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JOINT DECISION PRICING AND INVENTORY POLICY IN DUAL CHANNEL SUPPLY CHAIN

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This thesis is composed with the expectation of getting the approval from Industrial Engineering Department Magister Program, Supervisor and committee member of this research to fulfill the requirements for the Degree of Master in Industrial System Optimization

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STATEMENT OF AUTHENTICITY

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Is a complete independent work of mine, completed without using any illegal information neither the work of other that I recognized as my own work.

All citation are listed in the reference section of this thesis.

If it turns out that the statement is not true, I am willing to accept the consequences in accordance with the regulations

Surabaya, July 2nd, 2018

Yours Sincerely

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JOINT DECISION PRICING AND INVENTORY POLICY IN DUAL CHANNEL SUPPLY CHAIN

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ABSTRACT

The promising growth of e-commerce becomes the consideration of companies to expand their business channels. In the demand fulfillment, firms in a supply chain are not only doing it through face-to-face transaction (offline channel), but through their website (online channel), which is called Dual-Channel Supply Chain (DCSC). Implementing DCSC can lead to two different possible outputs, increased profit caused by enlarged market and decreased profit caused by channel conflict. DCSC problems will become more complex when the companies want to produce or maintain only enough inventory to meet immediate demands while to avoid stock-outs. The answer of this problem is channel cooperation that may bring each channel an addition to their profits. This research proposes a quantitative model to study about joint decision between pricing and inventory policy in DCSC. Two important variables, namely price and order quantity, are used to coordinate an extended DCSC structure consisting of offline, online and reseller channels. An EOQ model is added to establish the total gain of each channel and evaluate the financial performance of three scenarios observed, namely non-cooperative, semi-cooperative, and fully-cooperative scenarios. The study proposed a model to resolve the joint decision covering pricing and inventory policy in DCSC and to determine the optimum price and order quality for offline, online, and reseller channel, so that DCSC achieves maximum profit. Mathematical models are developed based on the scenarios proposed, then optimization process is done using MATLAB. The result of numerical experiments shows that fully-cooperative scenario generates the best financial performance. However, the decision about the best scenario is not an absolute decision, since it can be changed in the future regarding the changes in system conditions. The result of sensitivity analysis is done to see which parameter is critical to the total gain.

Keywords: *dual channel supply chain, inventory policy, joint decision-making, pricing strategy*

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TABLE OF CONTENT

LIST OF FIGURES

LIST OF TABLES

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CHAPTER 1
INTRODUCTION

This chapter consists of the background of the research, problem formulation, objectives and benefits of the research, scope of the research, and research outline.

1.1 Research Background

In the modern era, human cannot be separated from technology of the internet. The internet is defined as the worldwide interconnection of individual networks operated by government, industry, academia, and private parties. In a matter of very few years, the internet consolidated itself as a very powerful platform that has changed forever the way people do business, and the way people communicate. Internet has become the globalized source of information for millions of people, at home, at school, and at work. The number of internet users in 2018 is 4.021 billion, up 7 percent year-on-year (Statista, 2018).

Based on a research done by Indonesia Internet Service Provider Association (APJII) in 2016, the number of internet users in Indonesia has reached 132,7 million or 51,5% of the total of Indonesian population. These number increased by 33,6% from 2015. Based on the results of national research conducted by the Association of Internet Service Providers Indonesia (APJII) in cooperation with PusKaKom UI, the number of internet users in Indonesia can be divided into several parts based on the island, among others: 18.6 million users in Sumatra, 52 million users in Java, 4.2 million users in Kalimantan, 7.2 million users in Sulawesi, Papua of 5.9 million users in Papua. The projection of internet users in Indonesia by APJII is shown below in Figure 1.1.

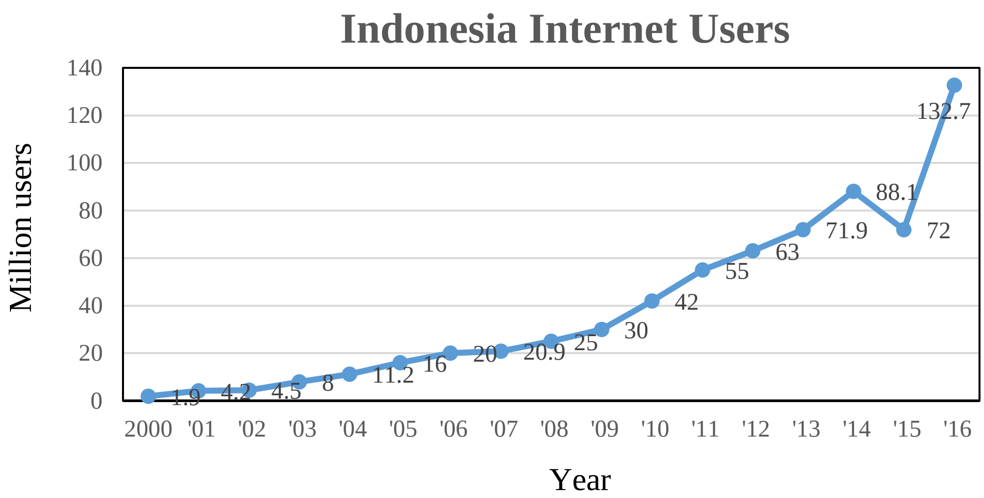

Figure 1.1 Growth Indonesia Internet Users

(Asosiasi Penyelenggara Jasa Internet Indonesia - APJII 2016)

Internet brings considerable benefit primarily for business purposes, in term of e-commerce. The application of e-commerce is important to support the success of product distribution. The growing prominence of e-commerce has fundamentally altered the way business is conducted. As a result, companies in all sectors – whether big or small – cannot afford to ignore this channel. Increasingly, businesses without an established e-commerce strategy and implementation plan will find it difficult to survive. It is, therefore, of paramount importance for businesses to stay abreast of the prevailing trends in the e-commerce field.

Figure 1.2 Retail E-commerce Sales Worldwide (eMarketer, 2017)

From Figure 1.2, it gives information on retail e-commerce sales worldwide from 2014 to 2021. In 2017, retail e-commerce sales worldwide amounted to 2.3 trillion US dollars and e-retail revenues are projected to grow to 4.88 trillion US dollars in 2021 (eMarketer, 2017). Online shopping is one of the most popular online activities worldwide but the usage varies by region. Based on a research done by Indonesia Internet Service Provider Association (APJII) in cooperation with Polling Indonesia in 2016, the most visited content of internet users is web online shopping (e-commerce) of 82.2 million internet users or 62%, followed by personal business reaches 45.3 million users and others of 5 million users (Figure 1.3).

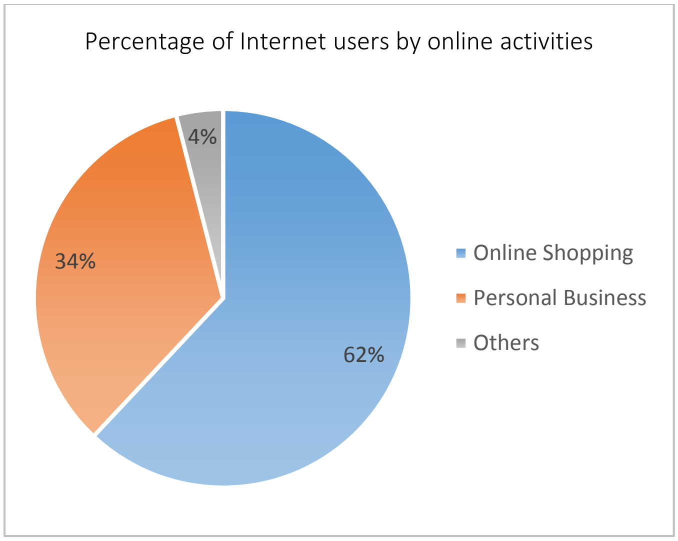

Figure 1.3 Percentage of Internet Users by Online Activities

The promising growth of e-commerce motives companies to expand their business channels. In the demand fulfillment, the company is not only doing it through face-to-face transaction (offline channel), but also through their website (online channel). Such concept is known as Dual Channel Supply Chain (DCSC). Other than the promising growth of e-commerce, the company wishes to increase their competitiveness become the underlying reason to expand their business to a wider scope. In order to do that, some companies use reseller channel to help them sell their product to meet customer demand.

