Master's Thesis

Centralized Approach of Inventory Performance Optimization with Controllable Service Level Under Sustainability Issue

by

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Certification Page

I, INDRA Darmawan (Student ID 52115623) hereby declare that the contents of this Master's Thesis are original and true, and have not been submitted at any other university or educational institution for the award of degree or diploma.

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Darmawan, Indra

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Summary

This research uses quantitative approach by using primary data of B2B company that represent supply chain activities which consists of purchasing, sales, and supply chain data to determine the overall supply chain performance. Based on these data, assumptions have been put into consideration to simplify the numerical calculation algorithm such as a *two-echelon supply chain* system which involve one manufacturer/distributor and retailer/customer and according to the real condition, warehouse location is considered as one warehouse system or *centralized distribution*. Normal distribution assumption is used to calculate appropriate *z*-value to be able determine number of expected backorder. A series calculation algorithm model has been designed as research simulation with controllable lead time and customer service level parameter.

By an empirical case study research on an actual company that has issue with their supply chain management with *minus ROI*, author would like to find a solution to those problems by answering “How a well-managed inventory control result in reduced holding cost and maintain adequate service level in B2B industry?” and more importantly “To what extent a service level parameter can be used as the main parameter to measure effectiveness of supply chain process?”. This research objective is to optimize the supply chain performance in B2B company with two stages supply chain network which involves manufacturer, and retailers. The purpose of this research is to identify the supply chain problem in this case study and by using conceptualization and supply chain simulation model to find the optimize condition for the warehouse operational performance. The data that will be used is from hair conditioner producer in Netherlands which is primary data of their supply chain operational activities.

Data are analyzed by using three different ways which associated each other to obtain the expected result. First, is the Centralized approach analysis by using mathematical formulation to determine the optimum expected revenue and obtain optimized operational condition of the supply chain activities. Parameters that are used as decisive variables are Lead time and service level. As the control variables are order quantity, and re-order point. Second step is to identify items and categorized them to different type of item using ABC analysis which later will be used for service level analysis and observing characteristic of each type under different service level condition. Third step is service level analysis to observe how expected revenue would response under different service level objectives.

Based on the result, shows how service level and lead time interrelated each other that high service level reflects quicker response from distributor to fulfill market demand. On the other side relation between service level and cost shows an inverse correlation that as service level goes higher cost of inventory utilization also increase therefore reduce the expected revenue of supply chain activities. The implication of this research provides insights of what variable directly and indirectly related as a measure for customer satisfaction. Broad perspective of correlated parameters within the inventory activities is also provided to show what control parameters need to be adjusted to meet certain service level objective

CHAPTER I

INTRODUCTION

1.1 Introduction

In the industry, supply chain has been considered as a critical factor that can determine company's long-term success with sustainable and stable business. Nowadays many scholars and business practitioners started to evaluate and improve their supply chain performance. There are ways to measure supply chain performance such as by using supply chain operation reference (SCOR), key performance indicator (KPI), or house of quality (HOQ). Specific performance variable also necessary to be taken to account as the focus of performance measurement. This research paper deals with measuring service level performance as main parameter to find a balance between warehouse stock and minimizing operational cost. Therefore, an important factor is required a well-managed inventory management.

In supply chain management, inventory management is considered as main parameter that determine whether the supply chain performance is efficient. As it deals with a various operational parameter such as lead time, production capacity, days inventory outstanding, holding cost, also can determine customer satisfaction through measuring service level. A world class company like Apple has achieved a great success over the past years after discovered the market interest and created a simple, friendly interface yet sophisticated technology. As a world class company apple has their own strategy of managing inventory to maintain stock level appropriate to market demand. Both type of product and product availability complement each other to meet market expectation and boost the customer satisfaction. Wal-Mart success story also attributed to their supply chain management. They made innovative supply chain process which makes a good collaboration with their suppliers and comprehensive information exchange throughout their supply chain line.

In this regard, an agile world class company must have a well-managed supply chain as their main factor that leverage their business to become success. Therefore, it can be considered that managing stocks in the warehouse should be minimum to a point where it still appropriate to the market demand. However, this is easier said than done practice since there are lots of uncertainties within the market which make deciding stock level is difficult. Market demand has an uncertain behavior which make warehouse stock managers need to take safety stock level into consideration. Thus, to maintain customer expectation can be managed through service level agreement between distributor and customer as a contract to how many stocks that manufacturer required to fulfill in a certain period.

Maintaining service level is two edges critical factor for a company because it is associated with internal and external success factors. From Internal perspectives, it is affecting the stock level that required to be provided to meet the demand and external perspective is how good customers are being treated by the company of providing enough amount of stocks within agreed time schedule. Amount of stock level contributes to company's production capacity, speed, efficiency, stock available in the warehouse, holding cost, and so on. Meet customers demand also important as a sustainable success factor in long term because company enable to gain customer's trust and ensure long term relationship. Therefore, it is important for company to know the balance of stock level with the service level agreement to keep minimum operational cost in the whole supply chain process by full filling the customer's service level agreement.

Gunasekaran A et al. (2003) has said that to a world class company customer satisfaction is their utmost priority because without customers supply chain strategy cannot be considered effective. Lee and Billington. (1992) and Van Hoek et al. (2001) emphasized that center of supply chain performance must focus on customer satisfaction. In that sense, supply chain performance can be evaluated from the customer satisfaction level perspective. Therefore, to have sustainable business and competitive advantages, it is important for a company to focus their supply chain improvement of services focus on customer service quality. Within the supply chain process considering on customer service quality also affect the distribution cost because measuring individual cost of product and considering the impact to each customer service quality encourage trade off that make distribution system more effective. Gunasekaran A et al. (2003) has discovered three highest supply chain important parameter that associated with customers in rating percentages 1) Quality of delivered goods 12.34 %, 2) On time delivery of goods 12.20%, 3) Flexibility of Service system to meet customer needs 11.43% . Therefore, customer service is important parameter in supply chain process that determined the overall performance of supply chain. As Paul Hoffman and Gerald Reiner. 2006 has argued that a performance measurement system providing information on ongoing process performance and showing the effects of process changes is basic prerequisite for improving process.

By an empirical case study research author would like to answer, "How a well-managed inventory control result in reducing holding cost and maintain adequate service level in B2B industry?" and more importantly "To what extent a service level parameter can be used as the main parameter to measure effectiveness of supply chain process?". This research objective is to optimize the supply chain performance in B2B company with two echelon supply chain network which involves manufacturer and retailers. The purpose of this research is to identify the supply chain problem in this case study and by using conceptualization and supply chain simulation model to find optimize condition for the warehouse stocks. The data that will be used is from hair conditioner producer in Netherlands which is primary data of their operational activity.

The data that will be used is from hair conditioner producer in Netherlands which are secondary data of their operational activity. The working definition of this research are two echelon supply chain (one warehouse – multi retailer) limited to one company's condition with only 7 types of products with B2B business model. In this research, the current condition of supply chain operational will be examined particularly the inventory performance by doing analysis on each class items and see how service level gives effect to the inventory control method in relation to operational cost. The working definition of this research are two echelon supply chain (one warehouse – one retailer) limited to one company's condition with only 7 types of products with B2B business model.

CHAPTER II

LITERATURE REVIEW

2.1 Literature Review

Supply chain management has been a critical factor that determine business productivity and profitability. A lot of studies and research has been conducted to improve and evolve current supply chain practice from various supply chain parameter perspective. The range of supply chain studies are quite vast since it involves overall aspect from upstream to downstream business such as supplier, internal company, distributor, and end customer. Basically, supply chain connects these aspects and deliver goods in an efficient way which is going forward toward end customer with minimum cost and high-quality service possible. These activities also supported by the flow of information in each supply chain stage which is going backward from end customers toward suppliers as a basis of coordination and decision making within supply chain process. Furthermore, it is necessary to measure supply chain performance based on its parameters and as one of important factors in business, one of the methods customer satisfaction can be measured by how much demand full filled by the product stock available as well as delivery time, lead time, minimum order quantity, production capacity, warehouse capacity, holding cost need to be considered.

Traditionally, inventory management in supply chain process is challenging because it gives direct impact to operational cost and customer service level which is critical to determine if the supply chain process is efficient. Operational cost such as holding cost can be reduced by minimizing stock in the warehouse and reduce days inventory outstanding (DIO). However uncertain demand, uncertain supply, production cycle times make it necessary to have safety stock at certain level to solve the volatility behavior of the supply and demand (W. Jammerneg and Gerald Reiner.2006). It is necessary to have access to measure supply chain process to monitor and evaluate whether there are any unnecessary steps within the line that can be adjusted, eliminated, or improved. In terms of improving a current process measurement such as KPI can be a valid parameter to determine the performance quality. To asses and improve company's process efficiency KPI gives a specific insight on operational parameter such as production processes, capacity, inventory turnover, lead times which are important. These indicators must cover two factors: contribute to efficiency requirements and must be possible determine financial effects (W. Jammerneg and Gerald Reiner.2006).

