	51.876	47.32	46.31	**26.182**	45.9756	34.879	**Winter**
	SKU42	63.6571	54.4034	33.0072	19.9673	71.5669	**18.808**	**ARIMA**
	SKU163	107.613	82.7778	90.3872	25.9261	122.549	**11.832**	**ARIMA**
C	**SKU158**	125.309	148.27	94.192	**31.108**	86.5013	47.589	**Winter**
	SKU42	94.3827	53.1386	63.3163	**16.9788**	80.8353	35.23	**Winter**
	SKU163	42.2222	24.7724	27.5883	**25.15**	52.5094	28.6072	**Winter**

According to the result from forecasting experimental of 12 models, it can be summarized that the same products from different customer cannot be conducted by the same forecasting methods. It depends on characteristic of demand. However, different forecasting methods should be selected to conduct for each model required the consideration of the lowest value of MAPE.

After the best fit forecasting model is selected for each SKU from each customer by using historical data from 2021 to 2022. The summary of forecast value compared to the actual data is shown below.

Table 10:Actual Demand and forecast demand of Customer A

Customer A					
SKU158		**SKU42**		**SKU163**	
Actual	**Forecast**	**Actual**	**Forecast**	**Actual**	**Forecast**
72	71	98	96	76	58
89	91	140	136	112	104
72	73	100	103	100	103
68	67	106	101	64	68
37	42	90	92	32	37
89	89	88	87	24	22
60	57	78	79	20	18
28	27	82	86	24	22
67	64	84	73	36	36
55	54	78	83	32	38
59	64	78	81	24	21
60	59	80	81	28	27

Table 11: Actual Demand and forecast demand of Customer B

Customer B					
SKU158		**SKU42**		**SKU163**	
Actual	**Forecast**	**Actual**	**Forecast**	**Actual**	**Forecast**
20	16	25	21	20	20
16	14	36	30	42	42
12	13	20	24	20	20
8	9	32	28	18	19
12	13	16	17	16	17
4	6	24	23	4	5
8	4	12	14	4	4
8	10	14	16	4	3

8	9	8	11	4	5
12	15	8	6	2	3
8	5	4	7	4	3
4	5	12	12	2	2

Table 12: Actual Demand and forecast demand of Customer C

Customer C					
SKU158		**SKU42**		**SKU163**	
Actual	**Forecast**	**Actual**	**Forecast**	**Actual**	**Forecast**
16	28	32	40	12	9
4	5	20	20	16	17
28	27	16	13	16	15
24	17	24	19	16	16
4	2	8	6	12	10
4	2	4	3	10	11
12	6	4	3	8	9
2	1	4	3	8	6
4	3	8	7	8	8
4	3	10	9	4	6
4	4	12	11	4	7
4	4	8	7	8	5

3.5 Demand Pattern Analysis

In this step the demand pattern analysis will proceed by analyzing variation of demand. This pattern analysis is necessary for the selection of inventory control and ordering policy. The indicator which is used to consider is Coefficient of variation. The formula is shown below.

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

Where CV = Coefficient of variation

SD = Demand's standard deviation

Mean = Mean of demand

In this research, the model with CV is between 0 and 0.5 considered as low variation pattern. While the model with CV from 0.5 to 0.9 is considered as medium variation pattern. Finally, the model with CV more than 0.9 is considered as high variation pattern (Agunbiade and Ogunyinka, 2013) .

Table 13: Coefficient of variation of every SKU's demand from three selected customers

Customer/ Sun-dealer	Product ID	Type of Demand	Standard Deviation	Mean	Coefficient of Variation (CV)	Level
A	**SKU158**	Actual	18.16	59	0.304	Low
		Forecast	16.52	60	0.278	Low
	SKU42	Actual	17.88	92	0.195	Low
		Forecast	16.82	94	0.184	Low
	SKU163	Actual	32.20	48	0.676	Medium
		Forecast	30.77	48	0.663	Medium
B	**SKU158**	Actual	4.67	10	0.467	Low
		Forecast	4.10	10	0.418	Medium
	SKU42	Actual	9.97	18	0.567	Medium
		Forecast	8.02	17	0.460	Medium
	SKU163	Actual	12.06	12	1.033	High
		Forecast	11.97	10	1.007	High
C	**SKU158**	Actual	8.881	9	0.9689	High
		Forecast	9.645	9	1.13	High
	SKU42	Actual	8.868	12	0.709	Medium
		Forecast	10.554	12	0.895	Medium
	SKU163	Actual	4.303	10	0.423	Low
		Forecast	4.074	10	0.413	Low

According to the above table, the demand patterns can be divided into three main patterns based on the demand variation. Therefore, the inventory control policy will be customized and selected for each demand pattern which are low, medium and high variation.

3.6 Inventory control policy

Based on the limitation of warehouse and lack of suitable product ordering criteria, high inventory cost is one of the main issues and challenges which sub-dealers are facing in order to meet the customers' demand. It is necessary to improve order and stock keeping policy to control the quantity of products for both of ordering from a company and keeping in sub-dealers' warehouse with new standard.

3.6.1 Inventory holding cost

The calculation of Inventory holding cost of sub-dealers and a company will be described below based on the interview.

Table 14: The calculation of inventory holding cost

Holding cost (HC)	Price of the product cost per unit
Annual unit cost of storage	3.50%
Insurance expense	2.00%
Cost of money - interest	2.50%
Inventory gap / theft cost	1.50%
Total Holding cost	**9.50%**

Therefore, the Inventory holding cost of SKU158 for Customer A equals to

The cost of SKU 158 1532.2

THB/unit

Annual unit cost of storage THB/unit	53.627
Insurance expense THB/unit	30.644
Cost of money – interest THB/unit	38.305
Inventory gap THB/unit	22.983
Total Inventory holding cost THB/unit	**145.559**

3.6.2. Ordering cost

Both a company and sun-dealers have the transportation cost at different rate depending on the distance and lot size. A company has to pay 2,000 THB for one order. The supplier pays another additional freight cost. On the other hand, the ordering cost of customer A is 1200 THB per order while 800 THB for customer B and 600 THB for customer C.

Chapter 4. Customers' policy for low demand variation products

According to Table 16, the low variation of demand pattern considered from CV are SKU158 from customer A, SKU42 from customer A and SKU163 from customer C. In this part, SKU158 will be sample to show the calculation method.

4.1 Inventory Control Policy

4.1.2 Economic order quantity

The appropriate optimal number of order quantities must be used to develop the ordering system for taking spare part quantity orders into consideration. For the low demand variation, the economic order quantity is suitable due to the balance between carrying cost and ordering cost in the computation. In inventory management, this calculation determines the order quantity that minimizes overall holding costs and ordering expenses based on the computing method in the chapter 3 and the product scheduling model.

4.1.2.1. Order quantity

The Optimal order quantity can be calculated by using the formula based on the literature review. The optimal order quantity of Customer A's SKU158 can be computed as:

$$Q_{opt} = \sqrt{\frac{2 \times 1200 \times 756}{145.59}} = 112\ units$$

For other SKUs with low variation of demand, the result will be shown table below.

Table 15: Optimal order quantity of products with low demand variation

Product ID	*Optimal Order Quantity (Actual Demand)*	*Optimal Order Quantity (Forecast Demand)*
SKU158 from Customer A	*112 units*	*111 units*

SKU42 from Customer A	*135 units*	*135 units*
SKU163 from Customer C	*32 units*	*31 units*

4.1.2.2 Order Frequency

The cycle of order can be calculated as:

$$Order\ Frequency = \frac{Average\ annual\ demand}{EOQ}$$

Therefore, the order frequency of Customer A's SKU158 is

$$Order\ Frequency = \frac{756}{112} = 6.7\ times\ per\ year$$

The order frequency is 6.7 times peer year or every 54 days

Product ID	***Cycle of order***
SKU158 from Company A	*54 days*
SKU 42 from Company A	*45 days*
SKU163 from Company C	*95 days*

4.2 The First Policy for Low Variation of Demand Products

4.2.1 1st policy experiment for low demand variation products

The first ordering policy for this type of demand pattern is ordering equal to the EOQ quantity per order and the time interval between order is following each product's cycle of order. For example, the EOQ of Company A's SKU158 is 112 and time interval is 54 days.

Table 16:The first policy experiment for Company A's SKU158

Month	***Actual inventory***	***1st policy inventory***	***Placed order***	***Order quantity***	***Demand***

Jan-22	*257*	*257*	*112*	*0*	*72*
Feb-22	*233*	*280*	*0*	*112*	*89*
Mar-22	*242*	*208*	*112*	*0*	*72*
Apr-22	*239*	*252*	*0*	*112*	*68*
May-22	*264*	*215*	*112*	*0*	*37*
Jun-22	*209*	*238*	*0*	*112*	*89*
Jul-22	*230*	*178*	*112*	*0*	*60*
Aug-22	*300*	*262*	*0*	*112*	*28*
Sep-22	*258*	*195*	*112*	*0*	*67*
Oct-22	*264*	*252*	*0*	*112*	*55*
Nov-22	*255*	*193*	*112*	*0*	*59*
Dec-22	*249*	*245*	*0*	*112*	*60*
total	*3000*	*2775*		*672*	*756*

4.2.2 Result of the First Policy

The key performance indicators for this experiment are Inventory turnover, Inventory holding day and the average inventory cost. All of these KPIs equations are based on the literature review in the chapter 2.

The graph below shows the comparison of inventory level in Year 2022 between Inventory from actual policy and the proposed on.

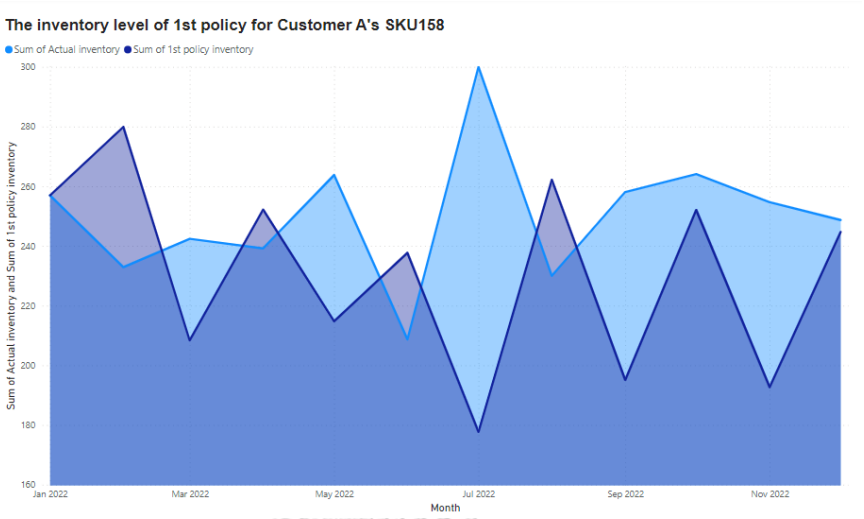


Figure 24: The comparison graph of Inventory between actual and 1st policy

Table 17: The result of 1st policy experiment for Customer A's SKU158

Key Performance Indicator	Actual Inventory	1st policy inventory
Inventory Turnover	**2.99**	**3.01**
Inventory Turning day	**122 days**	**121 days**
Average inventory cost	387,416 THB	384,352 THB
Average inventory holding cost	36,383 THB	25,503 THB
Logistic cost	13,200 THB	6,000 THB
Total cost	**437,000 THB**	**415,856 THB**

According to the result, the inventory turnover increases by 1%, and the Inventory holding day reduces by 1 day, while the total cost decreases by 5%. Even though the result of each key performance indicator is all better than an actual policy, the inventory turnover and inventory holding hardly changed.

4.3 Root Cause Analysis: Five Whys Method for Improvement

To investigate the cause of the almost none change of inventory turnover, the Five whys analysis will be performed. The initial problem is "The inventory turnover and holding day slightly change"

1st Why: The average annual inventory is still high and equal to the old policy which are 384,352 THB and 387,416 THB. The difference between them is only 3,064 THB.

2nd Why: The quantity of each month's inventory is still much more over the demand by 4 times in average.

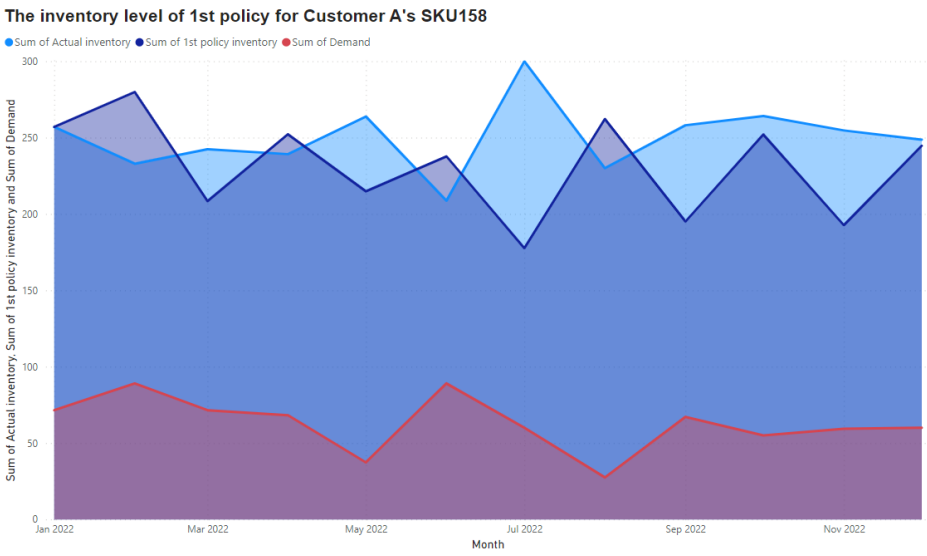


Figure 25: The comparison graph between the demand and 1st policy inventory level of Customer A's SKU158

3rd Why: The ordering period does not relate to the number of products in the stock at that time. The excessive stock at the beginning of the year had not been reduced yet when ordering the new order.