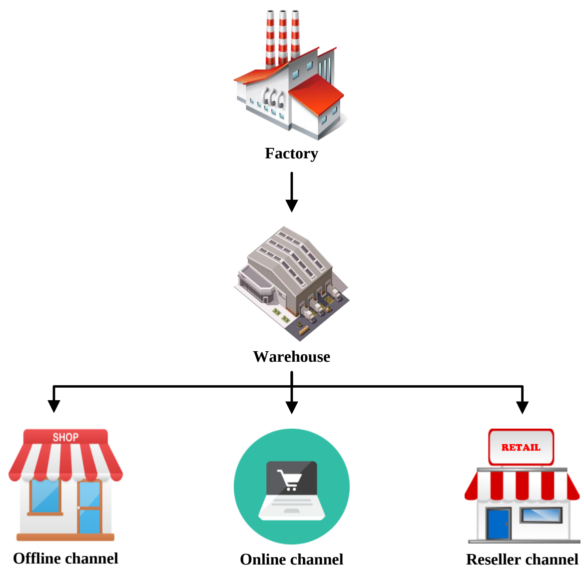

Figure 1.4 Dual Channel Supply Chain (DCSC) Concept

DCSC Concept (Figure 1.4) is a system that meets the customers' needs by selling its products in traditional retail stores (offline channel) and internet channels (online channel) (W. Y. K. Chiang and Monahan 2005). Channels in this supply chain are complementary to meet customer demand (Widodo et al. 2013). In dual-channel supply chain concepts, the price of a product should differ in each channel based on customers' preference of the channel that is affected by extra value received by customers when shopping offline (X. Chen and Simchi-Levi 2004). Bin, Jian, & Xu-mei (2008) stated that collaboration between channels may bring each channel an addition to their profits.

In practice, channels in a business are independently managed and compete with each other in meeting customer demand, therefore this will lead to what is called channel conflicts (Tsay and Agrawal 2004). Therefore, manufacturer requires *pricing policy* and distribution strategy for each channel in order to gain more profit (E. Teimoury 2008). DCSC problems will become more complex when the companies want to produce or maintain only enough inventory to meet immediate demands and to avoid stock-outs. When companies have excessive amounts of inventory, they are generally not selling enough to prevent inventory buildup. This is not a good situation as businesses need to turn over inventory efficiently to maintain reasonably high profit margins and to avoid the costs and other disadvantages that come with high levels of inventory (Wanguu, Sitienei, and Kipkirui 2015).

Some exemplary works of joint decision by using pricing in DCSC are (Huang, Yang, and Zhang 2012), (Xiao and Shi 2016), (Jingxian Chen et al. 2017), etc. On the other hand, some proponents of inventory policy using DCSC concept are (W. Y. K. Chiang and Monahan 2005), (Widodo 2015), and (Yang et al. 2017). However, none of those works has considered joint decision of pricing and order quantity for DCSC betterment. In fact, this practice commonly occurs when manufacturer independently managed each channel of implementing dual-channel supply chain system, setting the price without considering the preference of customers in each channel, and determining order quantity that should purchase without calculation.

As a continuation of authors work series in DCSC, the objectives in this paper are develop pricing model in DCSC and maximum the total gain of finding the optimal price and order quantity in each channel (offline, online, and reseller channel). Previous model of pricing under DCSC structure (Huang, Yang, and Zhang 2012) is the channel demand function model in self-price and cross-price with different parameters for each channel. For inventory policy, the previous model by Widodo (2015) is classical EOQ model in order to concatenate order quantity as decision variable in pair with price by determining optimal order quantity with regard to delivery, holding and shortage costs.

1.2 Research Objectives

Based on the research background, the idea of this research are to develop a model to study about joint decision between pricing and inventory policy in dual channel supply chain (DCSC) and determine the optimum price and order quality for offline, online, and reseller channel that generates maximum profit.

The objectives of this research are:

1. Build a model for pricing and inventory policy on DCSC structure.
2. Develop alternative joint decision pricing and inventory policy scenario for offline, online, and reseller channel based on DCSC concept.
3. Propose a recommendation of the best price and order quantity for each channel based on corresponding financial performance of each scenario.

The benefit of this research are providing systematic guidance for joint decision between pricing and inventory policy in order to generate maximum profit and giving an alternative view of scenarios to get the optimum price and order quantity by considering customers' preference of offline, online, and reseller channel.

1.3 Research Scope

Research scope states the limitations and the assumptions used in this research. The limitation of the present study is listed as following:

1. The model and scenario are developed for one variant of product.
2. Type of inventory policy used are ordering cost and holding cost.

Some assumptions of the study are as below:

1. The demand of the products is deterministic.

2. There is no significant change in demand trend for each channel.
3. Resellers' online and offline channel are ignored.
4. Other variables that affect customers' preference (lead time, competitors) are ignored.
5. Further assumptions used in modelling will be discussed in Chapter 4.

1.4 Research Outline

The research consists of six chapters which following the outline as explained at the following:

CHAPTER 1 INTRODUCTION

The chapter is a preliminary part of the whole research, which is explaining about research background, problem formulation, its objectives, benefits, scope of the research, and also overview of the research outline.

CHAPTER 2 LITERATURE REVIEW

The chapter consists of summary according to some references, such as books, journals, articles, or previous researches which are used as basic understanding in the research development.

CHAPTER 3 RESEARCH METHODOLOGY

The chapter is showing and explaining about detailed framework and procedures followed in conducting the research.

CHAPTER 4 MODEL DEVELOPMENT

The chapter is explaining about model development processes using model existed based on previous research, and then adjusting the model with the research real problem.

CHAPTER 5 NUMERICAL EXPERIMENT

The chapter is showing the numerical experiments using developed model in the research. The experiment is also completed with sensitivity analysis to analyze the model characteristics.

CHAPTER 6 CONCLUSIONS AND RECOMMENDATIONS

The chapter is closing part of the research which is explaining about the conclusion of whole research conducted and also suggestions proposed from the research.

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CHAPTER 2
LITERATURE REVIEW

This chapter contains the theories used in this research as the fundamental of idea development based on journals, books sections, articles, and previous research.

2.1 Dual Channel Supply Chain

Chopra & Meindl (2014) defined supply chain as a network of firms, whether it is directly or indirectly, in meeting customer demand. It includes the manufacturers, suppliers, transporters, warehouses, retailers, and customers. As stated in the previous chapter, the growth of internet technology and e-commerce initiates the emergence of the new supply chain concept. A lot of businesses nowadays expand their business channel by adding online channel or direct channel where they sell their products directly to the customers. A supply chain system like that is called Dual Channel Supply Chain (DCSC). DSCS is a system that meets the customers' needs by selling its products in traditional retail stores (offline channel) and internet channels (online channel) (W. Y. K. Chiang and Monahan 2005). DSCS aims to integrate a previously established traditional channel (offline channel) with a direct internet-based channel (online channel) in demand fulfillment facility and both of these channels works complementary in meeting customer demand (Widodo et al. 2010). The model of DCSC is shown below

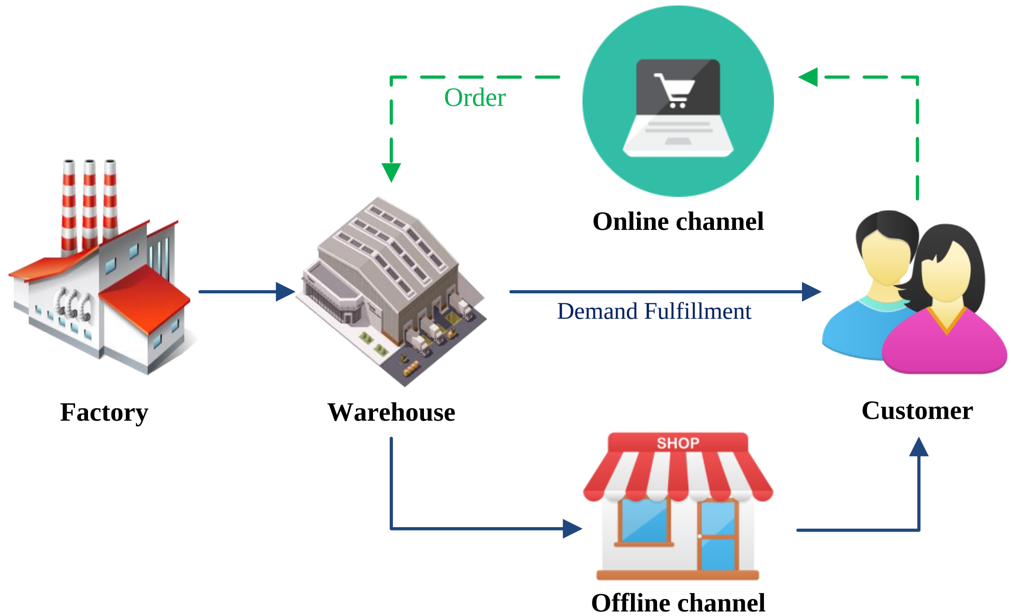


Figure 2.1 Dual Channel Supply Chain (DCSC) Model

Figure 2.1 shows DCSC model that explains how DCSC works. Customers can purchase the product in traditional way through conventional store that is called the offline channel. Customer can also order the product via the website and the product will be sent directly to the customers from the warehouse without intermediaries, which is why the online channel can also be called direct channel.