Measurement indicator that related to this research is a *Generic Supply Chain* KPI which W. Jammerneg and Gerald Reiner.2006 explained that it covers evaluation of the entire supply chain process. For instance, service level as reflected by the end customers can be used as a generic indicator that determine the quality for entire supply chain process also can be identify problems within stages of the chain. It has been researched that customer's perception is not always the same as manufacturer's perception in regard supply chain performance. For instance, customer may give more value to low cost, on time delivery, good product quality, customized product, delivery date certainty. Companies are focusing more on after sales services that make them possible to enhance customer satisfaction which is hold the key to sustainable business in the long run. Establishing relationship between customer-manufacturer-supplier can improve operational performance and customer satisfaction. Mostly customer oriented companies are focusing on how to deliver efficient and effective services to their customers without putting aside operational factors such as product description, product availability, order status, and so on. Quayle, (2006) states that customer service is defined by demand forecasting, service levels, order processing, after sales service/support, and after market operation. Therefore, a further analysis about how service level can be used to evaluate entire supply chain process quality which related to how well the inventory is managed to provide sufficient stocks with minimum holding cost and how it can be optimized to identify the optimum point of inventory and customer's service level relation.

As the rising awareness of how important considering customer satisfaction for sustainable business, both researchers and practitioners have started a research to investigate and find a relation between these two factors. Asif Salam et al in 2015 mentioned in their research that the key of customer satisfaction from technical perspective lies in inventory performance. As inventory performance defines stock availability to meet fluctuation of customer demand. Their findings show how inventory level significantly define customer service level. On the other side, to meet high service level means that inventory level also high which increase the inventory holding cost as a trade-off of high service level. The result suggests that information sharing between vendor and buyer need an accurate and real time to provides accurate demand forecast and minimum holding cost while keeping service level high. Asif Salam et al 's research discusses an appropriate coordination of inventory management policy for retail chain to provides better balance inventory and service level.

A. Gunasekaran et al. (2001) has said that in a supply chain, inventories consist of various range from raw materials, subassemblies, and assemblies to finished product.

It can judge that the role of inventory is crucial and in most cases inventory can hold up to 50% of company's assets and of course costly. Bad inventory planning and stock management can lead company suffer from high holding cost. Therefore, inventory need to be managed base on the customer's demand and product stock value classification. That way company can separately put each stock category in the inventory whether the stock considered as fast-moving goods or slow-moving goods. Harrington. (1996) noted that "Inventory is where the biggest cost is hidden in most business today". There are four basic link that constitute the supply chain (1) plan, (2) source, (3) make, and (4) deliver. Altogether these links can be used to measure the overall supply chain performance and identify specific aspect to make continuous improvements and enhance the quality in certain area. Lee Billington. (1992) has argued that there were no measures for the overall supply chain, however those companies that have metrics often do not directly related to customer satisfaction and they were not monitored regularly.

There are various aspects that affect the performance of supply chain management. Coordination issue is one of the most critical problem that determines the information flow within coordination to have an efficient practice of supply chain activities. As Yina Le, et al 2011 discussed of how coordination issue which consists of vendor and buyer within service level constraint under controllable lead time. Comparative studied has been conducted between centralized and decentralized approach to find which type of supply chain coordination provides highest expected revenue. Price discount mechanism is induced to make vendor and buyer accept centralized model. The result shows that, shorter lead time can improve expected revenue for supply chain system.

Saeed Alaei, Alireza Hajji, Reza Alaei, and Masoud behrasv in 2015 has researched a theoretical game approach for two echelon stochastic inventory system.

They studied the differences between centralized and decentralized approach. They formulated the condition which the retailer applies inventory policy and the relation with manufacturer. This condition is the one they focused to study in the research. Centralize approach is giving the optimal solution of the entire system and decentralize approach is based on Stackelberg game which the manufacturer is as upper echelon or the leader. Through two numerical studies to compare between two approaches they concluded that decentralized approach reduces system's cost efficiency. Moreover, rises the lead time and order quantity relative to the centralize approach.

Pablo and Rodrigo (2009) has studied the inventory level optimization within distribution network design problem by using the proposed approach which is deals with service level and inventory decision, simultaneously with network design decision, and incorporating unfulfilled demand cost in the previous inventory location model. They were used two step approach model which are first is determining the optimized service level and the second step addresses location and inventory decision. Their methodology was applied to a small example for a company which considers 6 warehouses and 10 customers to be served. Unit Penalty Cost 600,700,800 were considered as a comparison to the relation with optimal service level should be agreed for determining the inventory level. In calculating the optimum service level of each penalty cost variable was using iterative approach and the equilibrium solution of each penalty cost variable was done by three iterations for small numerical example. The results were compared to a simple service-level search procedure which solved the inventory-location model in 30 times for different service level value.

Asif Salam, et al 2016 had done a research about the role of inventory storage in retail supply chain service level. The research indicated that success factor of customer service lies in the product availability. Based on that product availability is considered as most vital decision that any retailers need to make. This study examines an inventory system utilizing a simulation based model in Thailand fast moving consumer goods company. The result suggests that, the responsive of service level depends on how well managing the supply chain process to reduce logistic cost. The findings revealed how demand variability and service level are found to be the most significant variables that influence the inventory level. This study promotes the importance of having well-managed inventory policy to have a better balance inventory and service level. As this paper suggest that, inventory management policy hold the vital role of overall supply chain process that affects broad operational factor that need to be configured carefully to give better cost balance within the operational activities.

Jha and Kripa (2008) also studied about supply chain inventory model with controllable lead time and service level constraint. The problem was two echelon supply chain models with single vendor and single buyer. Basically, they made a model for an integrated buyer-vendor problem to determine the optimal order quantity, lead time, and number of shipment together during the production cycle while minimizing the expected operational cost. Service level constraints are included in the model to determine the right proportion of demand to meet each cycle. A numerical model is proposed to illustrate algorithm procedure and observe the correlation between parameters to analyze behavior of the model. As the result of this calculation saving of buyer and vendor are investigated from implementation of integrated optimization that minimize their cost independently.

Pohlen and La Londe (1994) has studied activity-based costing implementation in logistic through open ended questionnaire and it indicated that the use of ABC method is enable them to extract information for budgeting and planning process. Application within planning area primarily focused on identifying reengineering area and strategic positioning. Based on the responses logistic and manufacturing division produced the highest response. It indicates that mostly ABC implementation area is on logistic and manufacturing division which it expressed from the survey result that implementation in manufacturing shows 47% and Logistic shows 65%. By implementing ABC method, the survey result shows that company has been able to identify cost driver and improve cost information. Related to this research, ABC analysis will be used to investigate whether there are differences in characteristic between different class items that affect the inventory performance.

To proceed toward research objective and to solve one of the issues of inventory control decision, in this paper four research questions has been set.

2.2 Research Question

1. How a well-managed inventory control result in reduced holding cost and maintain adequate service level?
2. How to determine optimized supply chain process condition through model simulation?
3. What variables dominantly affects the supply chain performance in this research case study?
4. To what extent a service level parameter can be used as the main parameter to measure effectiveness of supply chain process?

CHAPTER III

RESEARCH METHODOLOGY

In this research, a quantitative approach has been selected to investigate and provide solution for inventory issues in relation to have minimum inventory holding cost by considering on customer service level. Service level can be defined as trade-off between more inventory and more stock out. This trade-off can be described as the risk of potential over-stocks versus the risk of potential stocks-out. These two factors are opposite to one another but still in the same nature of safety stock (Liang, Liping; Atkins Derek. 2013). As Gunserakan A. (2001) has stated that almost 50% of company's asset is hold up by inventory, this way inventory must be considered as a critical factor of company's performance. Therefore, this research is aiming to provide some more insight on how step by step inventory should be handled properly and what measure should be taken to solve inventory problem and how it affects the supply chain process.

3.1 Industry Background

TCC company is one of personal product manufacturer in Netherland. The product lines of TCC is involved shampoo, conditioner, all-purpose crème, either in bottle or jar package. TCC is not only as manufacturer but also as distributor of their products to their customers all over the world. They deliver the order from stock the day after customer place an order. As manufacturer TCC produce all its products itself. The raw materials are mixed in a mixer and immediately after, bottled in bottling line. The bottling line is used for both types packaging bottle and jar.

Component are purchased from local and global suppliers. Each supplier has their own characteristic of providing qualified raw materials based on TCC standard quality. The ones that TCC chose as its supplier are the ones with feasible delivery time to be able keep up with the demand fluctuation. Supplier that are certified most likely have good delivery reliability. Among certified suppliers next consideration is price that is offered. Thus, supplier that is certified with good delivery reliability and the best offered price would be chosen by TCC. Components cannot be always immediately used for production. Therefore, TCC its own raw material warehouse to store them. Packaging material, Texapon, and Liposome are delivered in pallet. Preservatives and perfumes are delivered in reservoirs.

Recently a critical financial situation stroke TCC which affect their ROI became minus. Due to a tight market competition and the rising concern about product sustainability under European regulation. TCC started to invent new product lines that seemed promising in the market and tried to meet the sustainability concern. However, since TCC's supplier is from all over the world which the standard is not align with Europe regulation then it brought in problem to TCC and suffer from sustainability penalty.

Based on their financial statement in 2015 they had a good gross sales profit and sales bonus profit. However, on the other side this revenue is neglected because of this issue that caused by sustainability penalty that TCC suffer and had to pay big amount of money. Furthermore, some of the products they were selling had minus gross margin which possibly affect the sustainability penalty. Problem hypothesis of the problem is down to the supplier quality that provides raw materials to TCC.