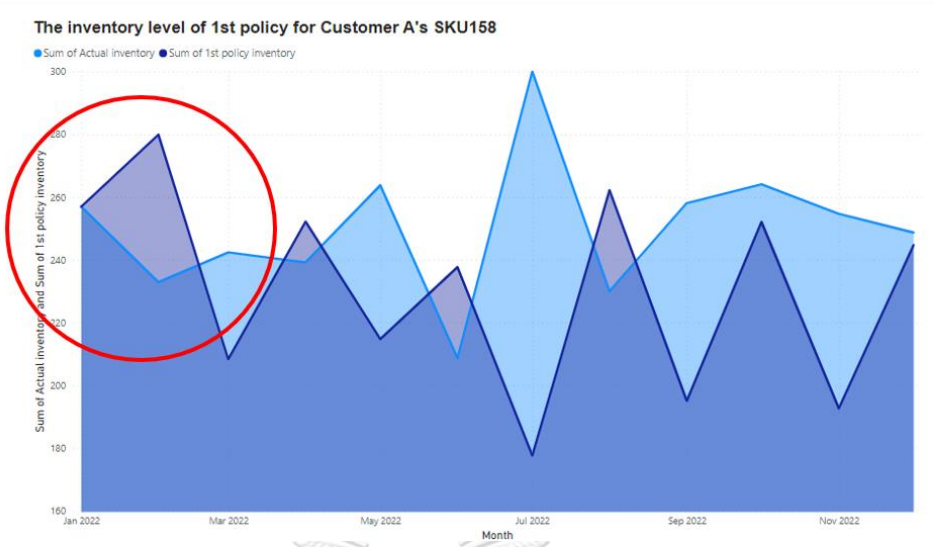


Figure 26: The comparison graph of excessive stock at the beginning of the year

4th Why: The cycle of order policy in the exact period is not suited for the inventory

5th Why: The reorder point and demand forecast value must be considered to know the appropriated point of order cycle.

According to this Five whys analysis, the cause of this inventory turnover issue can be concluded that it came from the unappropriated cycle of order and the mis considered of reorder point and demand forecasted value from the best-fit forecasting model from the previous chapter.

4.4. Improve Phase: Second Policy

4.4.1 Reorder point and Safety stock

To observe the suitable point of ordering, the reorder point and safety stock should be calculated based on the formula in the literature review. The reorder point and safety stock of Customer A's SKU158 will be calculated based on the data in the table below.

Table 18: Demand data of Customer A's SKU158

Month	**Demand (unit)**	**Lead time (Day)**
Jan-22	72	30
Feb-22	89	23
Mar-22	72	20
Apr-22	68	15
May-22	37	16
Jun-22	89	20
Jul-22	60	20
Aug-22	28	17
Sep-22	67	23
Oct-22	55	10
Nov-22	59	20
Dec-22	60	20
Total	756	
Average in Month	63	0.65
Average in Day	2.10	19.5
Standard deviation	17.99	

The safe stock (ss) will be considered at 90% targeted service rate whose coefficient service (Z) is 1.28, so the safety stock of this SKU will be

$$ss = 1.28 \times 17.99 \times \sqrt{0.65} = 18.5$$

Therefore, the reorder point (RO) will be

$$RO = 18.5 + 2.10 \times 19.5 = 59.5$$

The reorder point and safety stock of other SKU with low demand variation are shown in the table below.

Table 19: Reorder point and safety stock of SKU with low variation of demand

Product ID	Reorder point (unit)	Safety stock (unit)
SKU158 from Customer A	19	60
SKU42 from Customer A	23	115
SKU163 from Customer C	4	10

4.4.2 2nd policy experiment for low variation of demand product

The second policy is "ordering equal to the EOQ quantity when the stock nearly reach the reorder point or does not enough for the next demand forecast value plus with safety stock". For example, Customer A should order SKU158 in 112 units when the inventory nearly reach 60 units or less than next month forecasting value plus 19 unit.

Table 20: The second policy experiment for Company A's SKU158

Month	2nd policy inventory (unit)	Placed order (unit)	Order quantity (unit)	Demand (unit)	Demand forecast (unit)
Jan-22	257	0	0	72	71
Feb-22	168	0	0	89	91
Mar-22	96	0	0	72	73

Apr-22	**28**	112	0	68	67
May-22	103	0	112	37	42
Jun-22	**14**	112	0	89	89
Jul-22	66	0	112	60	57
Aug-22	**38**	112	0	28	27
Sep-22	83	0	112	67	64
Oct-22	**28**	112	0	55	54
Nov-22	81	0	112	59	64
Dec-22	21	0	0	60	59
total	982		448		

4.4.3 The Result of Second Policy

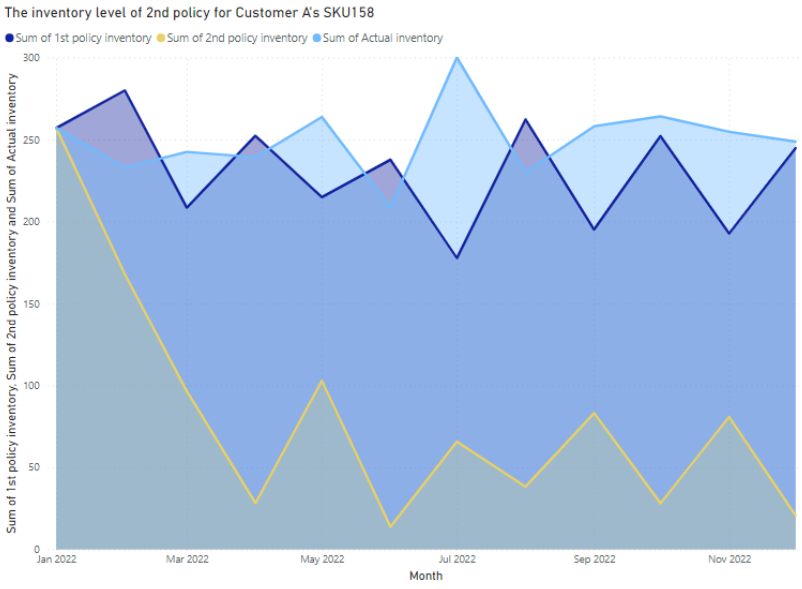


Figure 27: The comparison graph of inventory level of Customer A's SKU158 between three policies

Table 21: The result of 2nd policy experiment for Customer A's SKU158

KPI	Actual inventory	1st policy inventory	2nd policy inventory

Turnover	2.99	3.01	5.44
Turning day	122.11	121.14	67.06
Inventory cost in average	387,416.77	384,352.37	212,745.97
Inventory holding cost in average	36,383.69	25,503.15	11,917.64
Logistic cost	13,200.00	6,000.00	4,800.00
total cost	437,000.46	415,855.52	229,463.61

According to the experimental result, the inventory turnover from the 2nd proposed policy increased by 82% from the actual policy while the inventory holding day decreased by 55 days. The annual inventory cost in average also decreased by 47%. However, this 2nd proposed policy is suited for non-promotion scenario. Due to the tire market and the supplier who's manufacturer, there's the promotion period for overachieved sales target; therefore, this 2nd policy will not suited for the scenario with promotion.

4.5 Fault Tree Analysis for Scenario With Promotion

To investigate the possible factors and find the suitable policy for each product in the scenario with promotion, Fault tree analysis will perform.

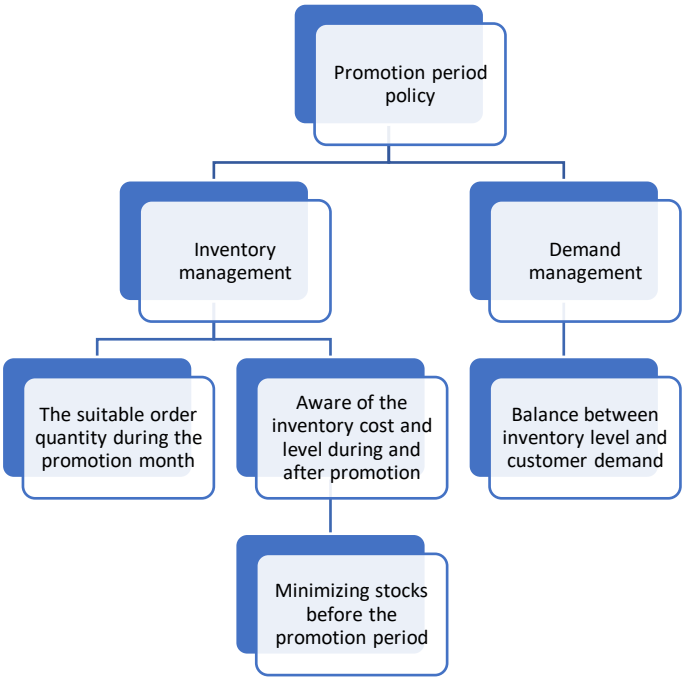


Figure 28: Fault tree analysis for promotion period policy

Based on the diagram, the policy with promotion scenario must consider in three main factors. The first one is the quantity of order during the promotion with discounted price. The second one is the inventory cost level which may be higher than necessary. Finally, the balance between the inventory level and customer demand is also important and avoid of excessive stock or if a company needs to minimize the stock before the promotion period, a company requires to ensure that the stock is enough for demands.

4.6 Third Policy for Promotion Scenario

4.6.1 The experiment of 3rd policy for Customer A's SKU158

The ordering policy for the promotion scenario is "Before the promotion period, Company should minimize the stock level as much as possible together with balancing with customer demands by comparing the ending stock in each month with following month's forecast value plus safety stock. During the promotion month, a company should order two times of EOQ quantity. After the promotion, a company should reorder in EOQ quantity when the stock turns to

reorder point". The experiment of 3rd policy for Customer A's SKU158 will perform below with the promotion period in June.

Table 22: The third policy with promotion experiment for Company A's SKU158

Month	3rd policy inventory with promotion	Placed order	Order quantity	Demand	Forecast Demand
Jan-22	257	0	0	72	71
Feb-22	168	0	0	89	91
Mar-22	96	0	0	72	73
Apr-22	28	112	0	68	67
May-22	103	0	112	37	42
Jun-22	**14**	**224**	**0**	**89**	**89**
Jul-22	**178**	0	**224**	60	57
Aug-22	150	0	0	28	27
Sep-22	83	0	0	67	64
Oct-22	28	112	0	55	54
Nov-22	81	0	112	59	64
Dec-22	21	112	0	60	59

4.6.2 The result of third policy

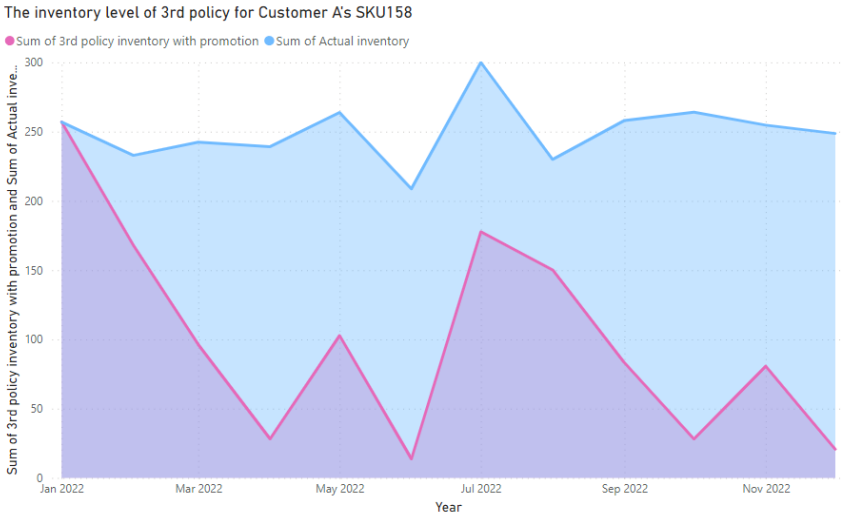


Figure 28: The comparison of inventory level between actual and 3rd policy for Customer A's SKU158

The comparison of actual inventory level between actual policy and 3rd policy with the same promotion period ordering in June.

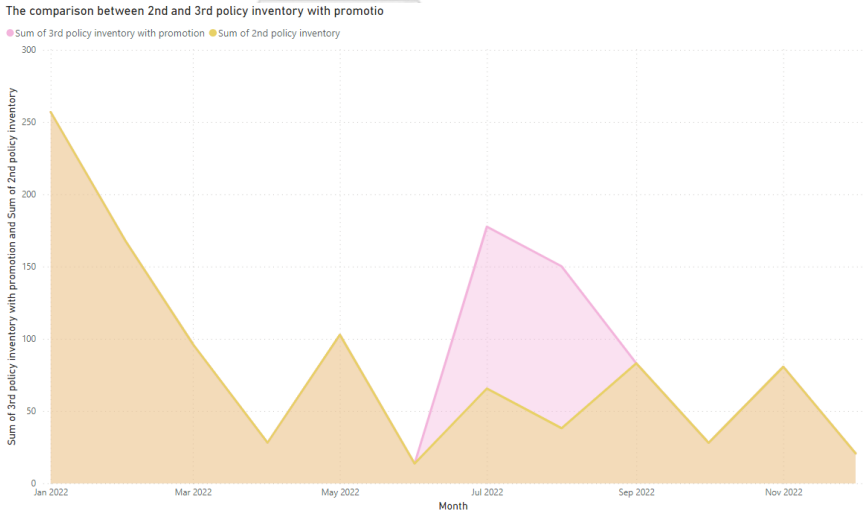


Figure 29: The comparison of inventory level between 2nd and 3rd policy for Customer A's SKU158

The comparison of inventory level between 2nd proposed policy without promotion scenario and 3rd policy with the promotion period ordering in June.