The emergence of the new channel (online), may lead to a competition between the online channel and the retailers in terms of gaining profit, potentially leading to tension referred as channel conflict (Tsay and Agrawal 2004), so that eliminating intermediaries (reseller, wholesaler, etc) which can increase the supply chain efficiency, may seem to be a promising strategy to the manufacturer. Moreover, by partnering with companies that offer complementary products or services can increase the sales activity, drive new revenues and customers, and more easily capture opportunities that may not have been exposed to (W. Y. K. Chiang and Monahan 2005). This statement is supported by Bin et al., (2008) that collaboration between channels may bring each channel an addition to their profits.

In dual- channel supply chain concepts, the price of a product should differ in each channel based on customers' preference of the channel that is affected by extra value received by customers when shopping offline (X. Chen and Simchi-Levi 2004). Besides that, other factors that affect customer' preferences are the transaction cost when buying the product in the offline channel. By shopping in the offline channel, the price of the product will be more expensive than the website (online channel) because the owner need to pay additional costs such as personal expense and store rent cost, but consumers have the opportunity to do the inspections on the products before purchasing.

Widodo et al., (2010) stated that, in DCSC concept, in order to achieve the best financial performance, there are some variables to be considered, such as central warehouse price, online price, and offline price. These variable are included in the demand functions conducted by Huang et al., (2012) as shown below.

$D_r = (1 - \rho)a - \alpha_1 p_r + \beta_1 p_d,$

$D_d = \rho a - \alpha_2 p_d + \beta_2 p_r$

$D_{sc} = a - (\alpha_1 - \beta)p_r - (\alpha_2 - \beta)p_d.$

where:

D_r = demand in offline channel

D_d = demand in online channel

a = forecasted potential demand if the products are free

p_r = offline price

p_d = online price

ρ = customer acceptance ratio of online product compared to the offline product

α = coefficient of self-price elasticity of D_r and D_d

β = coefficient of cross-price sensitivity of D_r and D_d

The research on dual-channel supply chain management had gained much attention among the supply chain management researchers. Tsay & Agrawal (2004) developed a model that captures key attributes to generate managerial insights into this important issue. They used game theory to study the channel conflict, coordination between the manufacturer and the reseller in a dual-channel supply chain, and proposed policies that could coordinate the actions of channel members. Chiang & Monahan (2005) investigated a price-setting game between a manufacturer and a reseller in a dual-channel supply chain based on consumer customer acceptance. They found that the online channel could not always be disadvantage to the reseller because it would be accompanied by a wholesale price reduction. Moreover, the introducing of online channel can increase the manufacturer's negotiated share of cooperative profits even if price efficiency is obtained by using other business practices.

Widodo et al., (2010) proposed two different scenarios in describing customer preferences in dealing with returning non-conformed online purchase. The Stackelberg leader scheme, which is a strategy of meeting such claim through one designated online facility have a better financial performance than The Bertrand scheme, which is re-fulfillment process involving a conventional store as channel counterpart (cross channel return).

Seifert, Thonemann, & Sieke (2006) developed models for both a dedicated and integrated supply chain, and analyzed how to coordinate the supply chain and allocate the supply chain's profit between the manufacturer and the retailer under decentralized decision-making environment. Cai (2010) investigated the impact of channel structures on the supplier, the reseller, and the entire supply chain in the context of two single-channel and two dual-channel supply chains. The analysis suggests the preference lists of the supplier and the reseller over channel structures with and without coordination are different. The suppliers prefer to use two resellers scenario over online and reseller channel scenario. However, the supplier has more negotiation power in online and reseller channel scenario while reseller has the advantage in the two reseller scenario. They also show that the suppliers' profit depends on parameters, such as channel base demand, channel operational costs, and channel substitutability.

Hua, Wang, & Cheng (2010) examined the optimal decisions of delivery lead time and prices in centralized and decentralized dual-channel supply chains using the two-stage optimization technique and Stackelberg game. In the centralized supply chain, the manufacturer increases the online sale price when decreases the lead time while whether or not the reseller' price depends on the difference between the demand transfer ratios in the two channels. However, in the decentralized dual channel supply chain, the manufacturer increases the online sale price when decreases the lead time while the reseller should decrease the reseller' price. Their numerical studies show that customer acceptance of the online channel has a great effect on the lead time and pricing decisions, product type has a great impact on the lead time and pricing decisions.

2.2 Pricing Strategy

Pricing strategy is a method adapted by firm or enterprise to find the optimum of a product and services selling price with some considerations such as business objectives, demand, competitor's pricing strategy, and economic trend (Pindyck and Rubenfeld 1997). The purpose of pricing strategy is profitability, however, achieving high profitability requires more than just setting a price level but includes ensuring that the products are capturing customers' needs or requirements. There are three major of pricing strategy, which are customer value-based pricing, competition-based pricing, and cost-based pricing. In this research, the pricing strategy used is customer value-based pricing strategy. Customer value-based pricing is a method uses customers' perceptions of value as the key to pricing, instead of the seller's costs. This also means that the company cannot design a product and marketing program then set the price. The price is considered along with all other marketing mix variables before the marketing program is set (Hinterhuber 2008).

In DCSC, pricing is critical. This condition was leaded by an influence of fluctuate demand according to product price set as one of the factors. According to (Widodo et al. 2011), there are two schemes generally used in pricing DCSC as follow:

1. Bertrand scheme

In this scheme, the price that determined in central warehouse, offline channel, and also online channel is set simultaneously. Since determined simultaneously, the price set depends on each player regulation. According to the scheme, global optimum result is indicated by the total profit of each channel.

2. Stackelberg scheme

Different with the previous scheme, the decision variable for this scheme is set sequentially. Offline channel set as the follower which decided to determine the price first, then followed by central warehouse and online channel. This research uses Stackelberg scheme.

Several number of researches on DCSC have focused on the pricing decision problem. W. K. Chiang, Chhajed, & Hess (2003) studied a price-setting game between a manufacturer and a retailer in DSCS based on consumer choice model. They found that the online channel can increase the manufacturer's negotiated share of cooperative profits even if price efficiency is obtained by using other business practices. Another work by Hinterhuber (2008) states that there are three pricing strategies, namely cost-based, competition-based, and value-based pricing. In that paper, price-based pricing is based on the value of consumer perceptions. Based on the literature, value-based pricing strategy is the best pricing strategy compared to others with the aim of increasing profits.

Chun & Kim (2005) analyzed why the price differences between the online channel and the traditional channel occur. Jing Chen et al., (2012) analyzed manufacturer's pricing strategies in dual channel supply chain, in which the manufacturer is a Stackelberg leader and the retailer is a follower. The result showed that the price of a product should differ in each channel based on preference of the customer in each channel that affected by extra value received by customers when shopping offline.

An interesting idea of pricing was given by a paper by Huang et al., (2012). They develop two-period pricing and production decision model in one manufacturer and one retailer in dual channel supply chain with demand disruptions. The result indicates that in the centralized dual-channel supply chain, the optimal production plan is strongly stand with demand disruptions when the market scale is not too much disturb. Only when the demand disruptions exceed some thresholds, the manufacturer should change the original production plan and prices should be adjusted to compensate for the deviation in market scale. Moreover, it is always beneficial for manufacturer to adopt the adjusted optimal pricing decisions when a demand disruption occurs in the centralized dual-channel supply chain.

Human behavior in manufacturers and retailers have an effect on pricing in dual channel supply chain (Shi, Jiang, and Ouyang 2013). Using Stackelberg game method, it is found that human behavior greatly gives influence to the customer's preference in pricing strategy. Those effect in manufacturer is stronger than in retailer. Hence, the more product sold in online channel then the lower price set in the retailer channel and the more profits produced by the manufacturer than the retailer.

Liu & Xu (2015) is proved that the addition of online channel into manufacturing distribution system not only causes competitive pricing, but also cost effective retail services. Based on dual channel supply chain, the channel members' attitude has a major impact on channel optimization. Therefore, dual- channel collaborative pricing enables to avoid risks effectively, and the channel members with higher degree of risk aversion tends to take collaborative pricing strategy.

2.3 Inventory Policy

Only a few papers study with regard to inventory policy problems of dual-channel supply chain. A paper by Bendoly (2004) proposed an information sharing in performing inventory control and order fulfillment under DCSC structure. The model reflected an idea of not only integrated in online and offline inventory but also sharing the information about stock availability in the whole DCSC network. The result showed that the proposed idea might provide better financial performance than that under no-information sharing.