The scope of this research is to evaluate current TCC's inventory performance under this sustainability issue. The result can be used for further decision making of adjusting inventory operational performance and determine supplier characteristic for a better quality of service and have been certified both in delivery reliability and product sustainability. A centralized approach has been chosen to give an insight of inventory performance prior to the revenue of supply chain expected revenue. Detail about the method will be discussed in the next sub-section.

3.2 ABC Analysis

The first step of analysis is determining the value of current items in inventory by using Activity Based Costing or ABC analysis. To utilize ABC analysis some variables are needed as determinant factors of item value such as annual demand of each item, unit cost per item, and inventory level status of each item. ABC method is an efficient inventory analysis method by assigning each class items in dollar value which is done by multiplying each item dollar value by the annual demand of the item. The top 10% of highest dollar value classified as class A items, the next 30% as class B items, and the rest 60% as C class items. Then the next step of this method is to determine the level of inventory of each class item. Class A items represent highest dollar value in the inventory, therefore A class items need tight inventory control. Class A items stock should be kept as low as possible in the inventory and the safety stock minimized. Class B and C items usually has less monitor and control also high level of stock usually can be maintained with larger safety stock (Russel; Taylor.2011). However, class B items need to be monitored for evaluating if there are potential items that can be A class item.

Table 3.1 Item Classification for ABC Analysis

Item Class	Dollar Value	Control	Assigned Service Level
A	Top 70%-80%	Tightly Frequent	96%-98%
B	Medium 15%-25%	Intermediate Frequent	91%-95%
C	Low $<$ 5%	Less Frequent	85%-90%

As table 3.1 shows the item classification for ABC analysis, once each item has been classified to each category a control measure can be decided appropriate to each class characteristic. Same control method on different characteristic items are inappropriate way of managing inventory, as described in ABC method that high dollar value items must be controlled strictly because it holds most of the total inventory value and can be fatal if company lose control over high value items since it will impact company's most profit.

3.2 Model Description

Analysis in this product is based on products from non-perishable product distribution center. Reason for this selection is because company's product is personal care product such as shampoo, conditioner, hand & body crème. Raw materials frozen period, expiry duration of raw materials is not considered in the calculation. Case Study model is a single distribution center where all distribution decision is centralized. Therefore, centralized approach is chosen to provide insights from centralized decision-making supply chain and determine the highest entire supply chain revenue.

The research has been conducted using historical secondary data of TCC manufacturing company for 6-months period. The historical data is consisted of:

1. Sales and demand data for the last six months
2. Supply chain data; on hand inventory, Process production performance
3. Financial Statement

This raw historical data is used to execute the simulation using centralized approach by following the proposed algorithm in excel. Decision variable in this research are *Q, L, m,* where:

Q:	Buyer's order quantity
L:	The lead time length
m:	Number of lots which product delivered from vendor to buyer

And other related variables are:

D:	Average Demand / year	*A:*	Buyer's ordering cost per order
P:	Producer's production capability (*P*>*D)*	*S:*	Vendor's setup cost per setup
p:	The buyer's retail price	h_r :	Buyer's unit holding cost
w:	Vendor's wholesale price	h_s:	Vendor's unit holding cost
C:	Vendor's unit production cost	θ :	Proportion of demand that are not met from stock

Through simulation an observation of 7 types of product the inventory performance of each product can be monitored. Simulation result is used to evaluate overall inventory performance and propose optimized solution. In-order to answer research questions, 3 out of 7 are representative sample that have an appropriate result which align with the basic assumption of the equation will be used to observe in more detail the relation of service level and inventory performance.

Assumption has been considered to limit the scope research and focus to make sure the significance of the result. The assumptions are:

1. There is a single vendor and a single buyer that represent 7 types of different products
2. Sustainability penalty factor is neglected to determine current inventory performance
3. Setup cost per setup is assumed equal value for each type of product
4. Calculation measurement unit is per week
5. Number of week per year is assumed 52 weeks
6. The buyer orders a lot size of Q and manufacturer produces mQ with a finite production rate P with P > D and ship in quantity over m lots; integer number
7. The demand during lead time is assumed to be normally distributed with mean DL and standard deviation $\delta\sqrt{L}$. That is $r = \mu L + k\delta\sqrt{L}$, where k is safety factor

Under leader-follower relationship theory which in this case vendor is the leader, this model can provide3 insights and measure performance within the internal company's supply chain by focusing on inventory performance measurement. On the leader/vendor side, vendor can choose supply chain policies to maximize their expected supply chain revenue by adjusting number of lots (m). Detail about this concept will be discussed further in the section 3.3.

3.3 Simulation Approach

In this research is using quantitative approach to provide insights of the inventory performance and evaluate of its current condition in the relation between lead time and customer service level. Numerical calculation is executed in excel program to make it easier for data findings and analysis as a table or graph presentation. Numerical formula that is used is centralized approach to analyze the relation of service level to the expected supply chain revenue with controllable lead time. Some excel features are also used such as “NORMDIST” and “goal seek” to find the expected number of backorder under certain service level constraint.

Centralized approach algorithm is used based on previous research that has been proved a solid method to determine the best lead time variable can provide highest revenue for long-run cooperation and centralized solution. Consider the situation is based on classic single decision-making system which requires central planner to manage all the decision for entire supply chain process expected revenue. Under the situation of integrated centralized supply chain mode, a formula is given

$$\text{Max } \pi_{sc}(Q, L, m) = (p - c)D - \frac{D(mA + S + mR(L))}{mQ} - h_r\left(\frac{Q}{2} + k\delta\sqrt{L} + (1 - \beta)\delta\sqrt{L}\Psi(k)\right) - h_s\frac{Q}{2}\left(m\left(1 - \frac{D}{P}\right) - 1 + \frac{2D}{P}\right) \quad (1)$$

s.t $\frac{\delta\sqrt{L}\Psi(k)}{\theta} \leq Q$

(Ouyang, et al.2004)

$\pi_{sc}\ (Q, L, m)$ is concave with the respect of order quantity and convex with respect to lead time. Hence for each L_i (i= 1, 2, ..., n) we can get optimum order quantity under centralized approach would be:

$$Q_i = \left\{ \frac{2D(A+\frac{S}{m}+R(L))}{h_r+h_s(m\left(1-\frac{D}{P}\right)-1+\frac{2D}{P}} \right\}^{\frac{1}{2}} \quad (2)$$

(Li Yina, et all. 2011)

And the maximum expected profit result for entire supply chain can be seen on the lead time interval $L = (L_i, L_{i-1})$ (i=1,2, …, n). As the service level taken into consideration, we can obtain Q with fix $L = (L_i, L_{i-1})$ the optimal order quantity of centralized supply chain mode will be max $\left(Q_{i,}\ \frac{\delta\sqrt{L}\Psi(k)}{\theta}\right)$

$\pi_{sc}\ (Q, L, m)$ is concave with fixed m for fixed Q and $L = (L_i, L_{i-1})$ which indicate that there must be an optimal m to meet eq. (2)

$$\pi_{sc}\ (Q, L, m) \geq\ \pi_{sc}\ (Q, L, m+1)$$

$$\pi_{sc}\ (Q, L, m) \geq\ \pi_{sc}\ (Q, L, m-1)$$

(3)

(Li Yina, et all. 2011)

Hence, Algorithm below suggested to find the optimal value of Q, L, and m under centralized approach.

ALGORITHM

Step 1	Start with m=1
Step 2	For each L_i calculate Q using eq. (2)
Step 3	Calculate $\frac{\delta\sqrt{L}\Psi(k)}{\theta}$ set x_i = max $\left(Q_{i,} \ \frac{\delta\sqrt{L}\Psi(k)}{\theta}\right)$
Step 4	For each set ($x_i, L_{i,}m$) calculate $\pi_{sc}\left(x_i, L_{i,}, m\right)$ using eq. (1)
Step 5	Optimum $\pi_{sc}\left(x_i, L_{i,}, m\right)$ is max $\pi_{sc}\left(x_i, L_{i,}, m\right)$ for any given m
Step 6	Set m=m+1, repeat step 2 to 5 to get optimum $\pi_{sc}\left(x_i, L_{i,}, m\right)$
Step 7	If $\pi_{sc}\left(x_m, L_{m,}, m\right) \geq \ \pi_{sc}\left(x_{m-1}, L_{m-1,}, m\right)$ go step 6, otherwise step 8
Step 8	Set $\pi_{sc}\left(x_m, L_{m,}, m\right)$ = $\pi_{sc}\left(x_{m-1}, L_{m-1,}, m\right)$ then it is the optimal solution for centralized decision model

(Li Yina, et all. 2011)

Under the theory of leader-follower relationship in supply chain both sides vendors and buyers have its own control to decide the optimal option to maximize their own revenue. Buyers as the follower will follow stackelberg game model by adjusting order quantity (Q) and lead time (L) variables to have optimal setting and get the highest revenue possible. On the other side, Vendors can consider corresponding number of lots (*m)* to maximize its expected maximum profit. Under such condition, from eq.3 can be obtained optimum number of lots (m) the first integer that satisfying following condition:

$$\frac{2DS}{m(m+1)} \leq h_s(x^2)\left(1-\frac{D}{P}\right) \leq \frac{2DS}{m(m-1)} \quad (4)$$

After obtaining a range number of optimum lots (m) result will be presented in comparison of different value of m within the range of eq.4. Result that shows the highest value of supply chain expected profit would be the solution for optimal lead time, lots, order quantity, safety stock, and reorder point within the constrain of certain service level variable.