Table 23: The KPI result of all policy for Customer A's SKU158

KPI	Actual inventory	1st policy inventory	2nd policy inventory without promotion	3rd policy with promotion
Turnover	**2.99**	**3.01**	**5.44**	**5.60**
Turning day (day)	**122.11**	**121.14**	**67.06**	**65.18**
Inventory cost in average (THB)	387,416.77	384,352.37	212,745.97	206,799.12
Inventory holding cost in average (THB)	36,383.69	25,503.15	11,917.64	14,634.74
Logistic cost (THB)	13,200.00	6,000.00	4,800.00	3,600.00
total cost (THB)	**437,000.46**	**415,855.52**	**229,463.61**	**225,033.86**

The inventory turnover from the 3rd policy increased from the old one by 87% and 5% with final policy without promotion period. The turning day reduced to 2 days from 2nd policy and 57 days from actual policy. The result for another two SKUs which are low demand variation will show in the section.

4.7 Results and Discussion

The comparation result from three proposed policy of SKU42 from Customer A is shown in the table below. All KPI are improved from the old policy. The inventory turnover increased to 5.77 for without promotion final policy and 5.96 for with promotion policy.

Table 24: The KPI result of all policy for Customer A's SKU42

SKU 42 from Customer A				
KPI	**Actual inventory**	**1st policy inventory**	**2nd policy inventory without promotion**	**3rd policy with promotion**
Turnover	5.32	5.77	5.77	5.96
Turning day	68.56	63.26	63.26	61.24
Inventory cost in average	317,165.40	292,650.20	292,650.20	283,315.13
Inventory holding cost in average	25,715.42	15,307.95	15,307.95	16,945.49
Logistic cost	14,400.00	6,000.00	6,000.00	6,000.00
total cost	357,280.82	313,958.15	313,958.15	306,260.62

The comparation result from three proposed policy of SKU163 from Customer C is shown in the table below. All KPI are improved from the old policy.

Table 25: The KPI result of all policy for Customer C's SKU163

SKU 163 from Customer C				
KPI	**Actual inventory**	**1st policy inventory**	**2nd policy inventory without promotion**	**3rd policy with promotion**
Turnover	1.79	2.07	2.07	2.17
Turning day (day)	203.44	176.52	176.52	168.44
Inventory cost in average (THB)	104,189.60	90,399.80	90,399.80	86,262.86
Inventory holding	8,248.34	6,962.57	5,021.79	6,962.57

cost in average (THB)				
Logistic cost (THB)	4200	1800	1200	600
total cost (THB)	116,637.94	99,162.37	96,621.59	93,825.43

The comparison result of Customer C's SKU 163. Although the inventory turnover and holding of 1st and 2nd policy are not different, the total cost is cheaper approximately 3,000 THB. On the other hand, the inventory turnover from these proposed policy without promotion increased from the original one by 15% and the third policy with promotion increased by 20% from the old policy.

According to these three SKUs from two different customers, there are two appropriated policies for this low demand variation products. The first policy without promotion is ordering equal to EOQ quantity when the stock level reaches reorder point or does not cover the following month's forecast value plus safety stock. The other policy is the policy with promotion which is divided into three parts. Before the promotion period, sub-dealer should order at EOQ quantity when the stock is not enough for the next month's forecast value to minimize the stock as much as possible. During the promotion period, sub-dealer should order 2 times of EOQ quantity and turns to order with 2nd policy after the promotion period ends.

Chapter 5. Customers' policy for medium demand variation products

According to Table 16, the medium variation of demand pattern considered from CV which are in the range of 0.5 – 0.9 are SKU163 from customer A, SKU158 and SKU42 from customer B and SKU142 from customer C. In this part, SKU42 from Customer C will be sample to show all of calculation methods.

5.1 Inventory Control Policy

Due to the characteristic of medium demand pattern, economic order quantity (EOQ) will be used to find the appropriated number of order and reorder point will be used to considered for the cycle of order together with forecast value and safety stock.

5.1.1 Economic order quantity

The appropriate optimal number of order quantities must be used to develop the ordering system for taking spare part quantity orders into consideration. The calculation is based on the formula in the literature review. Therefore, the economic order quantity of Customer C's SKU42 is

Table 26: Data of Customer C's SKU42 for EOQ calculation

Customer C's SKU42	
Annual Demand (Actual)	150 Units
Annual Demand (Forecast)	141 Units
Ordering cost per order	600 THB
Holding cost	145.56 THB

For actual demand $Q_{opt} = \sqrt{\frac{2\times600\times150}{145.59}} = 35\ units$

For forecast demand $Q_{opt} = \sqrt{\frac{2\times600\times141}{145.59}} = 34 units$

For other SKUs with medium demand variation, the optimal order of each will be shown table below.

Table 27: Optimal order quantity of medium demand variation products

Product ID	Optimal Order Quantity (Actual Demand)	Optimal Order Quantity (Forecast Demand)
SKU163 from Customer A	97 units	96 units
SKU158 from Customer B	36 units	36 units
SKU42 from Customer B	48 units	48 units
SKU42 from Customer C	35 units	34 units

5.1.2 Reorder point and safety stock

To observe the ordering point, the reorder point and safety stock should be calculated based on the formula in the literature review. The reorder point and safety stock of Customer C's SKU42 will be calculated based on the data in the table below.

Table 28: Demand data of Customer C's SKU42 for safety stock and Reorder point

Month	Demand order (units)	Lead time (days)
Jan-22	32	30
Feb-22	20	0
Mar-22	16	30
Apr-22	24	0
May-22	8	30
Jun-22	4	0
Jul-22	4	30
Aug-22	4	0
Sep-22	8	29
Oct-22	10	0
Nov-22	12	30

Dec-22	8	0
Total	142	
Average in Month	13	0.49
Average in Day	0.42	14.9
Standard deviation	8.86	

The safe stock (ss) will be considered at 90% targeted service rate whose coefficient service (Z) is 1.28, so the safety stock of this SKU will be

$$ss = 1.28 \times 8.86 \times \sqrt{0.49} = 8$$

Therefore, the reorder point (RO) will be

$$RO = 8 + 0.42 \times 14.9 = 14$$

The reorder point and safety stock of other SKUs with medium demand variation are shown in the table below.

Table 29: Reorder point and safety stock of SKU with medium variation of demand

Product ID	Reorder point (unit)	Safety stock (unit)
SKU163 from Customer A	88	40
SKU158 from Customer B	10	4
SKU42 from Customer B	18	9
SKU42 from Customer C	14	8

5.2 The First Policy for Medium Variation of Demand Products

5.2.1 1st policy experiment for medium demand variation products

The first ordering policy for this type of demand pattern is ordering equal to the EOQ quantity per order when the stock nearly reaches to reorder point or does not cover the forecast value plus safety stock. For example, the EOQ of Company C's SKU42 is 35 units while reorder point is 14 units and safety stock is 8 units.

Table 30: The experiment of 1st policy for medium variation of demand (SKU42 from Customer C)

Month	1st policy inventory	Placed order	Order quantity	Demand	Forecast Demand
Jan-22	86	0	0	32	27
Feb-22	66	0	0	20	20
Mar-22	50	0	0	16	17
Apr-22	26	0	0	24	23
May-22	18	35	0	8	9
Jun-22	49	0	35	4	4
Jul-22	45	0	0	4	4
Aug-22	41	0	0	4	4
Sep-22	33	0	0	8	6
Oct-22	23	35	0	10	12
Nov-22	46	0	35	12	14
Dec-22	38	0	0	8	8

5.2.2 Result of First Policy

The key performance indicators for this experiment are Inventory turnover, Inventory holding day and the average inventory cost. All of these KPIs equations are based on the literature review in the chapter 2.

The graph below shows the comparison of inventory level in Year 2022 between Inventory from actual policy and the proposed on.

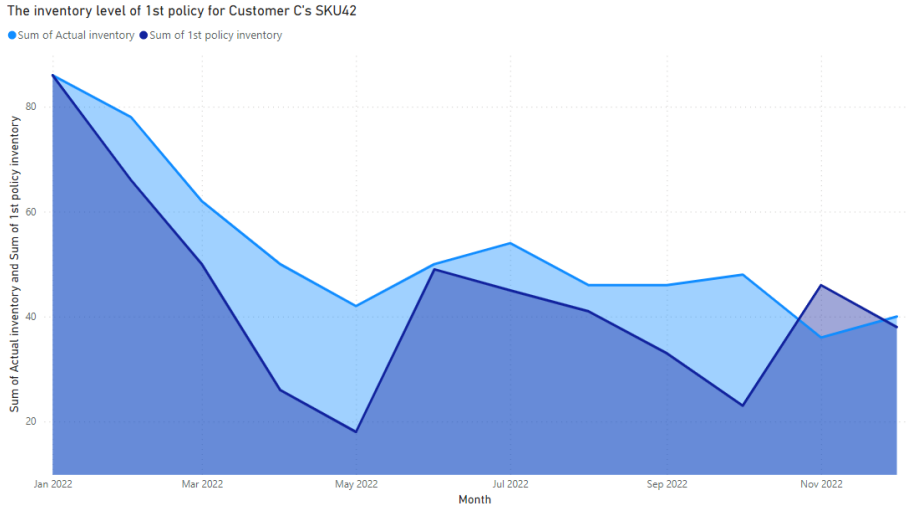


Figure 30: The comparison graph of Inventory between actual and 1st policy for medium variation demand

Table 31: The result of 1st policy experiment for Customer C's SKU42

KPI	Actual inventory	1st policy inventory
Turnover	2.38	2.42
Turning day (day)	153	151
Average inventory cost (THB)	96,528	94,996
Inventory holding cost avg (THB)	7,739	6,320
Logistic cost (THB)	3,600	1,200
Total cost (THB)	107,867.48	102,516.08

According to the result, the inventory turnover increases by 1.6%, and the Inventory holding day reduces by 2 days, while the total cost decreases by 5%. Even though the result of each key performance indicator is all better than an actual policy, the inventory turnover and inventory holding hardly changed.

5.3 Root Cause Analysis: Five Whys Method for Improvement

To investigate the cause of the almost none change of inventory turnover, the Five whys analysis will be performed. The initial problem is "The inventory turnover and holding day slightly change"

1st Why: The average annual inventory is still high. The difference between them is only 1,532 THB.

2nd Why: The quantity of monthly inventory in some quarter is still much more over the demand more than 10 times.

Table 32: The times between actual demand and 1st policy stock for Customer C's SKU42

Month	1st policy inventory	Placed order	Order quantity	Demand	Forecast Demand	Ratio between demand and inventory
Jan-22	86	0	0	32	27	2.7
Feb-22	66	0	0	20	20	3.3
Mar-22	50	0	0	16	17	3.1
Apr-22	26	0	0	24	23	1.1
May-22	18	35	0	8	9	2.3
Jun-22	49	0	35	4	4	**12.3**
Jul-22	45	0	0	4	4	**11.3**
Aug-22	41	0	0	4	4	**10.3**
Sep-22	33	0	0	8	6	4.1
Oct-22	23	35	0	10	12	2.3
Nov-22	46	0	35	12	14	3.8
Dec-22	38	0	0	8	8	4.8

3rd Why: The demand in each quarter is fluctuation; therefore, the excessive stock still occurs when the demand is lower than usual.

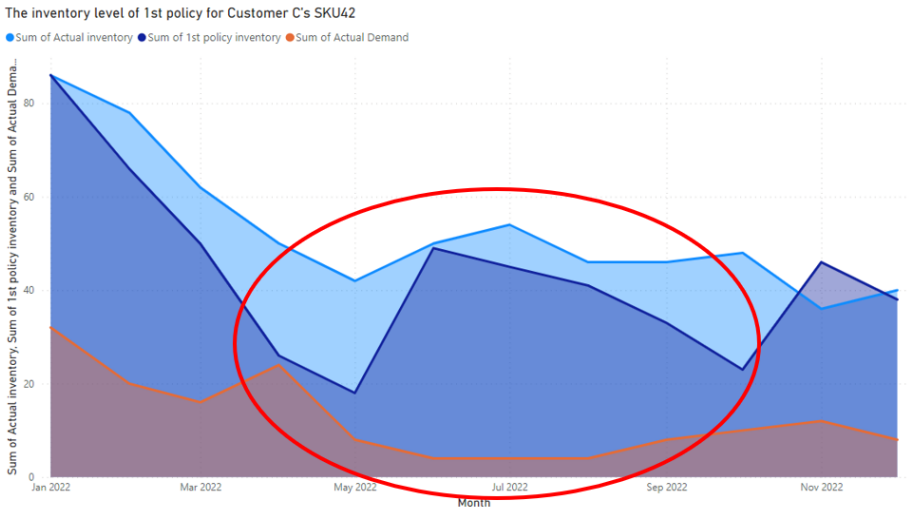


Figure 31: The comparison graph of excessive stock at the beginning of the year

4th Why: The exact ordering quantity based on EOQ does not relate to the demand of customer for every quarter of the year.