Chiang & Monahan (2005) proposed a two-echelon dual-channel supply chain model with setup of production and delivery and develops a new inventory control policy for the supply chain. In the inventory control policy, production is stopped when the warehouse inventory reaches the upper limit and is started again immediately after the inventory drops below the limit. Moreover, delivery to the retailer is stopped when the store inventory reaches the upper limit and is started again immediately after the inventory drops below the limit. The total cost that is of inventory holding costs and lost sales cost is considered, and setup costs are not considered in the total cost. As performance measure, the total cost that consists of inventory holding costs, lost sales cost, and production and delivery of setup costs is considered, and the total cost calculated on the basis of Markov analysis demonstrates the effectiveness of the proposed control policy. The result showed that the cost reductions that are obtained by using dual-channel strategy could be very significant, especially when the number of direct channel customers is close to the number of retail stores customers, and or when customers are less willing to deviate from their desired channel. Moreover, increasing the customers search rates can't always improve the channel performance, it can possibly increase the total inventory related cost. Therefore, companies need to be very cautious about their managerial actions.

Takahashi, Aoi, Hirotani, & Morikawa (2011) develops a new control policy for the two-echelon dual-channel supply chain with setup of production and delivery. The total cost that consists of inventory holding costs, lost sales cost, and production and delivery setup costs was calculated using Markov analysis, and the numerical calculation showed the effectiveness of the proposed control policy. Tetteh, Xu, & Liu (2014) analyzed the impact of speculation in a dual-supply chain to control the cost of inventory that can creates opportunities for manufacturers to expand their products and gain profit and also produces a hazardous side-effect for it can collapse the product.

A paper by Widodo (2015) proposes a model to study the impact of product substitution in dual channel supply chain behavior with two decision variables (price and order quantity) to coordinate offline and online channels under dual channel supply chain structure. The result indicates that there is a positive relationship between substitution level and offline channel profit but a negative relationship between substitution level and online channel profit.

Table 2.1 Research Position

No	Author	Year	Title	Decision Variable		Objective Function		Channel		Demand		Method
				Price	Inventory	Maximize Profit	Minimize Cost	Single	Dual	Deterministic	Probabilistic	
1	Wei-yu Kevin Chiang, Dilip Chhajed, and James D. Hess	2003	Direct Marketing, Indirect Profits: A Strategic Analysis of Dual-Channel Supply-Chain Design.	√		√		√		√		Optimization
2	Elliot Bendoly	2004	Integrated Inventory Pooling for Firms Servicing Both on-Line and Store Demand		√		√		√		√	Simulation and optimization
3	Se-Hak Chuna and Jae-Cheol Kimb	2005	Pricing Strategies in B2C Electronic Commerce: Analytical and Empirical Approaches	√		√			√	√		Theoretical approach and empirical analysis
4	Wei-yu Kevin Chiang and George E. Monahan	2005	Managing Inventories in a Two-Echelon Dual-Channel Supply Chain		√		√		√	√		Optimization
5	Katsuhiko Takahashi, Takahiko Aoi, Daisuke Hirotani, and Katsumi Morikawa	2011	Inventory Control in a Two-Echelon Dual-Channel Supply Chain with Setup of Production and Delivery		√	√			√		√	Markov analysis
6	Song Huang, Chao Yang, and Xi Zhang	2012	Pricing and Production Decisions in Dual-Channel Supply Chains with Demand Disruptions	√		√			√	√		Optimization

No	Author	Year	Title	Decision Variable		Objective Function		Channel		Demand		Method
				Price	Inventory	Maximize Profit	Minimize Cost	Single	Dual	Deterministic	Probabilistic	
7	Zheng Liu and Qi Xu	2015	Collaborative Optimal Pricing Model of Dual-Channel Supply Chain.	√		√			√	√		Optimization
8	Erwin Widodo	2015	A Model Reflecting the Impact of Product Substitution in Dual- Channel Supply Chain Inventory Policy		√	√			√	√		Optimization
9	Arpita Roy, Shib Sankar Sana, and Kripasindhu Chaudhuri	2016	Joint decision on EOQ and pricing strategy of a dual channel of mixed retail and e-tail comprising of single manufacturer and retailer under stochastic demand	√	√	√			√		√	Optimization
10	Sandra Oktavia Teguh, Kung-Jeng Wang, and Erwin Widodo	2018	Joint Decision Pricing and Inventory Control in Dual Channel Supply Chain	√	√	√			√	√		Optimization

CHAPTER 3
METHODOLOGY

The chapter is showing and explaining about detailed framework and procedures followed in conducting the research as can be seen at Figure 3.1.

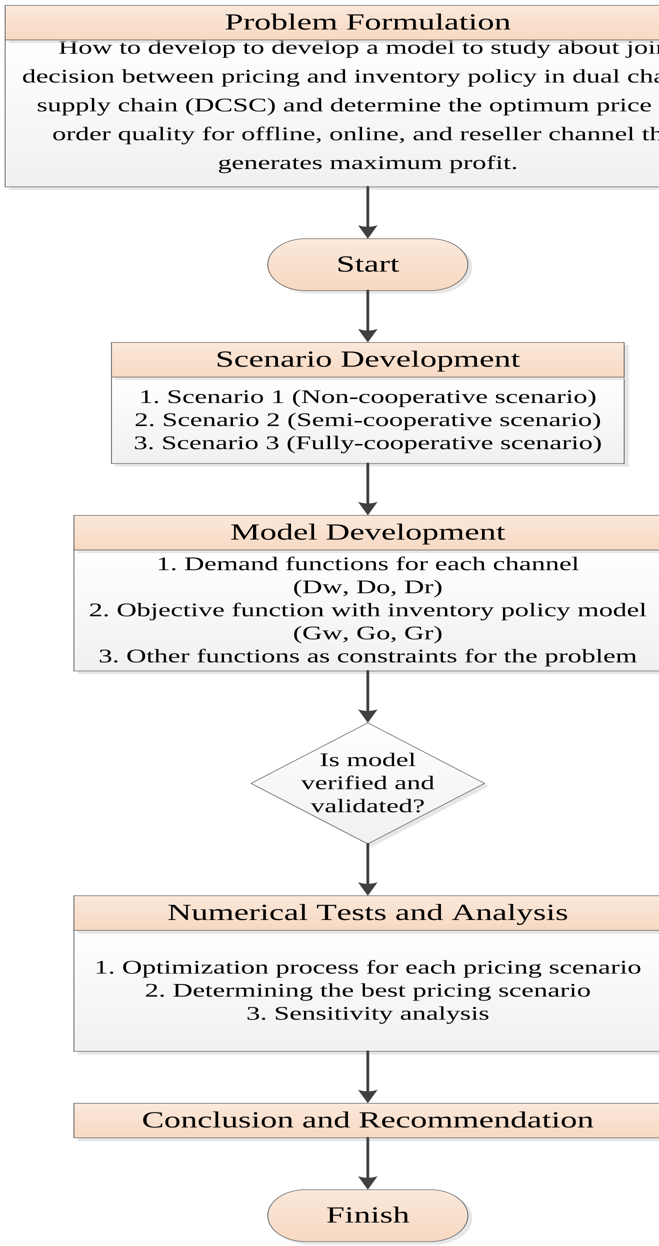


Figure 3.1 Research Methodology Flowchart

Figure *3.1*Figure 3.1 shows the research methodology flowchart. Based on the flowchart above, below is the explanations of the research methodology.

3.1 Scenario Development Phase

The first step of this research is developing scenario. The scenario is developed based on the theories on the literature study about DCSC, specifically about channel conflict. The scenarios are:

1. Non-cooperative scenario (Scenario 1)

   In this scenario, each channel works independently in meeting customer demand.

2. Semi-cooperative scenario (online and reseller channel) (Scenario 2)

   In this scenario, the online and reseller channel form a coordination and work complementary in meeting customer demand, while the offline channel works independently.

3. Fully-cooperative scenario (Scenario 3)

   In this scenario, all channels form a coordination and work complementary in meeting customer demand

3.2 Model Development Phase

In this research, the second phase which is needed to be conducted is develop the joint decision model based on DCSC structure. Previous model related to DCSC research can be used as the model references as main source to do the development processes.

The models needed in this research are demand function and objective function. There are three demand functions, which are offline demand function (D_w), online demand function (D_o), and reseller demand function (D_r). The demand function refers to previous research by Huang et al. (2012). The objective function for this research is maximum gain (profit) consist of the inventory policy model that refers to previous research by Widodo (2015). In addition, the formulation of the constraints is also conducted in this step.

3.3 Verification and Validation Phase

In order to eliminate error in the implementation of the model developed into the real system, verification and validation tests are required to be followed. Verification test is required to compare the model developed with the basic approach used for the research in order to evaluate error level in the model. The verification test can be performed by using MATLAB software to be the tool for model correction process. However, the validation is the test to compare model developed with the real system observed for the research. Validation test process has the aim to check whether the model developed had represented the real condition of the system or not. If there are some error found in the model by verification and validation check, then the model developed is required to be evaluated and model development process has to be conducted again.