CHAPTER IV

FINDINGS AND ANALYSIS

4.1 Inventory Performance Analysis

In this research, involves 7 different type of products uses centralized approach simulation model. Centralized approach emphasizes on entire supply chain revenue to be maximized under any circumstances. The raw data shows average annual demand for each product, A =823.765, B = 51.057, C =143.292, D = 302.428, E=215.136, F = 215.641, G = 67.888. It can be seen, differences of annual demand on each product suggest different inventory operational condition such as safety stock, re-order point, lead time, and service level. The inventory performance was analyzed at one service level parameter which is set at 99% service level to investigate if this product is beneficial for long-term sales. 99% service level variable considered to investigate the potential of each product at maximum service level possible and determine its characteristic on high service level. By doing so, each product can be classified whether it is good to provide it at high or low service level.

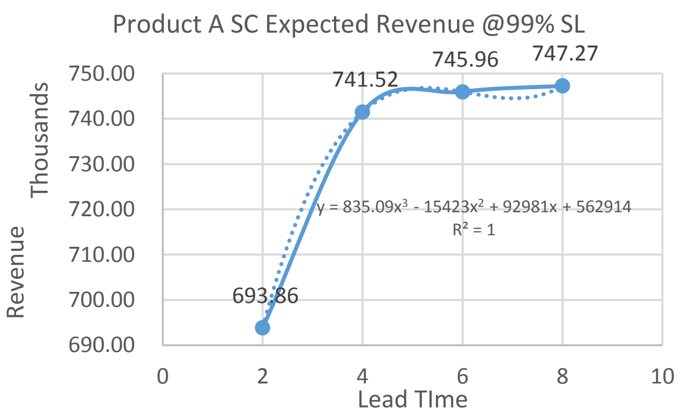
4.1.1 Product A

The simulation result for product A shows under optimal number of lots (m) m=90 at 99% service level variable in the table 4.1 below:

Table 4.1 Product A Centralized Simulation Result

L (Weeks)	Lead Time	Order Q (m)	Expected Shortage	X(i) Units	SC expected revenue
8	0.153	863.82	588	863.82	747269.77
6	0.115	887.33	509	887.33	745958.25
4	0.077	966.68	416	966.68	741518.08
2	0.038	1816.85	294	1816.85	693864.74

In table 4.1 “Expected Shortage” variable is calculated from number of demand can be met in one selling period under certain service level target. This simulation was conducted under 99% service level target also considering several assumptions to simplified the simulation model. Based on above in table 4.1, a scatter graphic representation can be made to show the overall pattern behavior of product A and a regression line equation can be obtained which is shown in figure 4.1:



L (weeks)	SC revenue
1	$641,307.09
2	$693,864.72
3	$725,597.43
4	$741,515.76
5	$746,630.25
6	$745,951.44

Figure 4.1 Product A Supply Chain Revenue Analysis

Based on the regression result as shown in the graph a line equation is obtained with $R^2 = 1$ which means that the regression line is representing 100% of the figured graph. Thus, the regression equation able to give a solid answer regarding every X and Y variables. As shown in figure 4.1, product A will have maximum supply chain revenue at

746630.25 euro on L = 5 weeks. Under these conditions to be maintained well inventory operational condition also need to be adjusted. A simulation result has been obtained by using excel software with NORMIDIST command and Goal Seek features. However, because insufficient data an assumption of standard deviation of annual demand has been put into consideration as much as 10% of annual demand for every variable. Based on centralized approach simulation result, inventory operational condition can be computed as the follow result shown: **(1) Re-order point = 167529 pieces, (2) order quantity = 927 units, (3) safety stock = 177180 pieces.**

Furthermore, further analysis has been conducted to investigate how this operational condition would affected Vendor's and Buyer's revenue. Since supply chain is not always considering on revenue but also beneficial for each actor which involves within the supply chain line to have sustainable business practice. As mentioned before that centralized approach focus on maximizing supply chain revenue, vendor's and buyer's revenue are not considered to be the maximum value. It is aligned with the condition that has been set on the earlier stage of analysis. Buyer's and vendor's is calculated using the same step of simulation with only different variables. The result is shown on table below:

Table 4.2 Vendor's and Buyer's Revenue for Product A

L (weeks)	Vendor's Revenue	Buyer's Revenue
1	$194,117.3	$347,035.45
2	$214,148.4	$395,426.4
3	$270,575.1	$447,272.75
4	$332,007.2	$505,074.4
5	$367,054.5	$571,331.25
6	$344,326.8	$648,543.2
7	$232,433.9	$739,210.15
8	$-14.4	$845,832

As shown in table 4.2 that lead time variable has been set to 5 according to centralized simulation result and resulting vendor's revenue is 367,054 euro and buyer's revenue is 571,331 euro which happen to be the maximum value compare to other lead time variables.

The overall result of product A analysis suggest that this product can be a sustainable product for a long-term business along the supply chain process. The current initial lead time of product A is 12 weeks and optimization result is 5 weeks. This change would make a great impact for the entire process and scheduling. Furthermore, through a proper inventory management this product can be promising for sustainable product because based on the simulation result optimized condition suggest that supply chain, vendor, and buyers can have maximum revenue upon the selling of this product. Among other product that TCC is selling, product A is the highest demand value and gives value added chain to maintain good relationship with retailers and suppliers since it is beneficial for both parties.

4.1.2 Product B

Product B analysis result is obtained under optimum number of lots (m) = 8 at 99% service level variable.

Table 4.3 Expected profit of Product B

L (weeks)	Supply Chain	Vendor	Buyer
1	-$14,045.77	-$13,489.01	$26,180.31
2	$6,786.24	-$9,312.27	$27,008.75
3	$18,885.01	-$6,400.70	$27,433.80
4	$24,427.52	-$4,515.22	$27,554.94
5	$25,590.75	-$3,416.75	$27,471.63
6	$24,551.68	-$2,866.22	$27,283.34
7	$23,487.29	-$2,624.56	$27,089.57
8	$24,574.56	-$2,452.69	$26,989.77

As we can see in table 4.3 the optimum lead time for maximum value expected supply chain revenue is $25,590.75 with L=5 weeks. However, compare with product an expected revenue for vendor and buyer shows different behavior. Vendor expected revenue shows negative value over all lead time (L) variable. Under optimum lead time (L) = 5 vendor's and buyer's expected revenue shows -$3,416.75 and $27,471.63. The result suggests that, product B gives a positive revenue toward supply chain line and buyer, but in the other hand it gives negative impact to vendor or seller. This product may lead to a greater loss in the long run though it has possibilities to make added value chain for retailer's side.

Based on table 4.3 we can see that the longer lead time smaller the loss, let us assume if the lead time is controllable and set the lead time for more than 10 weeks. The effect of long lead time will impact the stock availability, late distribution, cannot meet market demand, and eventually loss market share. Considering this impact that may affect company in the long run, product B can be considered as unsustainable product. However, there is also another factor that must be considered such as the service level variable. Product B might be able to be sustainable product in lower service level variable. Though, the characteristic won't be much different such as low expected revenue for vendor or seller. Figure 4.2 shows the behavior of supply chain revenue for product B

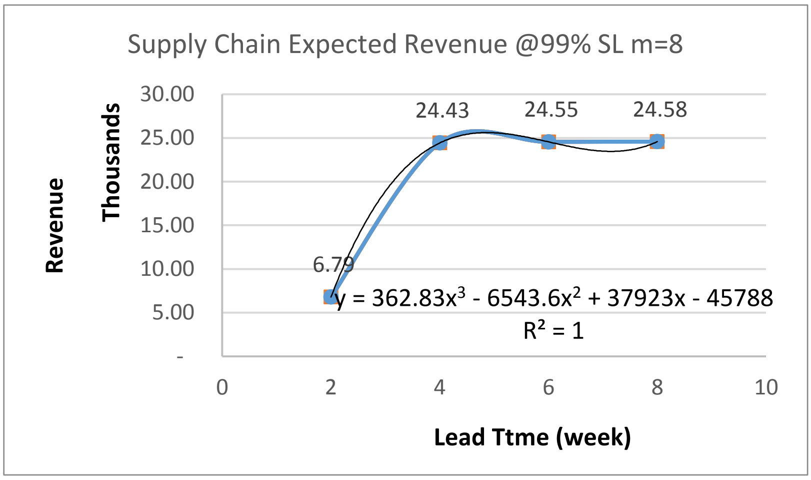


Figure 4.2 Product B Supply Chain Revenue Centralized Method

Figure 4.2 shows that lead time range from 2 to 4 weeks result in low expected revenue since faster lead time means that company should increase their production capability by making investment to buy more machinery, land for warehouse, increase number of staff, and so on. Furthermore, lead time range 4 weeks to 8 weeks shows that supply chain expected revenue can be considered as constant change. However, lead time range from 4 weeks to 6 weeks has maximum expected supply chain revenue value. The inventory performance for maximum supply chain revenue has been calculated which is **(1) Re order point = 13682 units, (2) order quantity = 844 units, (3) Safety Stock Level = 11709 units.**

4.1.3 Product C

Product C analysis result is obtained under optimum number of lots (m) = 22 at 99% service level variable as shown in table 4.4.