5th Why: Ordering fit to order based on the forecast value and safety stock should be considered.

According to this Five whys analysis, the cause of this inventory turnover issue can be concluded that it came from the unappropriated quantity per order in some quarter of the year which has lower demands. Ordering fitted to order should be better for this demand pattern by using the data of demand forecast value from chapter 3.

5.4. Improve Phase: Second Policy

5.4.1 2nd policy experiment for medium variation of demand product

The second policy is “ordering fitted to order using forecast value plus safety stock of following month when the stock nearly reach the reorder point or does not enough for the next demand forecast value plus with safety stock”. The safety stock of Customer C’s SKU42 is 8 units.

Table 33: The second policy experiment for Company C' SKU42

Month	2nd policy inventory	Placed order	Order quantity	Demand	Forecast Demand
Jan-22	86	0	0	32	27
Feb-22	66	0	0	20	20
Mar-22	50	0	0	16	17
Apr-22	26	0	0	24	23
May-22	18	12	0	8	9
Jun-22	26	0	12	4	4
Jul-22	22	0	0	4	4
Aug-22	18	14	0	4	4
Sep-22	24	0	14	8	6
Oct-22	14	22	0	10	12
Nov-22	24	0	22	12	14
Dec-22	16	0	0	8	8

5.4.2 The result of second policy

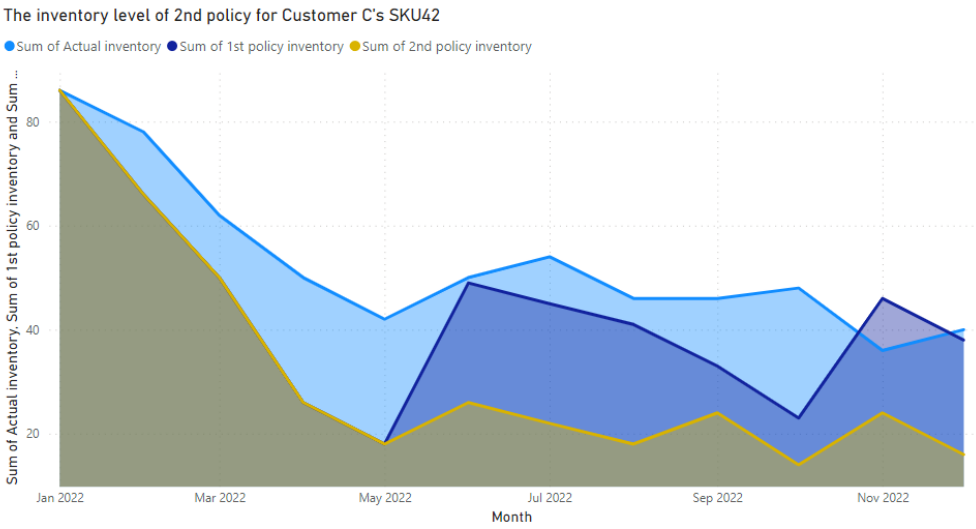


Figure 32: The comparison graph of 2nd policy inventory level for Customer C's SKU42

Table 34: The result of 2nd policy experiment for Customer C's SKU42

KPI	Actual inventory	1st policy inventory	2nd policy inventory
Turnover	2.38	2.42	2.94
Turning day (days)	153.30	150.87	124.10
Inventory average cost (THB)	96,528.60	94,996.40	78,142.20
Inventory holding cost in average (THB)	7,738.89	6,319.69	4,730.67
Logistic cost (THB)	3,600.00	1,200.00	1,800.00
Total cost (THB)	107,867.49	102,516.09	84,672.87

According to the experimental result, the inventory turnover from the 2nd proposed policy increased by 23.5% from the actual policy while the inventory holding day decreased by 29 days. The annual inventory cost in average also decreased by 22% which is approximately 23,000 THB. However, this 2nd proposed policy is for non-promotion scenario. Due to the tire market and the manufacturer, there's the promotion period once a year for overachieved sales target and boost the sale; therefore, this 2nd policy will not suit for the scenario with promotion.

5.5 Fault Tree Analysis for Scenario with Promotion

To investigate the possible factors and find the suitable policy for each product in the scenario with promotion, Fault tree analysis will perform.

Based on the diagram (figure 28), the policy with promotion scenario must consider in three main factors. The first one is the quantity of order during the promotion with discounted price. The second one is the inventory cost level which may be higher than necessary. Finally, the balance between the inventory level and customer demand is also important and avoid of

excessive stock; therefore, a company needs to minimize the stock before the promotion period, a company requires to ensure that the stock is enough for demands.

5.6 Third Policy for Promotion Scenario

5.6.1 The experiment of 3rd policy for Customer C's SKU42

The ordering policy for the promotion scenario is "Before the promotion period, Company should minimize the stock level as much as possible together with balancing with customer demands by comparing the ending stock in each month with following month's forecast value plus safety stock. During the promotion month, a company should order equal to EOQ. After the promotion, a company should reorder when the stock is not enough for the next month and order quantity equal to the forecast value. The experiment for this SKU will perform when the promotion is in June.

Table 35: The experiment of 3rd policy with promotion period for Customer C's SKU42

Month	3rd policy inventory with promotion	Placed order	Order quantity	Demand	Forecast Demand
Jan-22	86	0	0	32	27
Feb-22	66	0	0	20	20
Mar-22	50	0	0	16	17
Apr-22	26	0	0	24	23
May-22	18	0	0	8	9
Jun-22	14	**35**	0	4	4
Jul-22	45	**0**	**35**	4	4
Aug-22	41	0	0	4	4
Sep-22	33	0	0	8	6
Oct-22	23	0	0	10	12

Nov-22	11	8	0	12	14
Dec-22	11	0	8	8	8

5.6.2 The result of third policy

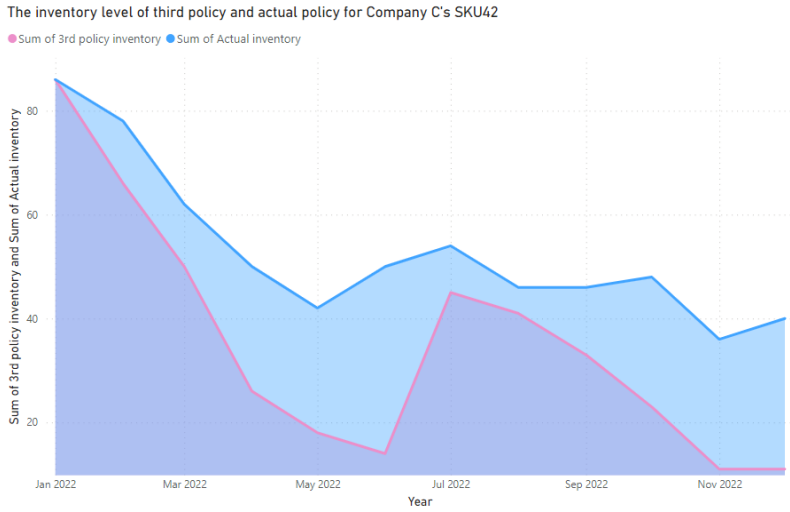


Figure 33: The comparison of inventory level between actual and 3rd policy for Customer C's SKU42

The comparison of actual inventory level between actual policy and 3rd policy with the same promotion period ordering in June.

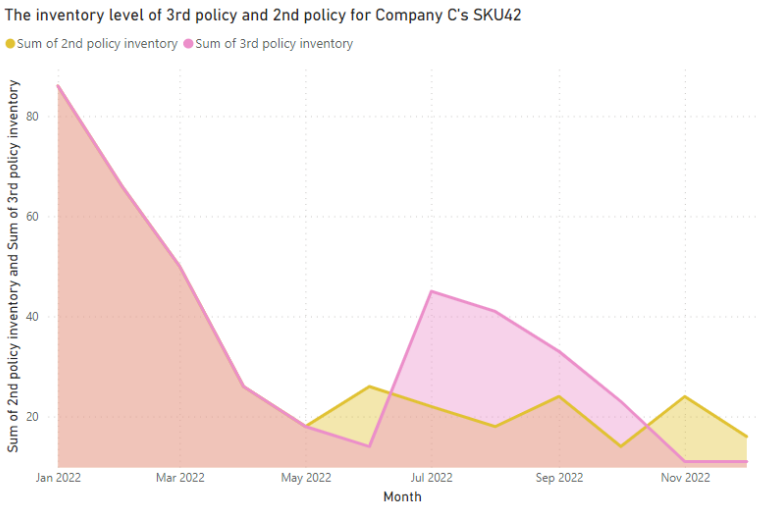


Figure 34: The comparison of inventory level between 2nd and 3rd policy for Customer C's SKU42

The comparison of inventory level between 2nd proposed policy without promotion scenario and 3rd policy with the promotion period ordering in June.

Table 36: The KPI result of all policy for Customer C's SKU42

KPI	Actual inventory	1st policy inventory	2nd policy inventory without promotion	3rd policy with promotion
Turnover	**2.38**	**2.42**	**2.94**	**3.15**
Turning day (day)	**153.30**	**150.87**	**124.10**	**116.10**
Inventory cost in average (THB)	96,528.60	94,996.40	78,142.20	73,047.64
Inventory holding cost in average (THB)	7,738.89	6,319.69	4,730.67	5,143.08
Logistic cost (THB)	3,600	1,200	1,800	1,200
total cost (THB)	**107,867.49**	**102,516.09**	**84,672.87**	**79,390.72**

The inventory turnover from the 3rd policy increased from the old one by 32% and 8.6% with final policy without promotion period. The turning day reduced to 8 days from 2nd policy and 37 days from actual policy. The result for another three SKUs which are medium demand variation will show in the section.

5.7 Results and Discussion

The comparation result from three proposed policy of SKU163 from Customer A is shown in the table below. All KPI are improved from the old policy. The inventory turnover increased to 3.86 for without promotion final policy and 4.48 for with promotion policy from 3.71. Although the inventory turnover for 1st proposed policy is hardly lower than the old policy, the total cost is cheaper about 5,000 THB.

Table 37: The KPI result of all policy for Customer A's SKU163

SKU 163 from Customer A				
KPI	**Actual inventory**	**1st policy inventory**	**2nd policy inventory without promotion**	**3rd policy with promotion**
Turnover	**3.71**	**3.53**	**3.86**	**4.48**
Turning day (days)	**98.27**	**103.37**	**94.44**	**81.39**
Inventory cost in average (THB)	235,958.80	248,216.40	226,765.60	195,432.11
Inventory holding cost in average (THB)	34,643.04	27,195.27	31,198.15	26,491.74
Logistic cost (THB)	14,400.00	4,800.00	4,800.00	3,600.00
Total cost (THB)	**285,001.84**	**280,211.67**	**262,763.75**	**225,523.85**

The comparation results between all new proposed policies and old policy of SKU158 from Customer B is shown in the table below. All KPI from 2nd and 3rd policy are improved from the old policy. Although the inventory turnover from the first policy is little lower than old policy due to the higher average inventory. The total cost is still lower about 1,000 THB.

Table 38: The KPI result of all policy for Customer B's SKU158

SKU 158 from Customer B				
KPI	**Actual inventory**	**1st policy inventory**	**2nd policy inventory without promotion**	**3rd policy with promotion**
Turnover	3.02	2.98	3.91	4.99
Turning day (days)	120.70	122.32	93.34	73.96
Inventory cost in average (THB)	60,767.50	61,533.15	46,977.25	36,753.90
Inventory holding cost in average	6,277.47	5,040.22	3,305.62	3,596.76

(THB)				
Logistic cost (THB)	9,600	1600	2400	1600
total cost (THB)	76,644.53	68,173.37	52,682.90	41,950.67

The comparation results of SKU42 from Customer B is shown in the table below. All of key performance indicators are improved step by step from the first proposed policy to the final policy with promotion.

Table 39: The KPI result of all policy for Customer B's SKU158

SKU 42 from Customer B				
KPI	**Actual inventory**	**1st policy inventory**	**2nd policy inventory without promotion**	**3rd policy with promotion**
Turnover	3.27	4.69	5.34	5.40
Turning day (days)	111.65	77.90	68.37	67.54
Inventory cost in average (THB)	98,826.90	68,949	60,521.90	59,781.47
Inventory holding cost in average (THB)	8,575.85	4,293.99	3,359.99	4,108.51
Logistic cost (THB)	9,600	2,400	3,200	2,400
total cost (THB)	117,002.75	75,642.99	67,081.89	66,289.98

According to the results of these four products with the same demand pattern, the conclusion policy of this medium demand variation SKU can be separated into two scenarios. The first is without promotion. The ordering policy is that the ordering quantity of the product should be following the forecast value plus safety stock when the stock nearly reaches the reorder point. Lastly, in the case that there is promotion period. Sub-dealer should minimize the stock as much as possible before the promotion month by comparing the current stock with the forecast. During

the promotion, sub-dealer should order equal to EOQ with discounted price, then back to use the 2nd policy without promotion when the promotion period ends.

Chapter 6. Customers' policy for high demand variation products

According to Table 16, the high variation of demand pattern considered from CV which are more than 0.9 are SKU163 from customer B, and SKU158 from customer C. In this part, SKU163 from Customer B will be sample to show all of calculation methods.