3.4 Numerical Tests and Analysis

There are several processes in the numerical tests and analysis phase for the research. First numerical test which is conducted is to find the optimal price and order quantity for each channel by using of MATLAB software. The tests are conducted in several times by changing the values of initial point in each channel. Then, based on the optimization results, it can be concluded which scenario provides the best financial performance. The last step is performing sensitivity analysis on the best scenario to see which parameter in the model is critical and sensitive to the objective function.

3.5 Conclusion and Recommendation

The last step of this research is to conduct conclusions based on the result of the research. The conclusions are built to answer the research objectives. Besides conclusions, recommendations are also made, whether it is addressed to the observed company or to the further researcher.

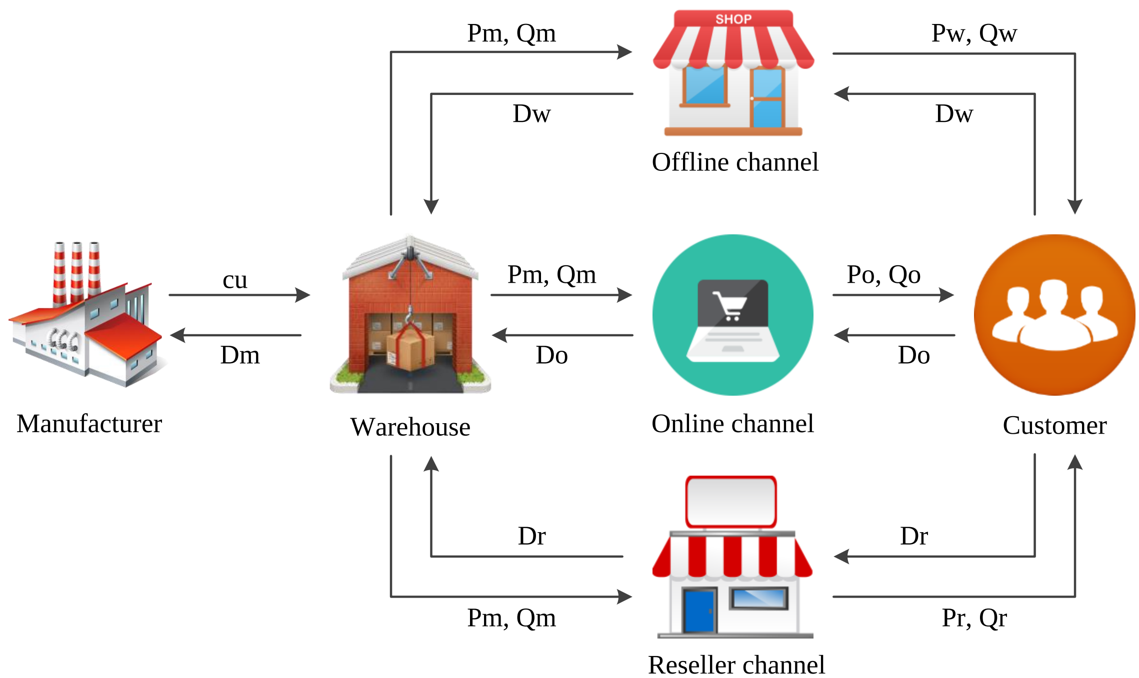
CHAPTER 4

MODEL DEVELOPMENT

This chapter explains the system description, model development of pricing and inventory policy, further limitations and assumptions used in the system, objective function and constraint formulation of each scenario, and also parameter value.

4.1 System Description

DCSC system under observation for the research is an enterprise works in apparel industry field, who distributes their products in stores (offline channel), online facilities such as website and social media accounts, and reseller channel. DCSC system of the observed object consists of manufacturer, central warehouse, retail stores, online facilities, and end-customer. Figure below shows an illustration about DCSC system in observed object for the research.



Where :

cu = unit cost of production	Pm = manufacturer price	Qw = order quantity for offline-channel
Dm = manufacturer demand	Qm = manufacturer order quantity	Qo = order quantity for online-channel
Dw = demand for offline-channel	Dw = demand for offline-channel	Qr = order quantity for reseller-channel
Do = demand for online-channel	Do = demand for online-channel	
Dr = demand for reseller-channel	Dr = demand for reseller-channel	

Figure 4.1 Conceptual Model

Figure 4.1 shows the demand fulfillment is done through three channels, which are offline, online, and reseller channel in the business process. They own one showroom which is their offline channel, one website as the online channel, and work with resellers.

In this research there are some limitations and assumptions used to limit and simplify the research scope. Details of limitations and assumptions used in the research development are listed below.

The limitations used in this system are:

1. Pricing and inventory policy model and scenarios is developed for product X.
2. The type of reseller used in this research is primary agent (maximum discount is 40%).

The assumptions used in this system are:

1. The price of product X is $ 200 (in New Taiwan Dollar)
2. Price elasticity in demand differs based on the characteristic of the scenario.

4.2 Model Reference

This research for pricing model refers to demand function by Huang et al. (2012) modelled as follows:

- Demand Function for offline channel

$$D_s = (1-\rho)d_s^{max} - \alpha_1 P_s + \beta_1 P_o \tag{4.1}$$

- Demand Function for online channel

$$D_o = \rho d_s^{max} - \alpha_2 P_o + \beta_2 P_s \tag{4.2}$$

- Total Demand Function

$$D_T = d_s^{max} - (\alpha_1 - \beta)P_s - (\alpha_2 - \beta)P_o \tag{4.3}$$

where:

D_s = customer demand of offline-channel

D_o = customer demand of online-channel

d_s^{max} = maximum demand when price is set near unit cost

P_s = price in store/offline-channel (decision variable)

P_o = price in online-cannel (decision variable)

ρ = customer acceptance ratio of online product compared to the offline product

α = coefficient of self-price elasticity of D_s and D_o

β = coefficient of cross-price sensitivity of D_s and D_o

A model reflecting the inventory policy in dual channel supply chain refers to the impact of product substitution model by (Widodo 2015).

$$C_o^s = S_o D_o / Q_o \quad (4.4)$$

$$C_o^h = h_o Q_o / 2 \quad (4.5)$$

$$C_S^S = S_S\left(\frac{D_S^A}{Q_S^A} + \frac{D_S^B}{Q_S^B}\right) \quad (4.6)$$

$$C_S^h = h_S (Q_S^A + Q_S^B)/2 \quad (4.7)$$

where

C_o^s = order's setup cost in online channel

S_o = fixed cost per order in online channel

C_o^h = holding cost in online channel

h_o = unit holding cost in online channel

C_S^S = order's setup cost in offline channel

S_S = fixed cost per order in offline channel

C_S^h = holding cost in offline channel

h_S = unit holding cost in offline channel

Q_S^A = order quantity of main product from offline channel (decision variable)

Q_S^B = order quantity of substitute product from offline channel (decision variable)

Q_o =order quantity from online-channel (decision variable)

4.3 Research Model

This section contains research models developed from the reference model based on the conducted scenario. The scenarios are as follows:

1. Scenario 1

This is non-cooperative scenario. In this scenario, each channel works independently in meeting customer demand Figure 4.2 is a graphical illustration of this scenario.

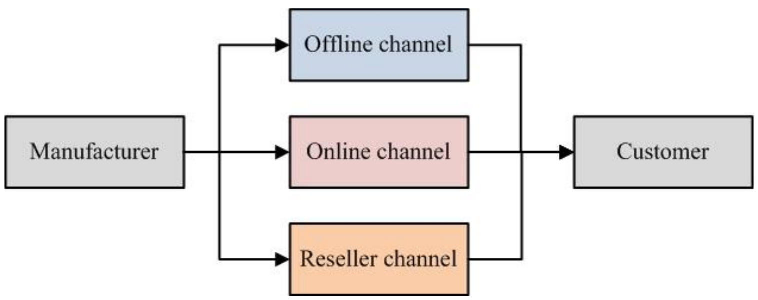


Figure 4.2 Non-cooperative Scenario

2. Scenario 2

This is the semi-cooperative scenario. In this scenario, the online and reseller channel form a coordination and work complementary in meeting customer demand, while the offline channel works independently. The coordination of the online and reseller channel is possible because both channel are not as strong as offline channel. Figure 4.3 is the graphical illustration of this scenario.

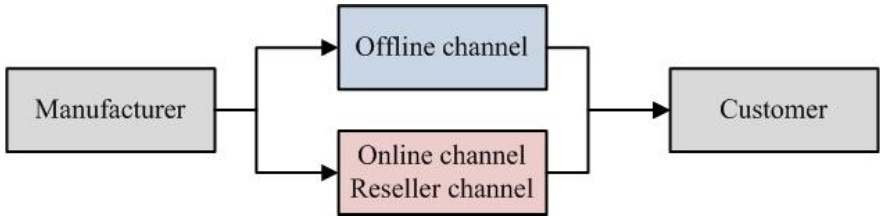


Figure 4.3 Semi-cooperative Scenario

3. Scenario 3

This is the fully-cooperative scenario. In this scenario, all channels form a coordination and work complementary in meeting customer demand. Figure 4.4 is the graphical illustration of this scenario.