Table 4.4 Expected profit of Product C

L (weeks)	Supply Chain	Vendor	Buyer
1	$28,248.71	$4,488.92	$68,518.76
2	$56,144.68	$9,103.46	$71,573.40
3	$72,772.17	$10,410.84	$74,650.10
4	$80,874.44	$9,662.18	$77,726.80
5	$83,194.75	$8,108.60	$80,803.50
6	$82,476.36	$7,001.22	$83,880.20
7	$81,462.53	$7,591.16	$86,956.90
8	$82,896.52	$11,129.54	$90,033.60

Analysis result in table 4.4 shows that the maximum value of expected supply chain revenue can be obtained at lead time L=5 weeks with revenue of $83,194.75. Furthermore, vendor's and buyer's revenue shows positive value with revenue of $8,108.60 and $80,803.50. Following the optimum value of L, inventory operational condition can be obtained to maintain good performance and earn maximum profit which are **(1) Re order point = 28215 units, (2) order quantity = 612 units, (3) Safety Stock Level = 28967units.**

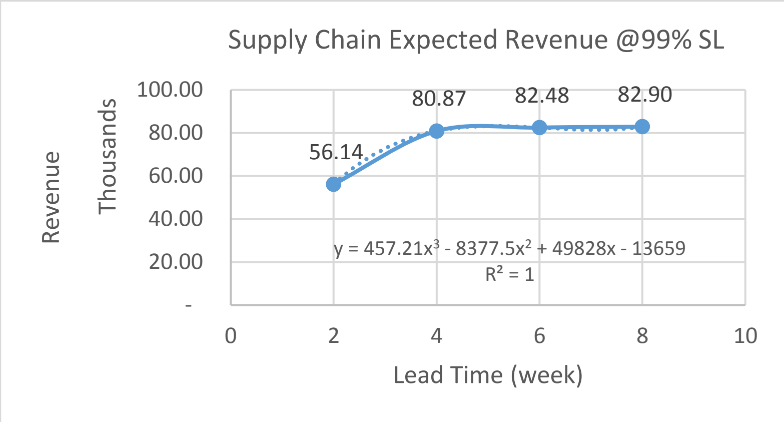


Figure 4.3 Product C Supply Chain Revenue Centralized Method

As we can see in figure 4.3 that product C expected supply chain revenue considerably constant at lead time range from 4 to 8 weeks. This indicates that this product has flexible lead time requirement to adjust with a sudden change in demand, delay, weather issue, and other technical issues that might occur during the distribution process. However, expected revenue decrease when the lead time variable is set below 4 weeks. Although from table 4.4 for we can see that below L=4 weeks expected revenue for each show positive value, it may decrease value chain of the supply chain which can give impacts to customer satisfaction, product quality, delivery reliability, and eventually customer satisfaction.

Based on the simulation result, product C can be considered as sustainable product that can be sold for long term business because have potential to retain retailers/customers in the long run with stable profit for the vendor.

4.1.4 Product D

The simulation result of product D was obtained at number of lots (m)=26 at 99% service level as shown in table 4.5.

Table 4.5 Expected profit of Product D

L (weeks)	Supply Chain	Vendor	buyer
1	$135,828.89	$(44,016.84)	$167,181.66
2	$139,130.42	$(35,373.32)	$169,875.65
3	$141,236.27	$(31,524.88)	$171,642.71
4	$142,393.11	$(30,939.96)	$172,668.58
5	$142,847.63	$(32,087.00)	$173,139.00
6	$142,846.49	$(33,434.44)	$173,239.70
7	$142,636.38	$(33,450.72)	$173,156.41
8	$142,463.98	$(30,604.28)	$173,074.87

In table 4.5 shows that supply chain maximum expected revenue is at lead time (L)=5 weeks with value of $142,847.63. Buyer expected revenue shows positive value of $173,139.00. In the other side vendor's revenue shows quite big negative value. Further analysis has been done to find positive value of vendor expected value and the first positive value can be obtained at L=11 weeks. Considering the amount of demand of product D which is 51057 units annually which is represent 3% of total demand from other products. This number is not significant than the loss that vendors must suffer for putting it into sales. A consideration not to sell it should be put into action to keep cash flow is good and can be used to make investment for other products service improvement.

Figure 4.4 shows that the behavior for supply chain expected revenue has maximum value between lead time L=4 to 6 weeks. More than 6 weeks shows that the revenue is decreasing. Lead time below 4 weeks shows that revenue is drastically plummet which means losing its value and not good for the business sustainability.

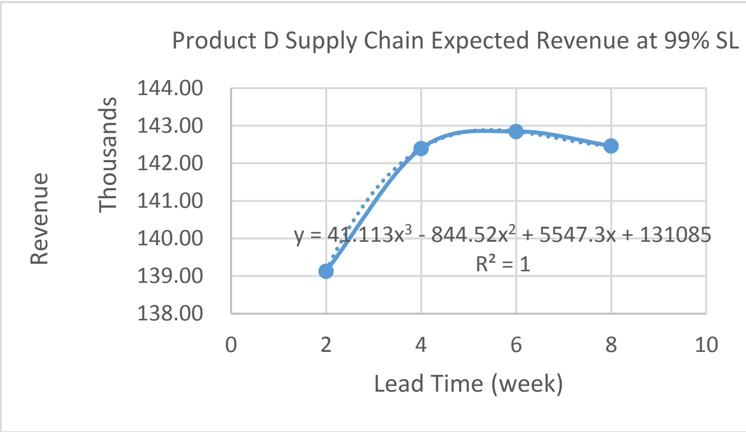


Figure 4.4 Product D Supply Chain Revenue Centralized Method

4.1.5 Product E

Product E simulation result was conducted and resulting the optimum lead time value for maximum supply chain expected revenue is at L=4 weeks and m=10. The result is shown in table 4.6

Table 4.6 Expected profit of Product E

L (weeks)	Supply Chain	Vendor	buyer
1	$231,763.67	$152,480.61	$78,712.30
2	$237,398.76	$156,628.89	$80,405.09
3	$240,249.89	$158,803.30	$81,235.19
4	$240,984.68	$159,456.30	$81,424.42
5	$240,270.75	$159,040.38	$81,194.63
6	$238,775.72	$158,007.98	$80,767.62
7	$237,167.21	$156,811.57	$80,365.22
8	$236,112.84	$155,903.63	$80,209.27

Table 4.6 shows that product E is beneficial for all aspects within the supply chain actors. Expected revenue for supply chain, vendor, and buyer all shows positive value at $240,984.68, $159,456.30, $81,424.42. Compare to other products, product E shows different characteristic of vendor's expected revenue which is has higher value than buyer's expected revenue. Product E can be TCC main product to generate more income for the company, moreover the positive expected revenue indicates that product E is sustainable to be sold in the long run. Product E has 215,136 annual demand which represents 12% of annual total demand. However, in figure 4.5 shows that product E doesn't have much tolerance to lead time changes to keep its good performance.

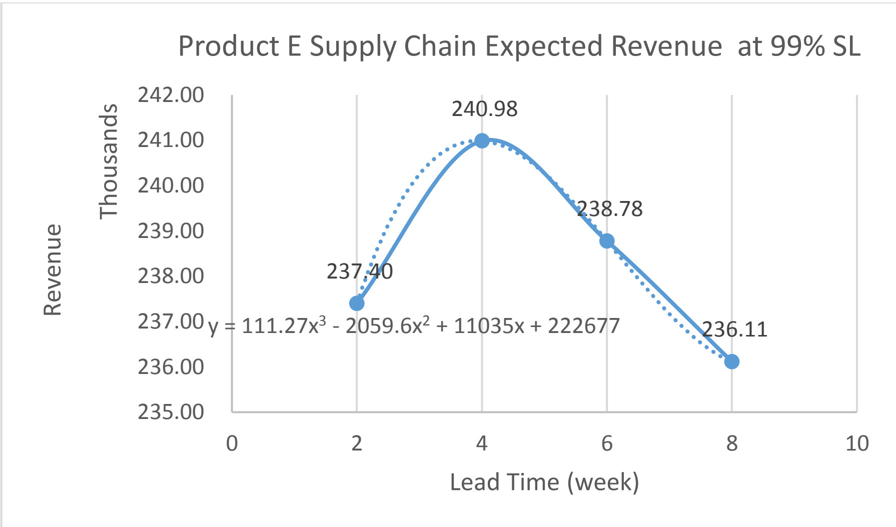


Figure 4.5 Product E Supply Chain Revenue Centralized Method

As in figure 4.5 shows that product E is a sensitive product that can easily be disaster without a proper handling. Outside the range of 4weeks lead time Product E behavior shows that it significantly decreased. However, to keep product E at the best performance, an analysis of inventory operational condition has been conducted and the result has been obtained which are **(1) Re order point = 34622 units, (2) order quantity = 1409 units, (3) Safety Stock Level = 36259 units.**

4.1.6 Product F

Simulation result of product F is shown at figure 4.6 which shows inconclusive result, since the maximum value can't be determined through lead time variable 2 weeks to 8 weeks. However, it shows that behavior of supply chain expected revenue reached maximum value at L=8 weeks. Further analysis has been conducted to see the pattern above L=8weeks as shown in table 4.7.