6.1 Inventory Control Policy

Due to the characteristic of high variation of demand, economic order quantity (EOQ) is not suited for this type of pattern. The order quantity fitted to lot or lot to lot ordering should be better. This means the number of quantities mainly depends on the demand forecast value and safety stock while the order cycle and order frequency also depend on the forecast value and reorder point.

6.1.1 Reorder point and safety stock

To observe the number of quantities, safety stock should be calculated based on the formula in the literature review. The safety stock of Customer B's SKU163 will be calculated based on the data in the table below.

Table 40: Demand data of Customer B's SKU163 for safety stock

Month	Demand order (units)	Lead time (days)
Jan-22	20	15
Feb-22	42	15
Mar-22	20	15
Apr-22	18	15
May-22	16	16
Jun-22	4	15
Jul-22	4	15

Aug-22	4	15
Sep-22	4	15
Oct-22	2	16
Nov-22	4	15
Dec-22	2	15
Total	140	
Average in Month	11.67	0.51
Average in Day	0.39	15.16
Standard deviation	12.06	

The safe stock (ss) will be considered at 90% targeted service rate whose coefficient service (Z) is 1.28, so the safety stock of this SKU will be

$$ss = 1.28 \times 12.06 \times \sqrt{0.51} = 11$$

For the order frequency, the cycle of order can be considered by reorder point; therefore, the reorder point (RO) will be

$$RO = 11 + 0.39 \times 15.16 = 17$$

The reorder point and safety stock of the other SKU with high demand variation are shown in the table below.

Table 41: Reorder point and safety stock of SKU with high variation of demand

Product ID	Reorder point (unit)	Safety stock (unit)
SKU163 from Customer B	17	11
SKU158 from Customer C	20	12

6.2 The First Policy for High Variation of Demand Products

6.2.1 1st policy experiment for high demand variation products

The first ordering policy for this type of demand pattern is ordering fitted to lot when the stock nearly reaches to reorder point or does not cover the forecast value plus safety stock. For example, Safety stock of Customer B's SKU163 is 11 units while reorder point is 17 units. The first order should in March 2022. The ending inventory in March is 24 which is nearly reorder point and the forecast value of April is 19. Therefore, 19 combines with 11 is 30 units which is higher than 24, then the order quantity should be 30 units as well.

Table 42: The experiment of 1st policy for high demand variation (Customer B's SKU163)

Month	1st policy inventory	Placed order	Order quantity	Demand	Forecast
Jan-22	86	0	0	20	20
Feb-22	44	0	0	42	42
Mar-22	24	30	0	20	20
Apr-22	36	0	30	18	19
May-22	20	0	0	16	17
Jun-22	16	0	0	4	5
Jul-22	12	14	0	4	4
Aug-22	22	0	14	4	3
Sep-22	18	0	0	4	5
Oct-22	16	0	0	2	3
Nov-22	12	13	0	4	3
Dec-22	23	0	13	2	2

6.2.2 Result of first policy

The key performance indicators for this experiment are Inventory turnover, Inventory holding day and the average inventory cost. All of these KPIs equations are based on the literature review in the chapter 2.

The graph below shows the comparison of inventory level in Year 2022 between Inventory from actual policy and the proposed one.

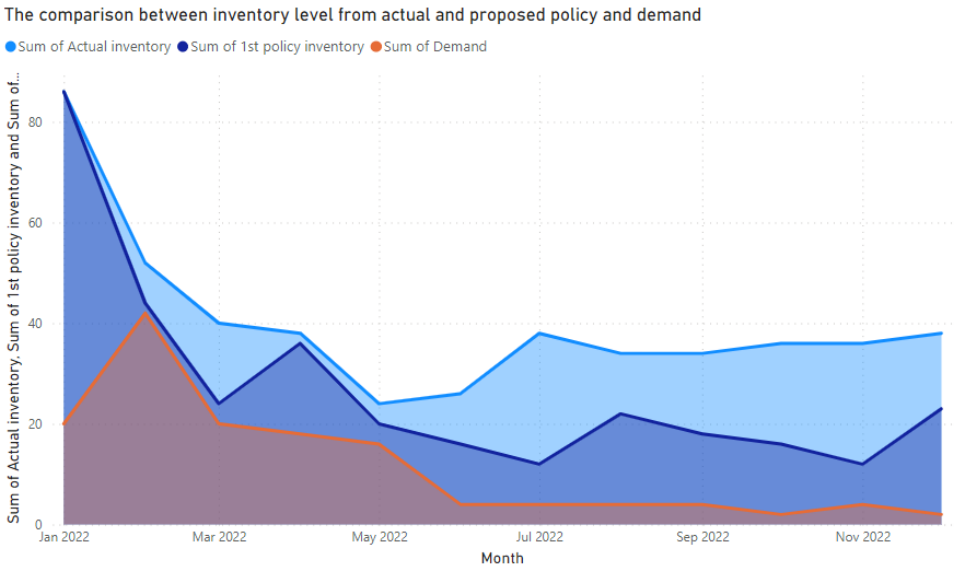


Figure 35: The comparison graph between inventory level of proposed policy and actual policy and demand

Table 43: The result of 1st policy for high demand variation (Costumer B's SKU 163)

KPI	Actual inventory	1st policy inventory
Inventory turnover	2.25	2.57
Inventory turning day (days)	161.64	142.09
Inventory cost in average (THB)	61,543.37	42,007.82
Inventory holding cost in average (THB)	5,846.62	3,990.74
Logistic cost (THB)	6,400.00	2,400.00
Total cost (THB)	144,015.82	138,159.94

According to table 46, the inventory turnover from new proposed policy increased to 2.57 from 2.25 which is approximately 14%. The inventory holding days decreased by 20 days. In the term of cost, all of average inventory cost, holding cost and logistic cost reduced from the old policy; therefore, the total cost is lower than old policy about 5,900 THB which is 4%. Due to the tire market and the manufacturer, there's the promotion period once a year for overachieved sales

target and boost the sale; therefore, this proposed policy will not suit for the scenario with promotion.

6.3 Fault Tree Analysis for Scenario With Promotion

To investigate the possible factors and find the suitable policy for each product in the scenario with promotion, Fault tree analysis will perform.

Based on the diagram (Figure 28), the policy with promotion scenario must consider in three main factors. The first one is the quantity of order during the promotion with discounted price. The second one is the inventory cost level which may be higher than necessary. Finally, the balance between the inventory level and customer demand is also important and avoid of excessive stock; therefore, a company needs to minimize the stock before the promotion period, a company requires to ensure that the stock is enough for demands.

6.4 Third Policy for Promotion Scenario

6.4.1 The experiment of 3rd policy for Customer B's SKU163

The ordering policy for the promotion scenario is "Before the promotion period, Company should minimize the stock level as much as possible together with balancing with customer demands by comparing the ending stock in each month with following month's forecast value plus safety stock. The order quantity before promotion is calculated by Current stock minus the sum of forecast value of following month and safety stock. During the promotion month, a company should order equal to the forecast value of the rest months plus safety stock. After the promotion, a company should turn to use the proposed policy without promotion.

Table 44: The experiment of 2nd policy for high demand variation with promotion period for Company's B SKU163

Month	2nd	Placed	Order	Demand	Forecast

	policy	order	quantity		
Jan-22	86	0	0	20	20
Feb-22	44	0	0	42	42
Mar-22	**24**	**23**	0	20	20
Apr-22	29	0	**23**	18	19
May-22	13	0	0	16	17
Jun-22	9	**32**	0	4	5
Jul-22	37	0	**32**	4	4
Aug-22	33	0	0	4	3
Sep-22	29	0	0	4	5
Oct-22	27	0	0	2	3
Nov-22	23	0	0	4	3
Dec-22	21	0	0	2	2

Due to the above table, the order quantity placed in March comes from the sum of forecasted values of demand in April and May and the safety stock which are 19 + 17 + 11 = 47, then deducted with the ending inventory in March, so the order quantity is 47 – 24 = 23 units to create the lean stock before the promotion as much as possible. On the other hand, the order quantity during the promotion in June comes from the sum of demand forecast value of July to December which is 21 units, then pluses with safety stock; therefore, the number of orders in promotion month is 21 + 11 = 32 units.

6.4.2 The result of third policy

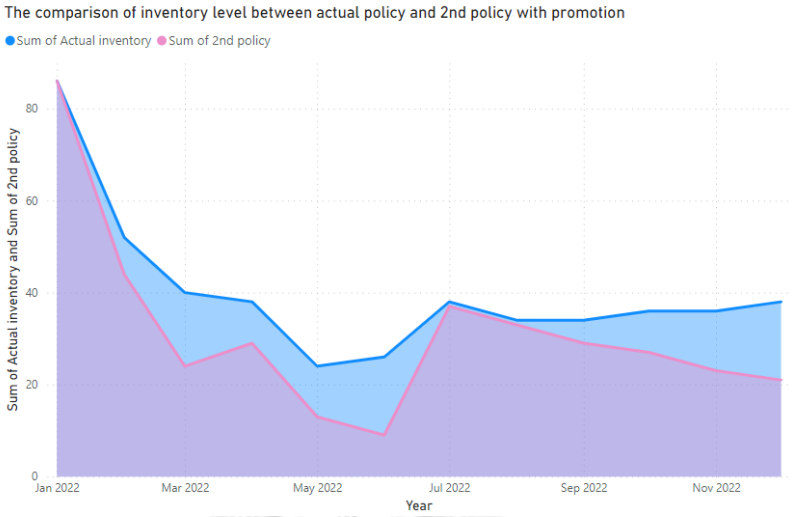


Figure 36: The comparison of inventory level between actual and 2nd policy for Customer B's SKU163

The comparison of actual inventory level between actual policy and 2nd policy with the same promotion period ordering in June.

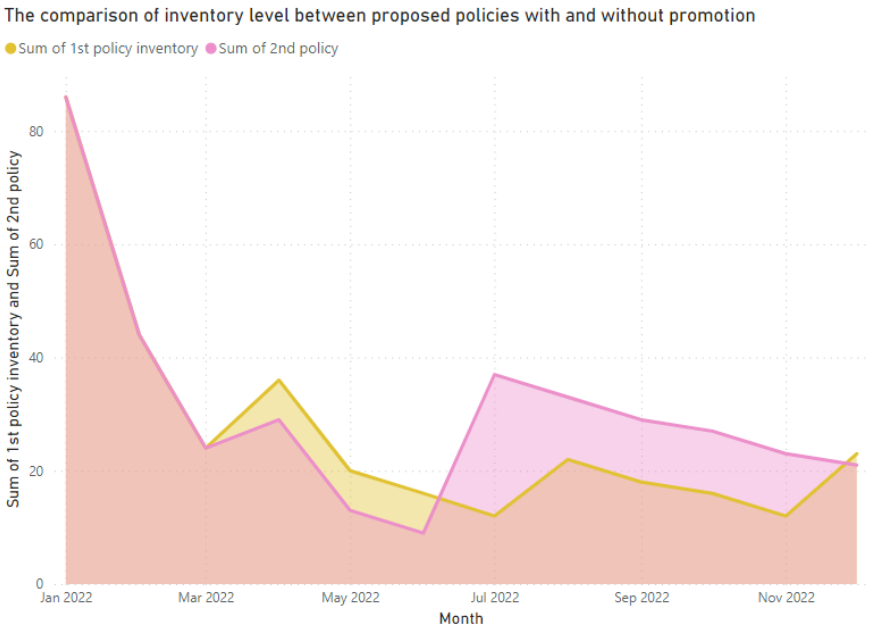


Figure 37: The comparison of inventory level between 1st and 2nd policy for Customer B's SKU163

The comparison of inventory level between 1st proposed policy without promotion scenario and 2nd policy with the promotion period ordering in June.

Table 45: The KPI result of all policy for Customer B's SKU163

SKU 163 from Customer B			
KPI	**Actual inventory**	**1st policy inventory without promotion**	**2nd policy with promotion**
Turnover	**2.26**	**2.57**	**2.70**
Turning day (day)	**161.64**	**142.09**	**135.38**
Inventory cost in average (THB)	61,543.37	42,007.82	40,699.06
Inventory holding cost in average (THB)	5,846.62	3,990.74	4,548.72
Logistic cost (THB)	6400	2400	1,600
total cost (THB)	**144,015.82**	**138,159.94**	**137,917.92**

The inventory turnover from the 2nd policy increased from the old one by 19% and 6% with proposed policy without promotion period. The turning day reduced to 1 week from 2nd policy and 26 days from actual policy. The result of the other SKUs which are high demand variation will show in the section.

6.5 Results and Discussion

The results from two new proposed policies of SKU158 from Customer C is shown in the table below. All KPI are improved from the old policy step by step. The inventory turnover increased to 3.24 for without promotion final policy and 3.62 for with promotion policy from 3.71 which are 65% and 47%. The total cost also reduced by 38,206 THB from 2nd policy and 30,516 THB from 1st policy.

Table 46: The KPI result of all policy for Customer C's SKU158

KPI	Actual inventory	1st policy inventory without promotion	2nd policy with promotion
Turnover	**2.20**	**3.24**	**3.62**
Turning day (Day)	**165.90**	**112.82**	**100.73**
Inventory cost in average (THB)	76,610	52,094.80	46,514.50
Inventory holding cost in average (THB)	5,361.42	4,160.56	3,250.82
Logistic cost (THB)	4,700	2,400	1,200
Total cost (THB)	**89,171.42**	**58,655.36**	**50,965.32**

Due to the comparison results from Customer B's SKU163 and Customer C's SKU 158, the ordering policy of high demand variation mainly depends on the forecast value from the best-fit forecasting model which is shown on the chapter 3. The number of order quantity is fitted to the order in the following month plus safety stock. For the promotion period, the order quantity comes from the demand estimating of the rest months in that year as well. While the order frequency is still based on reorder point and safety stock.