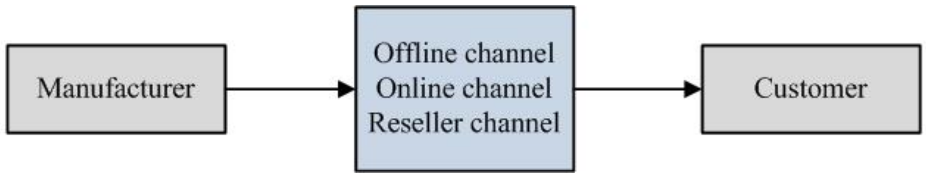


Figure 4.4 Fully-cooperative Scenario

4.3.1 Notations

The notations used in the research models are:

- Indirect Variables

D_w = demand function for offline channel

D_o = demand function for online channel

D_r = demand function for reseller channel

- Dependent Variables

G_w = profit gained by offline channel

G_o = profit gained by online channel

G_r = profit gained by reseller channel

G_{or} = profit gained by coordination of online and reseller channel

G_{wor} = profit gained by coordination all of the channels

G_{total1} = profit gained by the whole supply chain system in Scenario 1

G_{total2} = profit gained by the whole supply chain system in Scenario 2

G_{total3} = profit gained by the whole supply chain system in Scenario 3

- Decision Variables

P_w = price in offline channel

Q_w = order quantity of offline channel

P_o = price in online channel

Q_o = order quantity of online channel

P_r = price in reseller channel

Q_r = order quantity of reseller channel

- Parameters

d_s^{max} = maximum demand when price is set near unit cost

ρ = customer acceptance ratio of online product compared to the offline product

η = customer acceptance ratio of reseller product compared to the offline product

α = coefficient of self-price elasticity

β = coefficient of cross-price sensitivity

s_c = fixed setup cost per order

h_c = unit holding cost

cu = unit cost of production

4.3.2 Demand Functions for Pricing

In this section, demand functions for each channel will be modelled based on the model reference by (Huang, Yang, and Zhang 2012).

The offline or in-store demand function is adopted from (4.1) with α and β is not assumed to be 1 in order to represent the real condition more precisely in the model. P_r and η is also added to capture the interplay between offline, online, and reseller channel. The offline demand function is as follows.

$$D_w = (1 - \rho\eta)d_s^{max} - \alpha_w P_w + \beta_o P_o + \beta_o P_r \tag{4.8}$$

The online demand function is adopted from (4.2) with α and β is not assumed to be 1 in order to represent the real condition more precisely in the model. The online demand function is as follows.

$$D_o = \rho d_s^{max} - \alpha_o P_o + \beta_w P_w + \beta_r P_r \tag{4.9}$$

The reseller demand function is adopted from (4.2) with α and β is not assumed to be 1 in order to represent the real condition more precisely in the model. P_o is replaced by P_r and ρ is replaced by η to represent the reseller channel in the model. The reseller demand function is as follows.

$$D_r = \eta d_s^{max} - \alpha_r P_r + \beta_w P_w + \beta_o P_o \tag{4.10}$$

4.3.3 Objective Functions for Pricing and Inventory Policy

The objectives of this research is maximizing the profit (gain) of the whole supply chain system. Each scenario has different objectives function depends of the condition of the scenario itself. Generally, profit or gain can be formulated as follows:

$$Total\ gain = revenue - setup\ cost - holding\ cost \tag{4.11}$$

$$Total\ gain = demand \times (price - unit\ cost\ of\ production)$$

$-setup\ cost - holding\ cost$ (4.12)

Below is the profitability function for each channel of each scenario developed from the general profitability function.

4.3.3.1 Total Gain for Scenario 1

- For offline channel

$$G_w(P_w, Q_w) = D_w(P_w - cu) - S_w^C - H_w^c$$

(4.13)

$$G_w(P_w, Q_w) = \big((1-\rho\eta)d_s^{max} - \alpha_w P_w + \beta_o P_o + \beta_r P_r\big)(P_w - cu) - \left(\frac{S_c \times D_w}{Q_w}\right) - \left(\frac{H_c \times Q_w}{2}\right)$$

(4.14)

$$G_w(P_w, Q_w) = \big((1-\rho\eta)d_s^{max} - \alpha_w P_w + \beta_o P_o + \beta_r P_r\big)(P_w - cu) - \left(\frac{S_c \times (1-\rho\eta)d_s^{max} - \alpha_w P_w + \beta_o P_o + \beta_r P_r)}{Q_w}\right) - \left(\frac{H_c \times Q_w}{2}\right) \quad (4.15)$$

- For online channel

$$G_o(P_o, Q_o) = D_o(P_o - cu) - S_O^C - H_o^c \quad (4.16)$$

$$G_o(P_o, Q_o) = (\rho d_s^{max} - \alpha_o P_o + \beta_w P_w + \beta_r P_r)(P_o - cu) - \left(\frac{S_c \times D_o}{Q_o}\right) - \left(\frac{H_c \times Q_O}{2}\right) \quad (4.17)$$

$$G_o(P_o, Q_o) = (\rho d_s^{max} - \alpha_o P_o + \beta_w P_w + \beta_r P_r)(P_o - cu) - \left(\frac{S_O \times (\rho d_s^{max} - \alpha_o P_o + \beta_w P_w + \beta_r P_r)}{Q_o}\right) - \left(\frac{H_O \times Q_O}{2}\right) \quad (4.18)$$

- For reseller channel

$$G_r(P_r, Q_r) = D_r(P_r - cu) - S_r^C - H_r^c \tag{4.19}$$

$$G_r(P_r, Q_r) = (\eta d_s^{max} - \alpha_r P_r + \beta_w P_w + \beta_o P_o)(P_r - cu) - \left(\frac{S_c \times D_r}{Q_r}\right) - \left(\frac{H_c \times Q_r}{2}\right) \tag{4.20}$$

$$G_r(P_r, Q_r) = (\eta d_s^{max} - \alpha_r P_r + \beta_w P_w + \beta_o P_o)(P_r - cu)$$

$$- \left(\frac{S_c \times (\eta d_s^{max} - \alpha_r P_r + \beta_w P_w + \beta_o P_o)}{Q_r}\right) - \left(\frac{H_c \times Q_r}{2}\right) \tag{4.21}$$

$$G_{total1} = G_w + G_o + G_r \tag{4.22}$$

In the objective functions above, the first parts are the demand functions to accommodate the number of the products sold, the second parts are the difference between the price and the cost which shows profit per unit, and the third parts are the inventory policy (total setup cost and holding cost). The multiplication of first and second parts minus the inventory policy will result in gain for each channel. G_{total1} shows the total gain for the entire supply chain system in Scenario 1 (non-cooperative).

4.3.3.2 Total Gain for Scenario 2

- For coordination of online and reseller channel

$$G_{or}(P_o, Q_o, P_r, Q_r) = (D_o(P_o - cu) - S_O^C - H_o^c) + (\, D_r(P_r - cu) - S_r^C - H_r^c) \tag{4.23}$$

$$G_{or}(P_o, Q_o, P_r, Q_r) = \Bigg((\rho d_s^{max} - \alpha_o P_o + \beta_w P_w + \beta_r P_r)(P_o - cu) - \left(\frac{S_c \times D_o}{Q_o}\right) -$$

$$\left(\frac{H_c \times Q_O}{2}\right)\Bigg) + \Bigg((\eta d_s^{max} - \alpha_r P_r + \beta_w P_w + \beta_o P_o)(P_r - cu) - \left(\frac{S_c \times D_r}{Q_r}\right) - \left(\frac{H_c \times Q_r}{2}\right)\Bigg) \tag{4.24}$$

$$G_{or}(P_o, Q_o, P_r, Q_r) = \Bigg((\rho d_s^{max} - \alpha_o P_o + \beta_w P_w + \beta_r P_r)(P_o - cu) - \left(\frac{S_O \times (\rho d_s^{max} - \alpha_o P_o + \beta_w P_w + \beta_r P_r)}{Q_o}\right) - \left(\frac{H_c \times Q_O}{2}\right)\Bigg) + \Bigg((\eta d_s^{max} - \alpha_r P_r + \beta_w P_w + \beta_o P_o)(P_r - cu) - \left(\frac{S_r \times (\eta d_s^{max} - \alpha_r P_r + \beta_w P_w + \beta_o P_o)}{Q_r}\right) - \left(\frac{H_c \times Q_r}{2}\right)\Bigg) \quad (4.25)$$

$$G_{total2} = G_{or} + G_w \quad (4.26)$$

The objective function above (G_2) accomodates the coordination of both online and reseller channel which is shown in the sum of the gain for online channel with the gain for reseller. The decision variables, which are $P_o, Q_o, P_r,$ and Q_r will be derived from this objective function. G_w is the objective function to find the optimum P_w and Q_w for this scenario, while G_{total2} shows the total gain for the entire supply chain system in Scenario 2 (semi-cooperative).