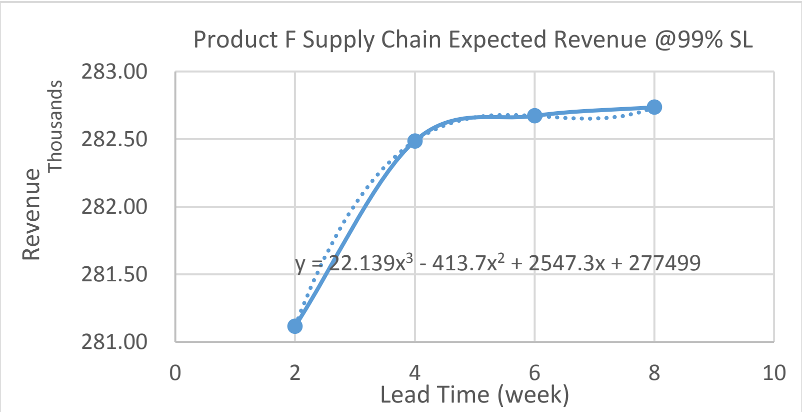


Figure 4.6 Product F Supply Chain Revenue Centralized Method

Table 4.7 Expected profit of Product F

L (weeks)	Supply Chain	Vendor	buyer
1	$279,654.74	$196,000.96	$79,640.36
2	$281,115.91	$195,214.83	$81,821.46
3	$282,015.35	$195,266.31	$82,975.64
4	$282,485.90	$195,867.10	$83,343.25
5	$282,660.38	$196,728.88	$83,164.63
6	$282,671.62	$197,563.34	$82,680.11
7	$282,652.48	$198,082.20	$82,130.05
8	$282,735.77	$197,997.13	$81,754.78
9	$283,054.33	$197,019.83	$81,794.65
10	$283,741.00	$194,862.00	$82,490.00
11	$284,928.61	$191,235.33	$84,081.17
12	$286,749.99	$185,851.51	$86,808.50
13	$289,337.98	$178,422.24	$90,912.33
14	$292,825.42	$168,659.22	$96,633.01
15	$297,345.13	$156,274.13	$104,210.88
16	$303,029.94	$140,978.66	$113,886.27
17	$310,012.71	$122,484.53	$125,899.54
18	$318,426.25	$100,503.41	$140,491.02
19	$328,403.40	$74,747.00	$157,901.06
20	$340,077.00	$44,927.00	$178,370.00
21	$353,579.88	$10,755.10	$202,138.18
22	$369,044.87	-$28,057.01	$229,445.94

Table 4.7 shows that product F simulation result couldn't find maximum expected supply chain revenue. However, as supply chain revenue goes up, vendor revenue goes down. As highlighted part in the table 4.7 that vendor's revenue at L=22 weeks goes negative which means the product is no longer beneficial if exceeded 22weeks lead time. Though it can be considered that product F is feasible to be sold from 1week to 21weeks lead time variable, considering a profit balance between supply chain, vendor, and buyer need to be considered by the supply chain managers. On the other hand, product F has

high tolerance to lead time changes so it is flexible to adjust with the technical issues that may occur on field.

Although considered as flexible product, based on figure 4.6 to maintain the supply chain expected revenue high, lead time should be 4 weeks or above and the inventory operational condition has been calculated as follow: **(1) Re order point = 35162 units, (2) order quantity = 1288 units, (3) Safety Stock Level = 37261 units.**

4.1.7 Product G

Optimum simulation result for product G has found a solution at number of lots (m) = 10 and 99% service level as shown in table 4.8

Table 4.8 Expected profit of Product G

L (weeks)	Supply Chain	Vendor	buyer
1	$31,647.72	$13,637.18	$16,889.85
2	$39,526.16	$14,010.52	$24,882.90
3	$44,316.24	$14,438.35	$29,513.75
4	$46,712.88	$14,862.00	$31,605.30
5	$47,411.00	$15,222.79	$31,980.45
6	$47,105.52	$15,462.05	$31,462.10
7	$46,491.36	$15,521.12	$30,873.15
8	$46,263.44	$15,341.31	$31,036.50

Table 4.8 suggests that product G reached maximum value of expected supply chain revenue at lead time (L) = 5weeks with supply chain revenue is $47,411.00. Vendor's and buyer's revenue shows positive value of $15,222.79 and $31,980.45. Product G can be considered as sustainable product since it gives positive revenue within the supply chain process, vendor, and buyer. However, there are also some lead time constraints that need to be considered to maintain its good performance. Constraint can be determined by considering pattern that showed by figure 4.5

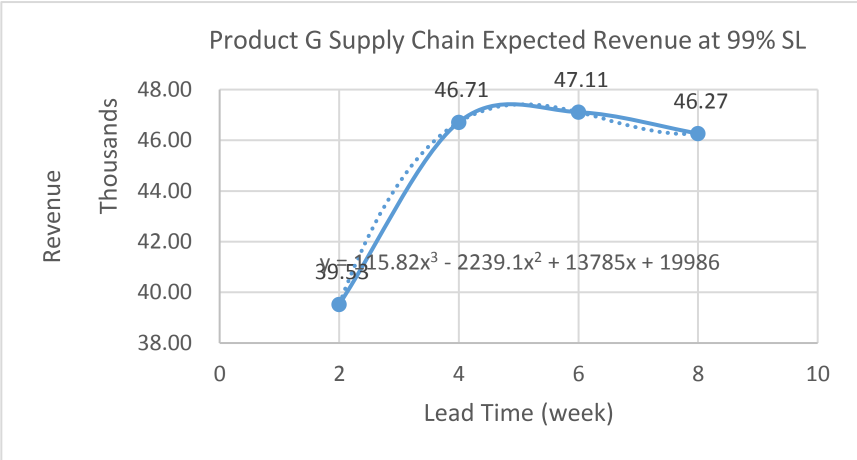


Figure 4.5 Product E Supply Chain Revenue Centralized Method

Based on figure 4.5 maximum supply chain revenue can be obtained at the lead time range between 4 weeks to 6 weeks. Therefore, to maintain this an inventory operational condition has been calculated as operational constraint that can be used as operational parameter to monitor its performance. The calculation results are as follow **(1) Re order point = 12369 units, (2) order quantity = 1310 units, (3) Safety Stock Level = 11728 unit**

Based on the result of this simulation, product lines of that are presented in this research can be categorized into sustainable or unsustainable product by computing each product's expected revenue for supply chain, vendor, and buyer. Furthermore, inventory parameter such as Re-order point, order quantity, and safety stock level can be computed with lead time, and number of lots (m) as decision variable. From this point supply chain managers should be able to make decision by carefully choose which product can be recovered to generate profit and which product need to be eliminated to reduce operational cost and gain more profit. Further discussion about analysis part will be discussed on the next chapter.

4.2 ABC Analysis

ABC analysis classifies products into different class item based on annual dollar value consumption to determine the best control method for each class under different assigned service level. In this analysis, the dollar value was calculated based on the production cost for each product prior to each product annual demand. Thus, will be able to see how much company needs to spend to produce these products and consider it as the company's investment. As the result of ABC analysis each product can be classified to each class as shown in table 4.9 below:

Table 4.9 ABC Analysis Item Classification Result

Product	Value	Value %	Inventory Quantity	Item Class	Assigned SL	Current SL
A	39.14%	71.45%	56.27%	A	96-98%	99.10%
D	20.63%		16.83%	A		98.90%
E	11.68%		5.44%	A		98.00%
F	11.09%	18.83%	5.02%	B	91-95%	97.50%
C	7.73%		8.70%	B		98.80%
G	6.65%	9.72%	4.12%	C	85-90%	93.40%
B	3.07%		3.62%	C		98.70%

The ABC analysis result suggests different priority level and how to control each item class to meet service level target. It shows that product A, product D and product E classified as class A item which represent 71.45% of total dollar value among other inventory items. This means that, a tight control is required to monitor the performance of these product since it can give significant impact to company's profit and possible affecting overall operational activities. Class B items requires medium control which means that these product need to monitor the potential and possibilities for class B products become class A item. Class C items are items that usually high in quantity but low in dollar value which means that the obtainable profit margin from these product is lower compare to other class. However, there are also some cases where class C items is low both on quantity and dollar value. Generally, class C items requires less inventory control, if it meets customer demand for customer retention and maintain stability for the whole business.

4.3 Service Level Analysis

In this section, will cover the relationship between service level and supply chain expected revenue. By analyzing service level relation with revenue, a proper demand that need to be fulfilled can be determined to promote more efficient production system, distribution process, and warehouse carrying cost. However, analysis in this part will use only sustainable products based on consideration from previous analysis. Product C, product D, and product G was chosen as a sample for this analysis. Each of it represent different category of item class of inventory based on ABC analysis. Product C represents item class B, Product D represents item class A, Product G represents item class C. By taking a sample of each item class a relationship of how service level affect each of this product can be observed.

4.3.1 Supply Chain Revenue Under Various Service Level

In this part, discusses the relationship between revenue vs service level for further analysis of how service level can be used as parameter for inventory performance measurement and customer satisfaction. Observation of the result is based on the graphic representation as follows.