Chapter 7: A Company's Demand Analysis and Policy

Apart from the improvement of the ordering policy and inventory of a company's customers, the new proper policy for a company to order the products from manufacturers and manage the inventory is very necessary by integrating with the new order demand from customers' proposed policy.

7.1 Demand Analysis

7.1.2 The comparison of actual and new demands

Due to the new order quantity of each SKU from three selected sub-dealer from the new policy in previous chapter, the number of a company's demand who's a distributor for those customers changed as well. The two comparisons for each SKU which are demand during non-promotion period and demand during promotion period are shown below.

SKU 158:

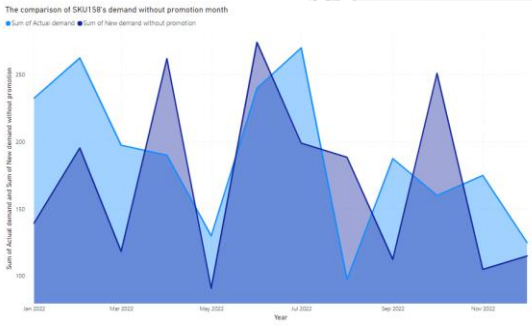


Figure 38: The demand comparison with promotion of SKU158

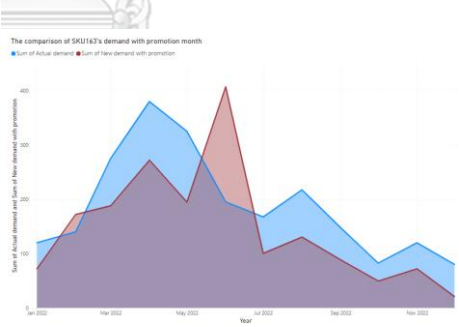


Figure 39: The demand comparison without promotion of SKU158

SKU 42:

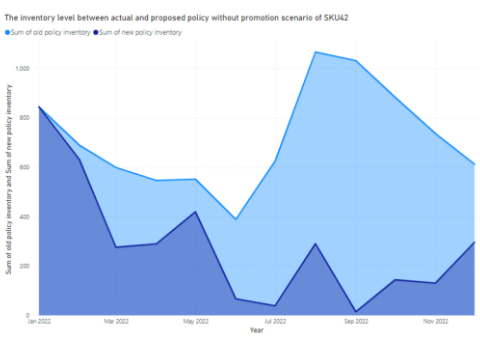


Figure 40: The demand comparison without promotion of SKU42

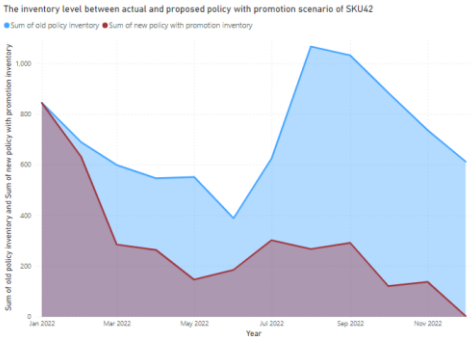


Figure 41: The demand comparison with promotion of SKU42

SKU163:

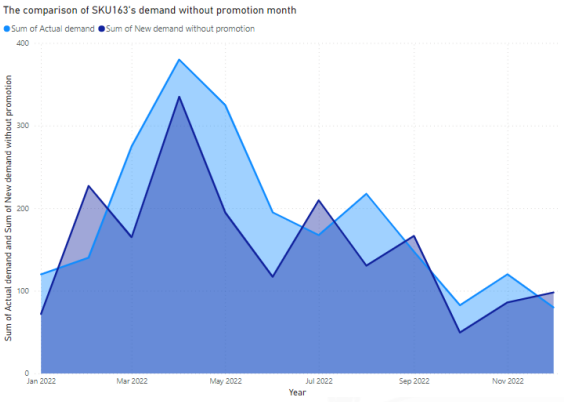


Figure 42: The demand comparison with promotion of SKU163

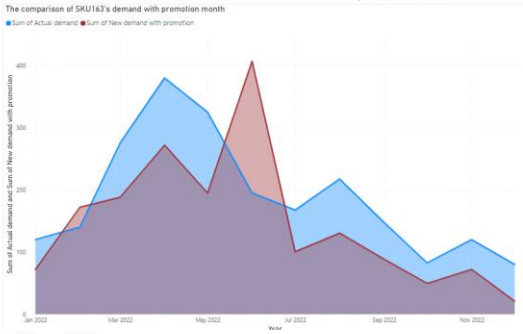


Figure 43: The demand comparison without promotion of SKU163

7.1.1 Coefficient of demand

The comparison of coefficient variation between the actual demand from the historical 2022 and demand from the experiment of two new proposed demand from previous chapter will be shown.

Table 47: The comparison of SKU158's demand

SKU 158			
Month	**Actual demand (units)**	**New demand without promotion (units)**	**New Demand with promotion (units)**
Jan-22	233	140	140
Feb-22	263	196	158
Mar-22	198	119	154
Apr-22	190	262	235
May-22	130	91	89
Jun-22	240	274	476
Jul-22	270	199	162
Aug-22	98	189	59
Sep-22	188	113	243
Oct-22	160	251	106
Nov-22	175	105	105
Dec-22	125	115	245
Standard deviation	55.20	66.09	111.23
Average	189	171	181
Coefficient of variation	**0.29**	**0.39**	**0.62**

Table 48: The comparison of SKU42's demand

SKU 42			
Month	**Actual demand (units)**	**New demand without promotion (units)**	**New Demand with promotion (units)**
Jan-22	235	141	141
Feb-22	355	213	213
Mar-22	290	355	346
Apr-22	253	287	322
May-22	195	170	117
Jun-22	363	353	562
Jul-22	265	328	183

Aug-22	58	49	35
Sep-22	235	276	276
Oct-22	248	171	171
Nov-22	248	314	284
Dec-22	224	135	135
Standard deviation	77.83	99.94	138.41
Average	247	232	232
Coefficient of variation	**0.31**	**0.43**	**0.59**

The coefficient of variation of SKU158 and SKU42 increase from the actual demand due to the fact that there are only three selected customers from 133 sub-dealers that changes their ordering policy. Therefore, the demand from these three customers in each month decreased from actual while the number of ordering quantity of the rest customers still remains the same as actual one. However, the new demand without promotion is still lower than 0.39 which is low demand variation. The demand with promotion is more variable from the higher order than other months during the promotion period.

Table 49: The comparison of SKU163's demand

SKU 163			
Month	**Actual demand (units)**	**New demand without promotion (units)**	**New Demand with promotion (units)**
Jan-22	120	72	72
Feb-22	140	227	172
Mar-22	275	165	188
Apr-22	380	335	272
May-22	325	195	195
Jun-22	195	117	407
Jul-22	168	210	101
Aug-22	218	131	131
Sep-22	148	167	89
Oct-22	83	50	50

Nov-22	120	86	72
Dec-22	35	98	21
Standard deviation	100.93	80.03	108.85
Average	184	154	147
Coefficient of variation	**0.55**	**0.52**	**0.74**

For SKU163, the new coefficient of variation without promotion slightly decreases from the actual demand. Therefore, the proposed policy for sub-dealer provides the demand to be more stable; even though, the proposed policies are conducted by only three customers from more than 100 sub-dealers. However, the demand with promotion is more variable from the higher order than other months during the promotion period.

To create the proper ordering policy for a company, all coefficient of variation is assumed to be low and medium. The demand from the new proposed policy without promotion is mainly used to considered the number of order quantity and cycle of order.

7.2 Inventory Control Policy

According to the interview, a company monthly orders each SKU in the fixed number of order quantity by mis considering the forecast values and current stock. For instance, a company orders 200 units of SKU163 every month before the promotion period. During the promotion, a company orders 400 units in that month and reduces to 100 units for every month after the promotion period ends. Therefore, a company has the unnecessary excessive stock and lose of the profit from unnecessary high inventory cost.

7.2.1 Economic order quantity

The ordering system must be developed using the right optimal number of order quantities in order to take spare part quantity orders into account. The formula from the literature review is the foundation for the calculation. In this chapter, SKU 158 is the sample to show the calculation method.

Table 48: Data of Customer C's SKU42 for EOQ calculation

SKU 158	
Actual demand	2268 Units
New demand	2052 Units
Ordering cost per order	2000 THB
Holding cost	123.72 THB

For actual demand $Q_{opt} = \sqrt{\frac{2\times2000\times2268}{123.72}} = 271\ units$

For new demand $Q_{opt} = \sqrt{\frac{2\times2000\times2052}{123.72}} = 258\ units$

For other SKUs, the optimal order of each will be shown table below.

Table 49: Optimal order quantity for a company

Product ID	Optimal Order Quantity (Actual Demand)	Optimal Order Quantity (New Demand)
SKU158	271 units	258 units
SKU42	310 units	300 units
SKU 163	270 units	245 units

7.2.2 Reorder point and safety stock

The reorder point and safety stock should be determined using the method from the study of literature in order to track the ordering frequency. The safe stock (ss) will be considered at 90% targeted service rate whose coefficient service (Z) is 1.28. The reorder point and safety stock of SKU158, SKU42, SKU163 will be shown below.

Table 50: Reorder point and safety stock of SKU with medium variation of demand

Product ID	Safety stock (units)	Re-order points (units)
SKU158	83	254
SKU42	90	206
SKU163	102	254

7.3 Proposed Policy Without Promotion

A company should order each SKU in the number of EOQ and reorder when the stock nearly reach the reorder point. The experiment of SKU 158 is conducted below by ordering 240 units per order when nearly reach or less than 254 units.

Table 51: The experiment of a company's SKU158 without promotion policy

Month	Proposed policy inventory (units)	Placed order (units)	Received order (units)	Demand (units)
Jan-22	587	0	0	140
Feb-22	392	0	0	196
Mar-22	273	240	0	119
Apr-22	251	240	240	262
May-22	400	0	240	91
Jun-22	126	240	0	274
Jul-22	167	240	240	199
Aug-22	219	240	240	189
Sep-22	346	0	240	113
Oct-22	95	240	0	251
Nov-22	230	240	240	105
Dec-22	355	0	240	115

7.4 Proposed Policy with Promotion

A company should order each SKU in the number of 2 times of EOQ in the promotion month and besides the promotion period, a company should order as proposed policy without promotion. The experiment of SKU 158 is conducted below by ordering 240 units per order when nearly reach or less than 254 units in the normal situation and 480 units during the promotion month.

Table 52:The experiment of a company's SKU158 with promotion policy

Month	Proposed policy inventory (units)	Placed order (units)	Received order (units)	Demand with promotion period (units)
Jan-22	587	0	0	140
Feb-22	430	0	0	158
Mar-22	276	240	0	153
Apr-22	281	0	240	235
May-22	192	480	0	89
Jun-22	196	240	480	476
Jul-22	274	0	240	162
Aug-22	216	240	0	59
Sep-22	213	240	240	113
Oct-22	347	0	240	96
Nov-22	242	240	0	105
Dec-22	237	0	240	115

7.5 Result and Discussion

7.5.1 SKU 158

SKU 158			
Month	**Old policy inventory (units)**	**New policy inventory without promotion (units)**	**New policy with promotion inventory (units)**

Jan-22	587	587	587
Feb-22	524.5	392	430
Mar-22	527	273	276
Apr-22	537	251	281
May-22	607	400	192
Jun-22	567	126	196
Jul-22	697	167	274
Aug-22	999.5	219	216
Sep-22	812	346	213
Oct-22	652	95	347
Nov-22	477	230	242
Dec-22	352	355	237
total	7339	3440	3490
Average	612	280	291

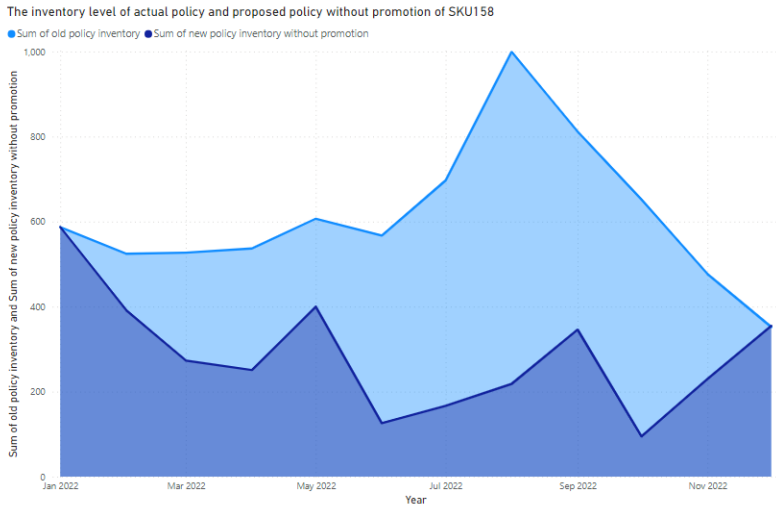


Figure 44: The comparison between actual and new policy in non-promotion scenario of SKU158

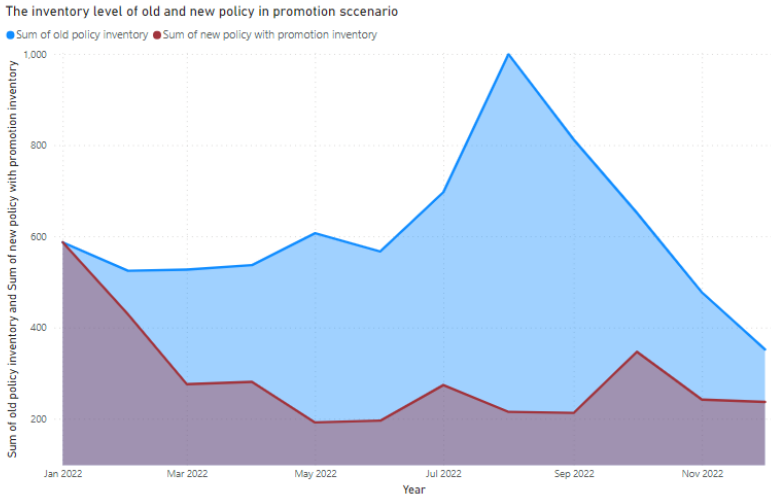


Figure 45: The comparison between actual and new policy in promotion scenario of SKU158

Table 53: the result of SKU 158

KPI	Old policy inventory	New policy inventory without promotion	New policy with promotion inventory
Inventory turnover	**4.62**	**5.31**	**5.61**
Inventory turning day (das)	**78.99**	**68.73**	**65.01**
Inventory cost in average (THB)	611,462.72	532,018.15	503,285.07
Inventory holding cost in average (THB)	75,668.24	34,699.28	35,983.40
Logistic cost (THB)	24000	12000	12000
Total cost (THB)	**711,130.95**	**578,717.43**	**551,268.47**

For SKU158, a company can increase the inventory turnover to 5.31 in non-promotion scenario and 5.61 in promotion scenario which are higher than an actual inventory turnover by 15% and 21% respectively. While the inventory turning day reduces by approximately 10 days and 13 days. In term of the cost, a company can spend more than 130,000 THB cheaper than usual.