4.3.3.3 Total Gain for Scenario 3

- For coordination all of the channels

$$G_{wor}(P_w, Q_w, P_o, Q_o, P_r, Q_r) = (D_w(P_w - cu) - S_w^C - H_w^c) + (D_o(P_o - cu) - S_O^C - H_O^c) + (\ D_r(P_r - cu) - S_r^C - H_r^c) \quad (4.27)$$

$$G_{wor}(P_w, Q_w, P_o, Q_o, P_r, Q_r) = \Bigg(\big((1 - \rho\eta) d_s^{max} - \alpha_w P_w + \beta_o P_o + \beta_r P_r\big)(P_w - cu) - \left(\frac{S_c \times D_w}{Q_w}\right) - \left(\frac{H_c \times Q_w}{2}\right)\Bigg) + \Bigg((\rho d_s^{max} - \alpha_o P_o + \beta_w P_w + \beta_r P_r)(P_o - cu) - \left(\frac{S_c \times D_o}{Q_o}\right) - \left(\frac{H_c \times Q_O}{2}\right)\Bigg) + \Bigg((\eta d_s^{max} - \alpha_r P_r + \beta_w P_w + \beta_o P_o)(P_r - cu) - \left(\frac{S_c \times D_r}{Q_r}\right) - \left(\frac{H_c \times Q_r}{2}\right)\Bigg) \quad (4.28)$$

$$G_{wor}(P_w, Q_w, P_o, Q_o, P_r, Q_r) = \Bigg(\Big(\big((1-\rho\eta)d_s^{max} - \alpha_w P_w + \beta_o P_o + \beta_r P_r\big)(P_w - cu) - \left(\frac{S_c \times (1-\rho\eta)d_s^{max} - \alpha_w P_w + \beta_o P_o + \beta_r P_r)}{Q_w}\right) - \left(\frac{H_c \times Q_w}{2}\right)\Big) + \Big((\rho d_s^{max} - \alpha_o P_o + \beta_w P_w + \beta_r P_r)(P_o - cu) - \left(\frac{S_c \times (\rho d_s^{max} - \alpha_o P_o + \beta_w P_w + \beta_r P_r)}{Q_o}\right) - \left(\frac{H_c \times Q_O}{2}\right)\Big) + \Big((\eta d_s^{max} - \alpha_r P_r + \beta_w P_w + \beta_o P_o)(P_r - cu) - \left(\frac{S_c \times (\eta d_s^{max} - \alpha_r P_r + \beta_w P_w + \beta_o P_o)}{Q_r}\right) - \left(\frac{H_c \times Q_r}{2}\right)\Big) \qquad (4.29)$$

$$G_{total3} = G_{wor} \qquad (4.30)$$

The objective function above (G_{wor}) accomodates the coordination of all channels (offline, online, and reseller channel) which is shown in the sum of the gain for each channel. The decision variables, which are P_w, Q_w, P_o, Q_o, P_r and Q_r will be derived from this objective function. G_{total3} is equal to G_{wor} and shows the total gain for the entire supply chain system in Scenario 3 (fully-cooperative).

4.3.4 Constrains

There are several constraints used in this research models, which are:

1. $P_w, P_o, P_r \geq cu$

The aim of this constrain is to make sure the price is higher than the production cost in order to gain profit.

2. $P_w \geq \frac{P_o}{\rho}$

This constraint shows that the opportunity for online sales is available after P_w reaches the threshold value (Widodo et al. 2013).

3. $P_w \geq \frac{P_r}{\eta}$

This constraint is conducted by modifying and following the form of the second constraint above, and shows that the opportunity for reseller sales is available after P_w reaches the threshold value.

4. $D_w, D_o, D_r \geq 0$

This constraint to make sure that the demands will not be negative value.

5. $P_r \geq 0.6P_w$

The aim of this constraint is accommodate reseller regulation which limit the price difference of offline and reseller channel to be maximum of 40%.

6. $P_w \geq P_o, P_r$

This constraint shows the price leadership in DCSC concept, where P_w is more than or at least equal to P_o and P_r.

7. $Q_w, Q_o, Q_r \geq 0$

This constraint to make sure that the optimal order quantity will not be negative value.

8. $Q_w \geq 0.8Q_o$

The aim of this constraint is accommodate offline' stock regulation which is the order quantity in offline channel is more than 80% of order quantity in online channel.

4.3.5 Parameters

This section explains about the parameter needed for this research. Parameter ρ captures customers' preference for the online channel when the products are free of charge compared to offline channel. The larger ρ is, the more intense the channel conflict is. This is because if the online channel captures more demand, the retailer will think that the offline channel corrodes its own market share. Assuming that the score of offline channel is 100 then the online channel is allowed to get the score between 0 to 99 based on the customer's preferences.

Parameter η symbolizes customer's preference of reseller channel compared to offline channel. Assuming that the score of offline channel is 100 then the reseller channel is allowed to get the score between 0 to 99 based on the customer's preferences.

According to Huang et al. (2012), parameter α symbolizes the self-price elasticity of demand. The purpose of this parameter is to convert the price into units to demand. The self-price elasticity of demand shows how many demand can be obtained by particular price in the same channel. There are three different α which are α_w (self-price elasticity of demand in offline channel), α_o (self-price elasticity in demand of online channel), and α_r (self-price elasticity of demand in reseller channel). The value of α that obtained from trial in MATLAB are 0.05, 0.03, 0.021.

Parameter β symbolizes the cross-price elasticity of demand (Huang, Yang, and Zhang 2012). The aim of this parameter is to convert the price into units of demand. The cross-price elasticity of demand shows how many demand in one channel can be obtained by particular price in the other channel.

d_s^{max} represents the forecasted potential demand if the products are free of charge. The share of the demand goes to the online channel is ρ, the reseller channel is η, and the rest $(1 - \rho\eta)$ goes to the offline channel, when P_w, P_o, P_r are zeros.

The summary of parameters needed in this research is shown in Table 4.1 below.

Table 4.1 Value of Parameters

No	Parameter	Value
1	P_w	\$200
2	P_o	\$200
3	P_r	\$200
4	ρ	0.8
5	η	0.6
6	α_w	0.05
7	α_o	0.03
8	α_r	0.021
9	β_w	0.05
10	β_o	0.03
11	β_r	0.021
12	d^s_{max}	278
13	cu	\$50
14	S_c	\$5
15	H_c	\$2

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CHAPTER 5
NUMERICAL EXPERIMENT

This chapter is showing the numerical experiments using developed model in the research. The experiment is also completed with sensitivity analysis to analyze the model characteristics.

5.1 Model Verification and Validation

In this section, verification and validation are important processes in this research, regarding that the model developed in this research has to be evaluated. verification and validation will be done to check whether the model developed is able to represent the real condition or not.

5.1.1 Model Verification

Verification is a process to compare and evaluate the model developed with the conceptual model which had been built previously. This process can be done by checking the input algorithm into MATLAB software, whether it contains of error or not in the m-file which had been made. The verification process for this research are done in two times which are objective function which consist of demand function and matrix development because the model developed into m-file in MATLAB software will be used in numerical experiments in order to do optimization process. These following figures are showing the verification processes in MATLAB software by observing the m-file script.