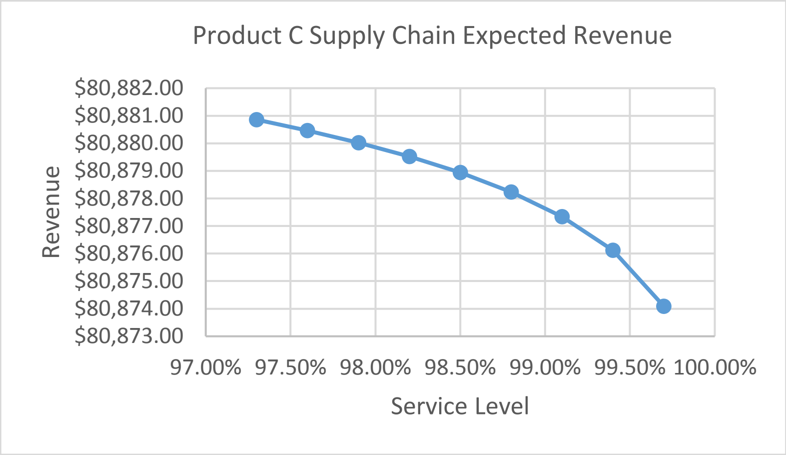


Figure 4.6 Product C Supply Chain Revenue Under Various Service Level

Product C, product D, and product G result of supply chain revenue vs service level shows inverse relationship. The higher service level, less expected supply chain revenue. This indicates that the higher service level objective, available stock at warehouse need to be high and will result higher carrying cost and reduce the expected revenue. This relation shows a trade-off between inventory stock level and cost. It also means that the higher service level higher utilization of available inventory.

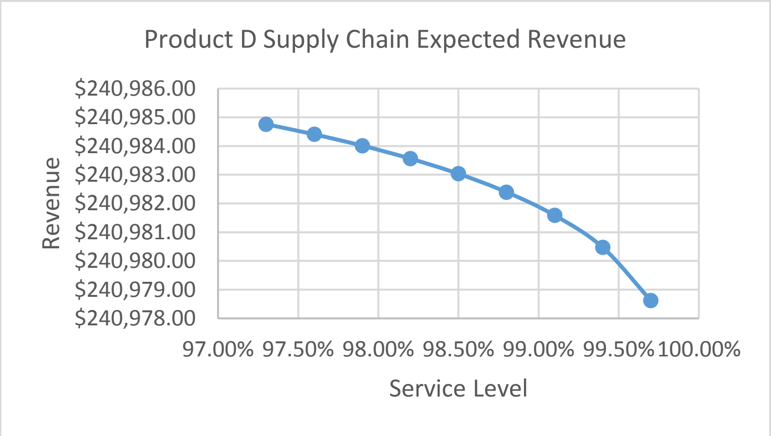


Figure 4.7 Product D Supply Chain Revenue Under Various Service Level

Furthermore, as shown on these figures service level alone is insufficient to be used as parameter to measure the entire inventory performance. Though it able to determine how much cost reduction as the service level increase, practitioners use more technical parameter such as lead time to adjust their operational processes.

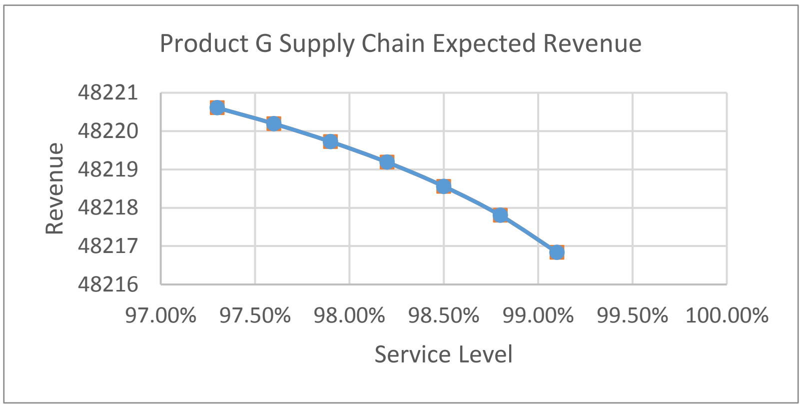


Figure 4.8 Product G Supply Chain Revenue Under Various Service Level

Service level and inventory performance parameters is not directly related. By only using service level as parameter unable to determine demand variability which is affect the inventory level.

4.3.2 Vendor’s Revenue Under Various Service Level

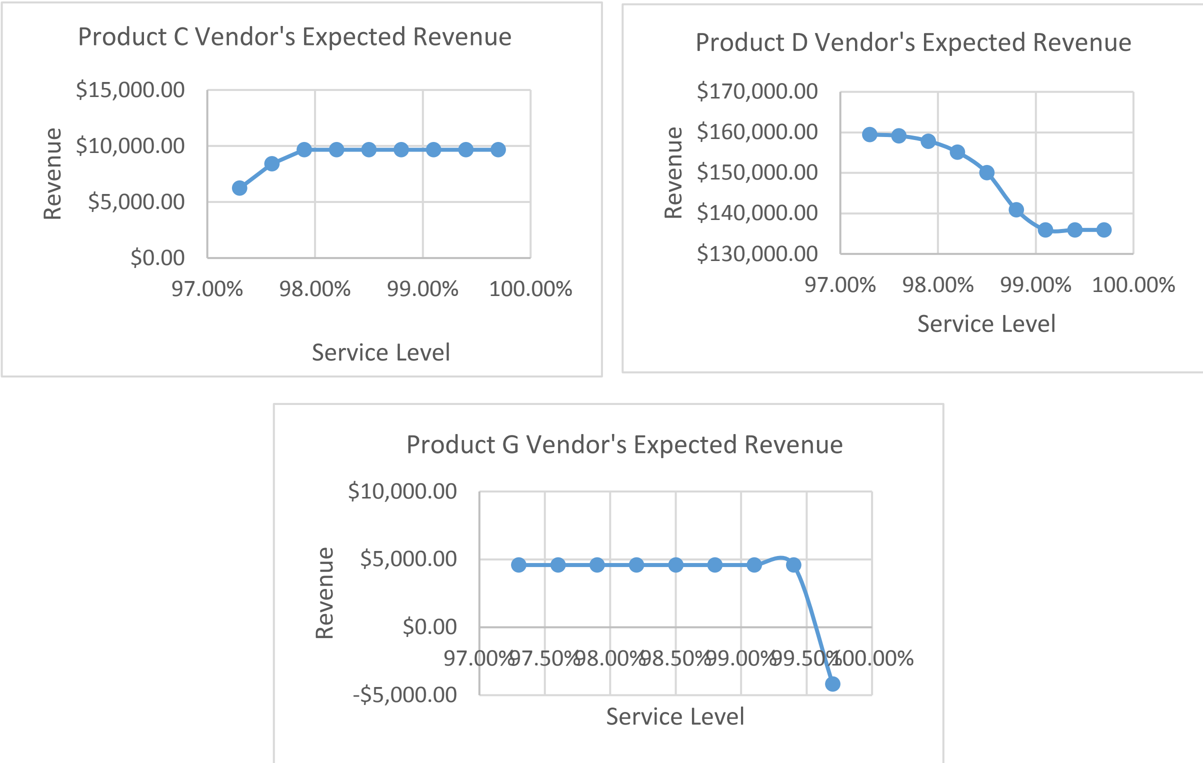


Figure 4.9 Product C, D, G Vendor’s Revenue Under Various Service Level

The simulation result vendor’s revenue vs service level can be observed in figure 4.9 that different product gives different respond. Sensitivity of each product under different service level constraint shows different behavior. Product C as item class B with moderate dollar value based on ABC analysis shows considerably constant value to higher service level. However, at the range of 97% - 98% service level, vendor’s expected revenue incline. Class B item is controlled with normal procedures and less service level objective. The result suggests that if high service level assigned to class B item can provide stagnant expected revenue for vendors.

Product D as item class A shows that it is sensitive to different service level constraint. According to the theory that this result suggests class A item with highest dollar value in the inventory need to be tightly controlled as its hold more than 50% of the entire inventory value. As the result of product D in figure 4.9 shows that the higher service level the revenue for vendor's significantly decline which also means that inventory utilization volume for item class is the highest when service level goes high it cost more and reducing the expected revenue.

Product G is C item class based on ABC analysis as the lowest value stock in the inventory with minimal control procedure procedures. C item class normally assigned 85% - 90% service level objective which means that from figure 4.9 product G provides constant revenue at the higher assigned service level. However, need to be noted that above 99% will give negative impact to revenue drastically.