7.5.2 SKU 42

SKU 42			
Month	**Actual inventory (units)**	**New inventory of proposed policy without promotion (units)**	**New inventory of proposed policy with promotion (units)**
Jan-22	844	844	844
Feb-22	689	631	631
Mar-22	599	276	285
Apr-22	547	290	264
May-22	552	420	147
Jun-22	389	67	185
Jul-22	624	39	302
Aug-22	1067	291	268
Sep-22	1032	15	292
Oct-22	884	144	121
Nov-22	737	131	138
Dec-22	612	296	3
Total	8574	3442	3478
Average	714.49	286.79	289.82

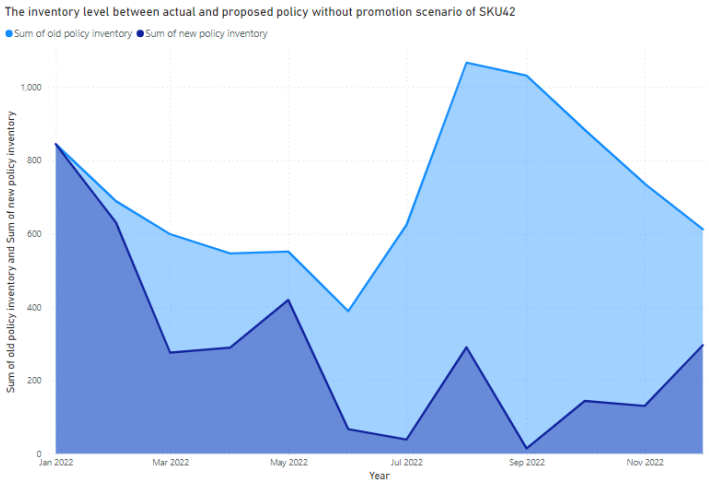


Figure 46: The inventory level between old and proposed policy without promotion of SKU42

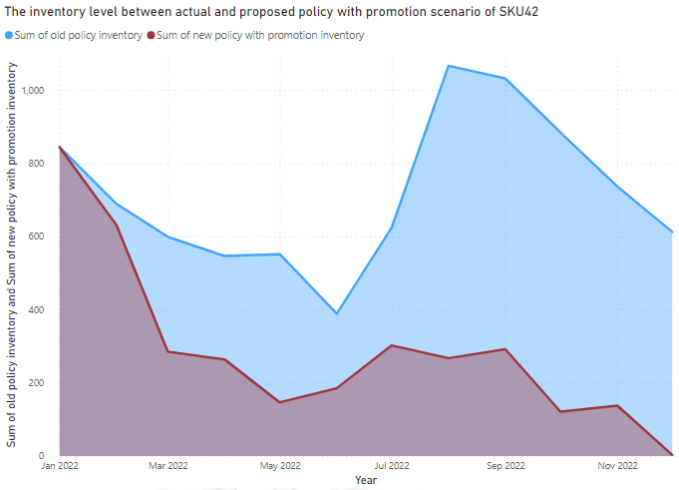


Figure 47: The inventory level between old and proposed policy with promotion of SKU42

Table 54: the result of SKU 42

KPI	Old policy inventory	New policy inventory without promotion	New policy with promotion inventory
Inventory turnover	**3.82**	**5.71**	**6.57**
Inventory turning day (days)	**95.54**	**63.93**	**55.53**
Inventory cost in average (THB)	1,115,696.97	746,564.45	648,544.85
Inventory holding cost in average (THB)	88,399.90	35,379.77	35,857.86
Logistic cost (THB)	24,000	14,000	8,000
Total cost (THB)	**1,228,096.87**	**795,944.22**	**692,402.71**

For SKU42, a company can increase the inventory turnover to 5.71 in non-promotion scenario and 6.57 in promotion scenario which are higher than an actual inventory turnover by 49% and 72% respectively. While the inventory turning day reduces more than 1 month. In term of the cost, a company can spend more than 432,152.67 THB cheaper than usual for non-promotion scenario. For promotion scenario, the cost is cheaper almost half of the actual cost.

7.5.3 SKU 163

Month	Actual inventory (units)	New inventory of proposed policy without promotion (units)	New inventory of proposed policy with promotion (units)
Jan-22	651	651	651
Feb-22	711	424	479
Mar-22	636	259	291
Apr-22	456	168	264
May-22	331	217	314
Jun-22	336	344	397
Jul-22	569	379	297
Aug-22	551	248	411
Sep-22	504	326	323
Oct-22	521	276	273
Nov-22	501	434	201
Dec-22	521	336	180
total	6287	4061	4080
Average	524	338	340

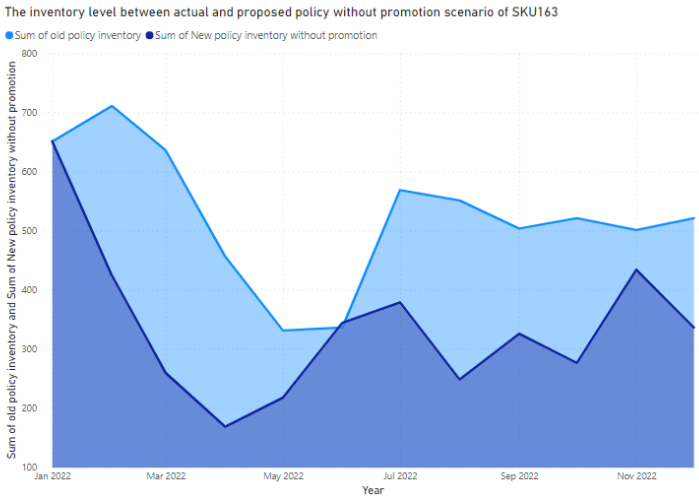


Figure 48: The inventory level between old and proposed policy without promotion of SKU163

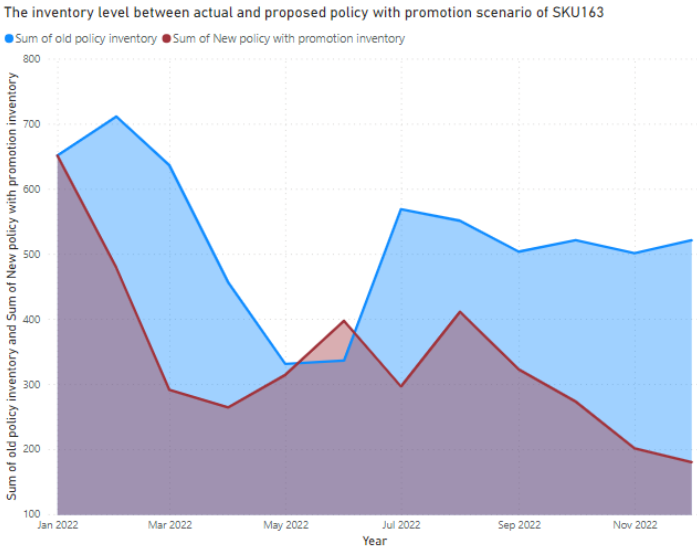


Figure 49: The inventory level between old and proposed policy with promotion of SKU163

Table 55: the result of SKU 163

KPI	Old policy inventory	New policy inventory without promotion	New policy with promotion inventory
Inventory turnover	**3.02**	**3.58**	**4.40**
Inventory turning day (days)	**120.98**	**101.88**	**82.99**
Inventory cost in average (THB)	763,188.82	642,719.60	523,552.74
Inventory holding cost in average (THB)	64,821.67	41,870.65	42,066.55
Logistic cost (THB)	24,000	12,000	8,000
Total cost (THB)	**852,010.49**	**696,590.25**	**573,619.29**

For SKU163, a company can increase the inventory turnover by 19% and 46% respectively. While the inventory turning day reduces more than 1 month in the promotion scenario. In term of the cost, a company can spend more than 155,420 THB cheaper than usual for non-promotion scenario and 278,391 THB for promotion.

Chapter 8: Conclusion and Recommendations

8.1 Conclusion

The objective of this research is to improve the inventory level of a case study company by presenting the new policy to help a company to have better performance in inventory management in order to decrease the overstock. The overstock of inventory is the main issue that cause the negative impact on the company's financial performance and liquidity. In order to investigate and propose the proper policy to achieve the objective, the study starts with understanding a case study company's overview including current ordering policy and inventory performance. To scope down the area and find the problematic area, ABC classification is conducted to select the three appropriated SKUs from the best-selling product, radial tires for sedan car which are SKU42, SKU158 and SKU163. The key performance indicators which are used to evaluate these three products are inventory turnover, inventory holding day and the average cost of inventory. Next part is the reviewal of demand and inventory related literature to be able to translate the theory to be applicable with the defined problem. The proposed phase is the part where the customer segmentation, demand forecasting, demand analysis and inventory control are proposed to achieve the research objectives.

For the customer segmentation, Pareto principle is the main method to classify the customers then selects the best three sub-dealers based on the highest sale volume to be determine and analyze their customers' demand of SKU42, SKU158 and SKU163. Six forecasting techniques such as 3 months moving average, single exponential smoothing, double exponential smoothing, Holy's winter method, linear regression and ARIMA are conducted through Minitab software to find the best-fit forecasting model to each SKU of each sub-dealer by comparing MAPE value. Due to the seasonal demand pattern, the most suitable forecasting model for tire are Holt's winter method and ARIMA.

In demand analysis part, the demand variation is the key point to classify the demand into three patterns of each sub-dealers' SKUs. The calculation of coefficient of variation is performed

based on the formula in the literature review. The criteria is that the value of CV which is lower than 0.5 is low variation, while the CV between 0.5 to 0.9 is medium variation and refer CV more than 0.9 as high demand variation.

For the low demand variation pattern, there are Customer A's SKU 158, Customer A's SKU 42 and Customer C's SKU 163. The first proposed policy for this type of demand is that order quantity equals to EOQ and cycle of order also depends on the order frequency using annual demand divided by EOQ. Due to the result of 1st policy experiment, the change of inventory turnover and holding day is only 1%; therefore, the five whys analysis is conducted to find the root cause for better solution in the improve phase. From the root-cause analysis, the cycle of order from 1st proposed policy does not match to the inventory. The 2nd policy in the improve phase is proposed which change to order by considering the reorder point and comparing the current stock to the forecast value plus safety stock. According to the nature of tire market, the 3rd policy with promotion period is also proposed for promotion scenario whose order quantity during the promotion is 2 times of EOQ.

For the medium demand variation pattern, there are Customer A's SKU 163, Customer B's SKU 158, Customer B's SKU 42 and Customer C's SKU 42. The first proposed policy for this type of demand is that order quantity equals to EOQ and cycle of order is considered from reorder point and the comparison between current stock and forecasting demand of following month plus safety stock. Due to the root-cause analysis of 1st policy, the demand in each quarter is fluctuation, so the order quantity in EOQ is not suited for this demand pattern because the excessive stock occurs in the last half of the year. The 2nd policy which changes the number of each order to be calculated by the forecast demand value plus safety stock of next month is proposed. For the promotion scenario, the 3rd proposed policy is ordering the products during the promotion month equal to EOQ and minimize the stock as much as possible before the promotion period.

Finally, the 1st policy for high demand variation SKUs which are Customer B's SKU 163 and Customer C's SKU 158 is the number of each order to fit to lot by ordering in the number of forecast values plus safety stock of the next month when the current stock nearly reach or below re order point. For promotion period, the sub-dealer also orders to EOQ units for each SKU as similar as the medium demand policy.

The result of each sub-dealer with each SKU are shown in the below. The result of Customer B's SKU 163 and Customer C's SKU 158 in the 2nd proposed policy are similar to the 1st policy. However, the inventory turnover of each customer's SKU increases step by step from the old policy to the final proposed policy while the inventory holding day decreases. This can be concluded that the inventory level of these three selected customers with new policy are better than the current one.

Customer A																
	Actual inventory				1st policy inventory				2nd inventory (improve)				3rd policy inventory with promotion			
KPI	SKU158	SKU42	SKU163	Total	Sku158	SKU42	SKU163	Total	SKU158	SKU42	SKU163	Total	SKU158	SKU42	SKU163	Total
Turnover	2.99	5.32	3.71	**4.01**	3.01	5.77	3.53	**4.10**	5.44	5.77	3.86	**5.02**	5.60	5.96	4.48	**5.35**
Holding day	122.11	68.61	98.38	**91.11**	121.26	63.26	103.40	**88.95**	67.10	63.26	94.56	**72.66**	65.18	61.24	81.47	**68.27**

Figure 50: The summary of Customer A's result

Customer B																
	Actual inventory				1st policy inventory				2nd inventory (improve)				3rd policy inventory with promotion			
KPI	SKU158	SKU42	SKU163	Total	Sku158	SKU42	SKU163	Total	SKU158	SKU42	SKU163	Total	SKU158	SKU42	SKU163	Total
Turnover	3.02	3.27	2.26	**2.85**	2.98	4.69	2.57	**3.41**	3.91	4.35	2.57	**3.61**	5.00	5.03	2.70	**4.24**
Holding d	120.79	111.65	161.50	**128.06**	122.32	77.90	142.02	**106.94**	93.38	83.95	142.02	**101.14**	73.06	72.50	135.19	**86.01**

Figure 51: The summary of Customer B's result

Customer C																
	Actual inventory				1st policy inventory				2nd inventory (improve)				3rd policy inventory with promotion			
KPI	SKU158	SKU42	SKU163	Total	Sku158	SKU42	SKU163	Total	SKU158	SKU42	SKU163	Total	SKU158	SKU42	SKU163	Total
Turnover	2.20	2.38	1.79	**2.13**	3.24	2.42	2.07	**2.57**	3.24	2.94	2.07	**2.75**	3.33	3.14	2.17	**2.88**
Holding day	165.91	153.30	203.44	**171.76**	112.82	150.87	176.52	**141.79**	112.82	124.10	176.52	**132.82**	109.67	116.24	168.44	**126.81**

Figure 52: The summary of Customer C's result

For a case study company, the integration of new sub-dealers' demand from the proposed policy and the new ordering policy is conducted to improve its inventory level and supply chain performance. Due to the sub-dealers' new ordering and inventory control policy, the change of order quantity has effects on a company's demand in both non-promotion and promotion scenario. The CV values of some SKU is higher than actual because this is the total demand from

more than 100 customers and the change of demands are only from three customers. However, the average number of all SKU is lower than a current situation. The new proposed policy for a company's inventory is based on the new demand.

Table 56: The summary of a company's demand

A company's demand						
Type of demand	**SKU 42**		**SKU 158**		**SKU 63**	
	CV	**Average (units)**	**CV**	**Average (units)**	**CV**	**Average (units)**
Actual demand	0.31	247.22	0.29	188.96	0.55	183.75
New demand without promotion	0.43	232.42	0.39	170.96	0.52	154.52
New demand with promotion	0.60	231.83	0.62	180.79	0.74	147.33

Due to the demand variation of a company, the policy is that the number of quantities equals to EOQ and cycle of order is calculated from reorder point in the non-promotion scenario. On the other hands, the order quantity changes to 2 times of EOQ during the promotion month to make sales reach to target and lower the product cost with discounted price. The summary of EOQ, reorder point and safety stock of each SKU are shown below.

Table 57: The summary of a company's EOQ, RO and SS

A company			
	SKU 42	**SKU 158**	**SKU 163**
Economic order quantity (units)	300	258	245
Re-order point (units)	206	254	254

Safety stock (units)	90	83	102

	Actual inventory				New policy inventory				New policy inventory with promotion			
Month	**SKU158**	**SKU42**	**SKU163**	**Total**	**Sku158**	**SKU42**	**SKU163**	**Total**	**SKU158**	**SKU42**	**SKU163**	**Total**
Jan-22	587	844	651	2082	587	844	651	2082	587	844	651	2082
Feb-22	525	689	711	1925	392	631	424	1447	430	631	479	1540
Mar-22	527	599	636	1762	273	276	259	808	276	285	291	852
Apr-22	537	547	456	1540	251	290	168	709	281	264	264	809
May-22	607	552	331	1490	400	420	217	1037	192	147	314	653
Jun-22	567	389	336	1292	126	67	344	537	196	185	397	778
Jul-22	697	624	569	1890	167	39	379	585	274	302	296.5	873
Aug-22	1000	1067	551	2617	219	291	248	757	216	268	411	894
Sep-22	812	1032	504	2347	346	15	326	686	213	292	322.5	827
Oct-22	652	884	521	2057	95	144	276	515	347	121	273	741
Nov-22	477	737	501	1715	230	131	434	795	242	138	201	581
Dec-22	352	612	521	1485	355	296	336	987	237	3	180	420
Total	7339	8574	6287	22200	3440	3442	4061	10943	3490	3478	4080	11048
Average	612	714	524	1850	287	287	338	912	291	290	340	921
Turnover	4.62	3.82	3.02	**3.82**	5.31	5.71	3.58	**4.87**	5.61	6.57	4.40	**5.53**
Holding day	79.0043	95.5497	120.861	**95.54974**	68.7382	63.9229	101.96	**75**	65.06239	55.55556	82.95455	**66.043**

Figure 53: The summary of a company's results

The results of two proposed policies are better than the current policy. The inventory level of SKU 42 does the best performance whose inventory turnover increases by about 49% and turning day decreases by one month in the normal situation. In term of promotion scenario, inventory turnover of SKU42 increases by 72 and turning day decreases by 40 days. For SKU 158, turnover and holding day are changed by 15% and 10 days for normal situation and by 21% and 14 days for promotion situation. SKU 163's turnover increases from 3.02 to 3.58 and 4.40 and holding days decreases from 121 days to 102 and 83 days for normal and special situation respectively.

Finally, the best-fit demand forecasting methods with the lowest error and suitable inventory policies will lead to better plan in ordering and control the stock. The ability to manage and control the inventory will allow the better performance of a company's supply chain as well as the sub-dealers. In addition, the reduction of issues of overstock which is also related to the financial part and a company's liquidity.

8.2 Managerial Recommendations

In this section, the managerial recommendations are provided based on the studies and limitations of this research. There are two main areas, demand forecasting methods and inventory control policies, are proposed in order to improve a case study company's inventory performance.

For demand forecasting, selected forecasting techniques are part of time series analysis which used a historical data to predict and analyze the future demand by statistical computation. The limitation is the limited historical data. Due to Covid 19, the historical data and demand sales are changed and lower than normal situation; therefore, the data used in this research are available only year 2021 and 2022. However, the accuracy of forecast value is nearly to the actual one for 2022. The selection of forecasting models for other SKUs of other customers are suggested to conduct in the future. This make both sub-dealers and a company know more accurate demand and make better decision of inventory plan.

In term of an inventory control, this research focuses on only three best-selling products from the group of sedans redial tire. Demand analysis and forecast value from the suitable techniques are the input to stimulate the inventory control policy. Moreover, this experiment in this research might not be the representative of the real situation since this simulation are done with ideal environment. The proposed policy is suggested to be perform in the real situation to determine the real outcomes. The policies for other products are also suggested to be performed. A company may start with the top 3 best-selling products of other types of tires to determine the change.

Lastly, it can be acknowledged through this research that the proposed forecasting models and policies to improve the inventory control begun with data collection which data plays a key role in the inventory management. The inventory improvement also includes an appropriated policy. The application of an inventory-related strategy and commitment from a company's management level and sub-dealers is advised. With the help of management's

inventory-related plans, the proposed policy will be implemented more effectively in terms of data collecting and with more precision. The improvement of external communication between the sub-dealers and a company is also recommended in order to has better in coordination and data update.

REFERENCES

AGUNBIADE, D. A. & OGUNYINKA, P. I. 2013. Effect of Correlation Level on the Use of Auxiliary Variable in Double Sampling for Regression Estimation. *Open Journal of Statistics,* Vol.03No.05**,** 7.

ANJANI, A. & NIZAR, A. 2021. Inventory management and cost efficiency: A case study in medical devices distributor. *International Journal of Research in Business and Social Science (2147-4478),* 10**,** 217-227.

BALAJI, K. & KUMAR, V. S. 2014. Multicriteria inventory ABC classification in an automobile rubber components manufacturing industry. *Procedia CIRP,* 17**,** 463-468.

BÓNA, K. & LÉNÁRT, B. 2014. Supporting demand planning process with Walsh-Fourier based techniques. *Periodica Polytechnica Transportation Engineering,* 42**,** 97-102.

BOYLAN, J. E., SYNTETOS, A. A. & KARAKOSTAS, G. C. 2008. Classification for forecasting and stock control: a case study. *Journal of the operational research society,* 59**,** 473-481.

CACHON, G. P. 1999. Managing supply chain demand variability with scheduled ordering policies. *Management science,* 45**,** 843-856.

FARAHANI, R. 2011. *Logistics operations and management: concepts and models*, Elsevier.

GORDON, I. 2003. Measuring customer relationships: what gets measured really does get managed.

GUPTA, A. & MARANAS, C. D. 2003. Managing demand uncertainty in supply chain planning. *Computers & chemical engineering,* 27**,** 1219-1227.

HUNG LAU, K. 2012. Demand management in downstream wholesale and retail distribution: a case study. *Supply Chain Management: An International Journal,* 17**,** 638-654.

JONSSON, P. & MATTSSON, S.-A. 2008. Inventory management practices and their implications on perceived planning performance. *International journal of production research,* 46**,** 1787-1812.

LAI, C.-H. & CHANG, H.-L. 2015. Developing An Optimal Multivariate Forecasts Model For Supply Chain Inventory Management—A Case Study Of A Taiwanese Electronic Components Distributor.

MAHARAJ, S. 2017. *Dynamics of demand order management on the Just in Time approach: a case at a stationery distributor.*

MARTIN, C. 2005. *Logistics and supply chain management: creating value-adding networks*, Pearson Educación Limited.

MISHKIN, F. S. 2015. *Operations Management: Processes and Supply Chains, Global Edition*, Pearson Education Limited.

MURRAY, P. W., AGARD, B. & BARAJAS, M. A. 2015. Forecasting supply chain demand by clustering customers. *IFAC-PapersOnLine,* 48**,** 1834-1839.

NENES, G., PANAGIOTIDOU, S. & DEKKER, R. 2010. Inventory control policies for inspection and remanufacturing of returns: A case study. *International Journal of Production Economics,* 125**,** 300-312.

NERDNOI, N. 2014. *Inventory control system improvement in an automotive adhesive company.* Chulalongkorn University.

NULDÉN, N. 2017. Enhancement of Short Term Demand Planning in Highly Dynamic Supply Chains. A case study at a pharmaceutical distributor.

RAMOS, E., PETTIT, T. J., FLANIGAN, M., ROMERO, L. & HUAYTA, K. 2020. Inventory management model based on lean supply chain to increase the service level in a distributor of automotive sector. *Int. J. Supply Chain Manag,* 9**,** 113-131.

REINARTZ, W., KRAFFT, M. & HOYER, W. 2004. The customer relationship management process: its relationship management measurement and. *Journal of Marketing,* 41**,** 293-305.

RELPH, G. & MILNER, C. 2015. *Inventory Management: Advanced methods for managing inventory within business systems*, Kogan Page Publishers.

RIZKYA, I., SYAHPUTRI, K., SARI, R., SIREGAR, I. & GINTING, E. Comparison of Periodic Review Policy and Continuous Review Policy for the Automotive Industry Inventory System. IOP Conference Series: Materials Science and Engineering, 2018. IOP Publishing, 012085.

SANDERS, N. R. 2013. *The Definitive Guide to Manufacturing and Service Operations: Master the Strategies and Tactics for Planning, Organizing, and Managing How Products and Services Are Produced*, Pearson Education.

SEIFERT, D. 2003. *Collaborative planning, forecasting, and replenishment: How to create a supply chain advantage*, AMACOM Div American Mgmt Assn.

SHIVSHARAN, C. T. 2012. Optimizing the Safety Stock Inventory Cost Under Target Service

Level Constraints.

SYNTETOS, A. A., KEYES, M. & BABAI, M. Z. 2009. Demand categorisation in a European spare parts logistics network. *International journal of operations & production management,* 29**,** 292-316.

TASDEMIR, C. & HIZIROGLU, S. 2019. Achieving cost efficiency through increased inventory leanness: Evidences from oriented strand board (OSB) industry. *International Journal of Production Economics,* 208**,** 412-433.

ULAGA, W. & EGGERT, A. 2006. Value-based differentiation in business relationships: Gaining and sustaining key supplier status. *Journal of marketing,* 70**,** 119-136.

VAZ, A. & MANSORI, S. 2017. Target days versus actual days of finished goods inventory in fast moving consumer goods. *International Business Research,* 10**,** 19-34.

WATERS, D. 2021. *Logistics An Introduction to supply chain management*, Palgrave macmillan.

VITA

NAME	Vasinee Chantaraponpun
DATE OF BIRTH	26 November 1997
PLACE OF BIRTH	Bangkok
HOME ADDRESS	5/23 Watcharapol road, Tarang, Bangkhen, Bangkok 10220