4.3.3 Buyer's Revenue Under Various Service Level

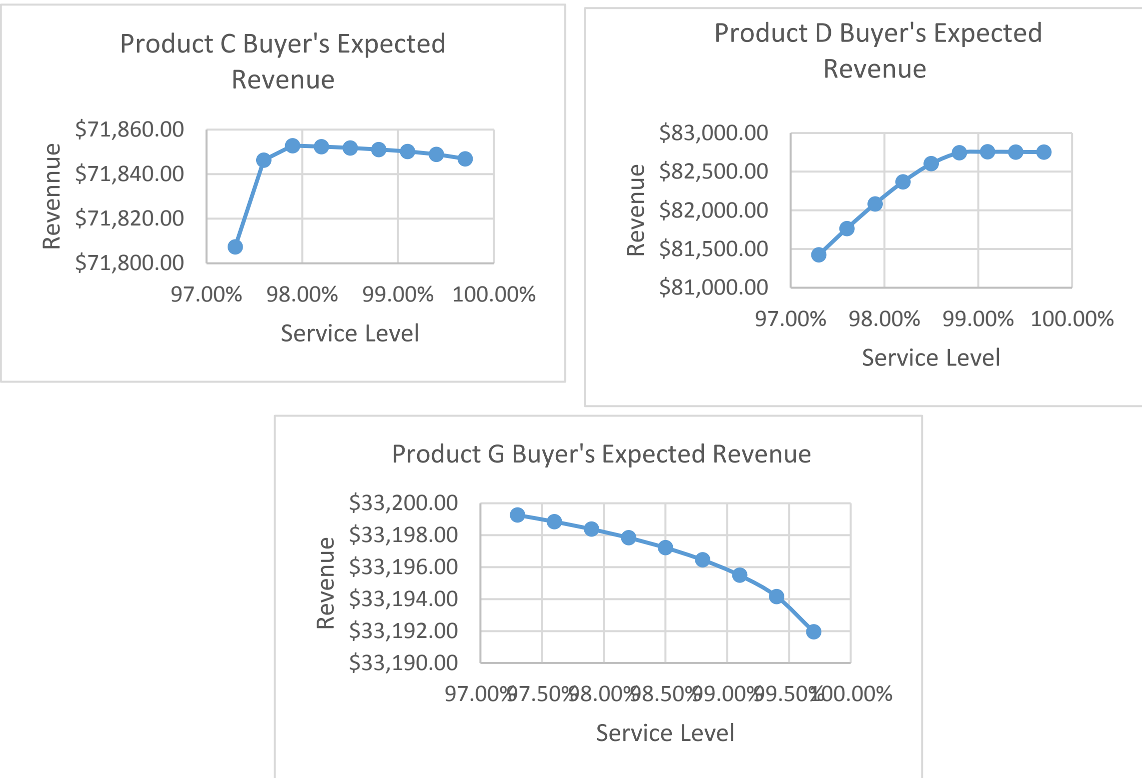


Figure 4.10 Product C, D, G Buyer's Revenue Under Various Service Level

For buyer perspective under different service level of each product also gives various response to the buyer's revenue. Product C and product D result in figure 4.10

shows that the higher service level the revenue considerably constant which means these products provides good incentive for buyers to be assigned in high amount of stock. However, this condition need to be adjusted with vendor's revenue and find a balance where the revenue for both parties reasonably good to make a fair business environment and sustainable.

Product G shows opposite respond to product C and product D. As service level goes higher revenue for vendor goes lower. This indicates that class C item give more loss at higher assigned service level, since class C item only represent up to 10% of total inventory stock value. High inventory level of C product that has low profit margin, low market demand lead to a drastic revenue decrease.

The service level analysis result suggest that the higher service level requires more inventory utilization which means more cost for the operational activities. This also shows a trade-off relationship between service level and inventory performance. As service level goes higher, the operational cost increase and decrease the value of expected supply chain revenue.

As part of sustainability analysis, the consideration whether a product would be sustainable is based on its expected revenue value for 3 parties which are supply chain's side, vendor's side, and buyer's side. The simulation results can be summarized as shown in the table 4.9 below:

Table 4.10 Product Sustainability Analysis Result

Product	Supply Chain Revenue	Vendor's Revenue	Buyer's Revenue	Sustainability
Product A	$746,630.25	$367,054.5	$571,331.25	yes
Product B	$25,590.75	-$3,416.75	$27,471.63	no
Product C	$83,194.75	$8,108.60	$80,803.50	yes
Product D	$142,847.63	-$32,087.00	$173,139.00	no
Product E	$240,984.68	$159,456.30	$81,424.42	yes
Product F	$369,044.87	-$28,057.01	$229,445.94	no
Product G	$47,411.00	$15,222.79	$31,980.45	yes

As table 4.9 shows that from expected revenue perspective product B, product D, and product D shows negative value for vendor's expected revenue. Thus, if these products continue to be sold, it can make company suffer a greater loss. Eliminating these products from sales could be one of alternative that can be taken and only taking sustainability products for sale gives certain profit and minimized cost so that the company can have a good cash flow for continuous business cycle. Based on that consideration the simulation of sustainability products results as shown in table 4.10

Table 4.11 Optimized Inventory Operational Condition

Product	Lead time (weeks)	Lots (m)	Re-Order Point	Order Quantity	Safety Stock
Product A	5	90	167529	957	177180
Product C	5	22	28215	612	28967
Product E	4	10	34622	1409	36259
Product G	5	10	12369	1310	11728

In table 4.10 suggest that under the optimized operational condition these sustainable category products can maximize profit for the supply chain line, vendor, and buyer. This condition can lead to a long-term and profitable business practice which need to be monitored regularly to maintain the supply chain performance.

By the increase of service level, it affects the lead time for the whole supply chain performance. The result of how service level affect lead time is shown in table 4.11 below:

Table 4.12 Optimization Result Change

Product	Current Service Level	Current Lead Time	Optimized Service Level	Optimized Lead Time	Change %
A	99.10%	12.08	99.8%	5	58.6%
C	98.70%	12.08	99.8%	5	58.6%
E	98.80%	9.23	99.8%	4	56.6%
G	98.90%	13.70	99.8%	5	63.5%

As shown in table 4.11 we can see that the service level increase, reduce the lead time duration. This result suggest that high service level also make the response in the supply chain line shorter. Quick response is directly related to the customer satisfaction as they coordinate better and can build trust between distributor and retailers (Yina, Li.2011). An optimized lead time duration also increases expected revenue for buyers as they can maintain a good coordination and scheduling for replenishment cycle, so they can keep available stocks with minimum holding cost to a certain extent. Based on the calculation result buyer expected revenue for product D under 5weeks lead time is $173,240 and when lead time exceed the trend decrease and the expected buyer revenue become $173,075. Therefore, there is a balance to have an optimum profit for each party within the supply chain activities.

Asif salam, et al 2016 argued in his paper that well managed inventory policy is important to promote better balance of inventory and service level is align with this result. It has been found that among other operational parameters lead time is the most vital parameter that influence the performance of product availability and delivery. As Gunaserakan et al 2001 also stated that inventory hold 50% of all company assets is also can be seen in the results that well-managed inventory policy can reduce cost and maximize expected revenue. Furthermore, analysis on different type of stocks based on ABC analysis also promote how each type should be treated to give the best method of treatment for a certain assigned service level. It would affect the production process, production cost, scheduling, and so on that can lead to a lower total cost.

CHAPTER V

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

This research paper assume service level variable is controllable and show how it affect toward lead time with expected revenue for supply chain, vendor, and buyer being monitored to measure the changes. The result was obtained through numerical simulation using centralized approach which assume that a certain company only have centralized warehouse with customer around the world. The simulation result suggests that with adequate service level an efficient practice of supply chain activities can be applied by determining optimum operational condition of inventory performance. This adequate service level was obtained by finding a balance of expected revenue between supply chain, vendor, and buyer through centralized approach calculation algorithm to an extent where it gives maximum profit for all parties. However, it is also shown that service level doesn't seem feasible to be controlled in the real operational practice. On the other side, lead time is more feasible to be controlled as decision variable to determine inventory performance measurement.

Based on the simulation result, shows how service level and lead time interrelated each other that high service level reflects quicker response from distributor to fulfill market demand. On the other side, relation between service level and cost shows an inverse correlation that as service level goes higher cost of inventory utilization also increasing therefore reducing the expected revenue of supply chain activities. Service level can be used to estimate and forecast the amount of order need to be met to determine inventory performance parameter such as re-order point, order quantity, safety stock level, also lead time of each product order. On the other side, lead time is an operational parameter that can be used to monitor supply chain activities performance to make adjustment and operational decision regarding supply chain process efficiency. On other words, it can be concluded that both service level and lead time are a dominant variable that reflects supply chain activities performance. By combining both, it can work in balance as service level can measure customer satisfaction and lead time can be used to adjust operational performance to determine inventory parameter. This way company can have measurement systems that monitor customer satisfaction as their main parameter to adjust the internal company inventory performance. According to this result, Lee Billington in 1992 argued that there is no measure for the overall supply chain to directly monitor customer satisfaction is answered that Lead time can be directly related to measure customer satisfaction.

The implication of this research provides insights on what variable directly and indirectly related as a measure for customer satisfaction. A broad perspective of correlated parameters within the inventory activities is also provided to show what control parameters need to be adjusted to meet certain service level objective. The adjustment consist of overall inventory parameters such as order quantity, lead time, number of lots, safety stock level, and re order point. Thus, how customer satisfaction related with operational activities which can be used to monitor and evaluate the inventory performance to provide sustainable product and maintain customer satisfaction.

5.2 Recommendation

This research has some constraints that put limitation in real life application. It is assumed there is only one retailer in the simulation. Thus, it provides no further solution for multiple retailers with centralized warehouse case study. Decentralized solution for this case study also hasn't covered to make a comparison between centralized and decentralized. Since one of the purpose of this research is to find a solution to an existing condition under budget limitation. Therefore, centralized approach is the most feasible method to give an alternative solution in this case.

Supplier factor is also neglected in this research. Certain factor of supplier can also give a better insight for a full view of supply chain process that consist of supplier, distributor, and retailer to promote a better decision making for a solid supply chain strategy. A better data collection method should be taken to avoid unnecessary assumption in the calculation to give an absolute value that can provides more consideration in decision making process.

Extending the research scope not only in the supply chain context but also analyze how the benefit that company get from efficient supply chain process can affect their Return on Investment. This way, will provide even more broad perspective of how important the role of supply chain affecting the whole business and can be a good consideration for company’s further investment consideration whether how beneficial for companies to expand their business from supply chain perspective.

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