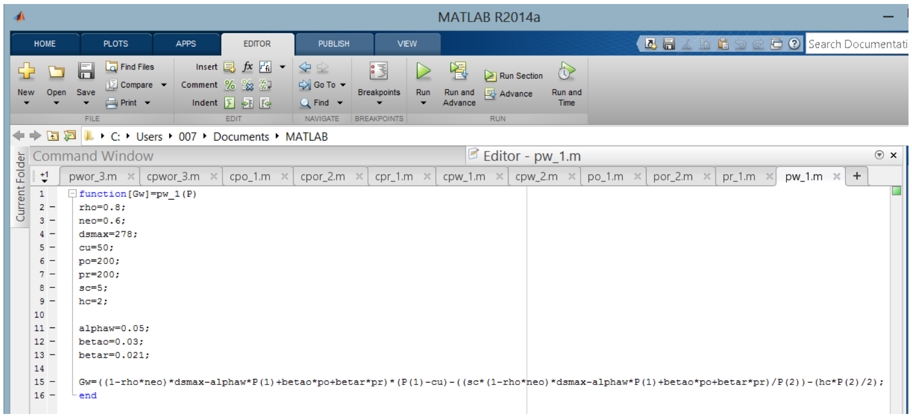

Figure 5.1 Verification Process for Objective Function in Offline Channel Scenario 1

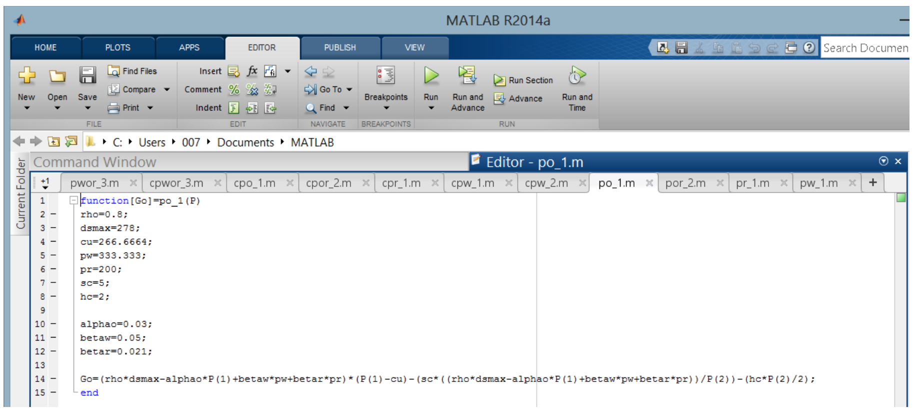

Figure 5.2 Verification Process for Objective Function in Online Channel Scenario 1

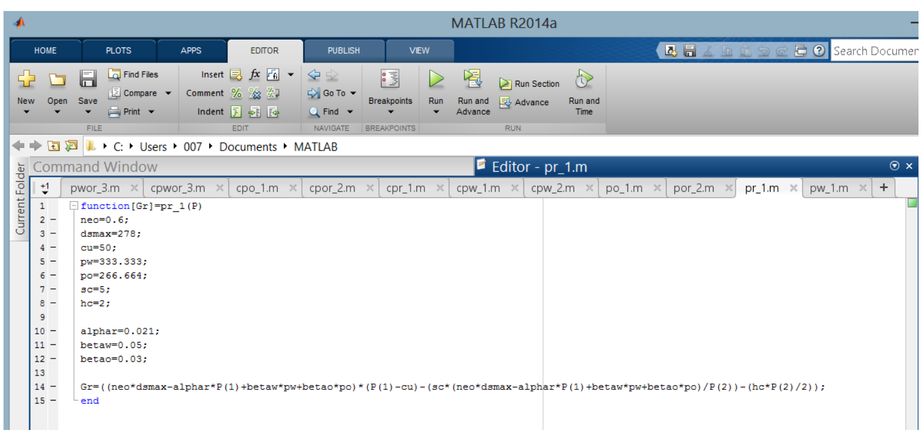

Figure 5.3 Verification Process for Objective Function in Reseller Channel Scenario 1

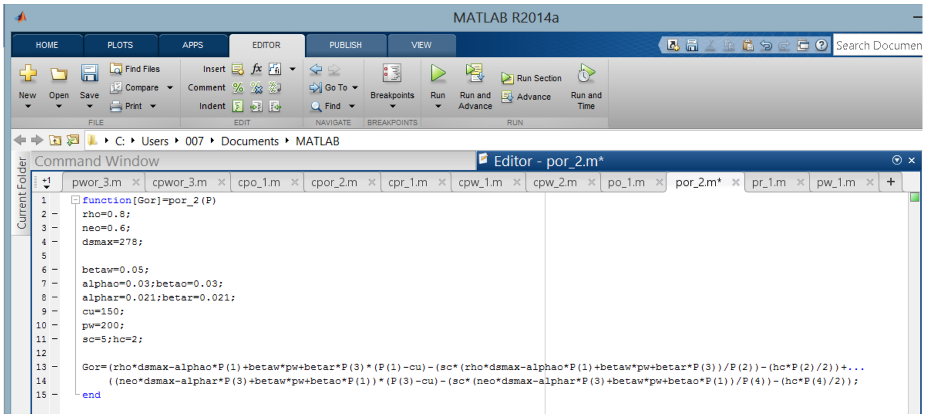

Figure 5.4 Verification Process for Objective Function in Coordination Online and Reseller Channel Scenario 2

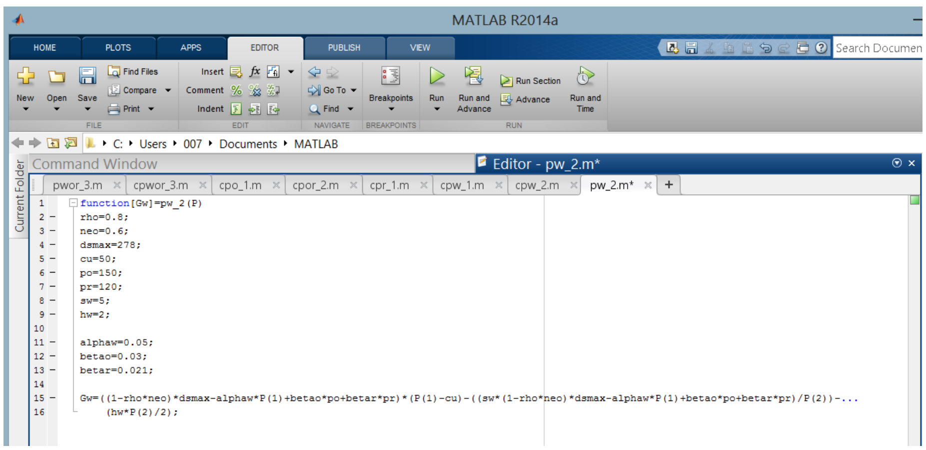

Figure 5.5 Verification Process for Objective Function in Offline Channel Scenario 2

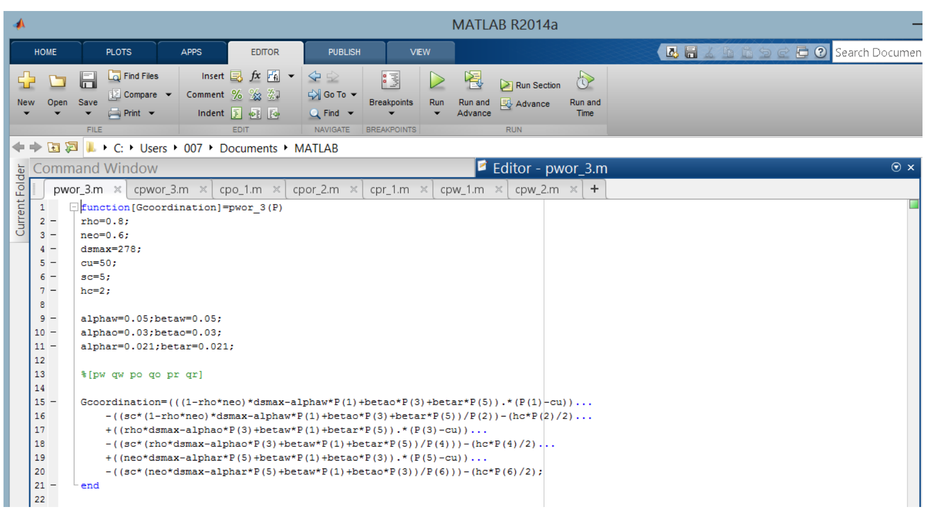

Figure 5.6 Verification Process for Objective Function in Scenario 3

As can be seen at Figure 5.1 to Figure 5.6 above, algorithm to accommodate total profit maximization objective function has been verified. It is showed by green sign in the upper right side of the m-file in MATLAB software that indicates that m-file which had been made has no contain any error. The file can be run in MATLAB software smoothly later if recalled by using command window or optimtool options.

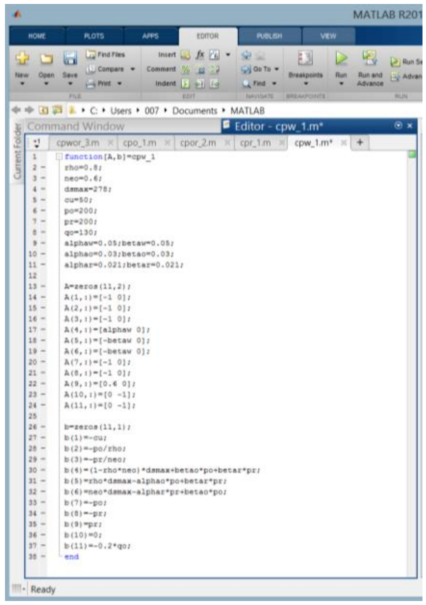

Figure 5.7 Verification Process for Constrains Matrix in Offline Channel Scenario 1

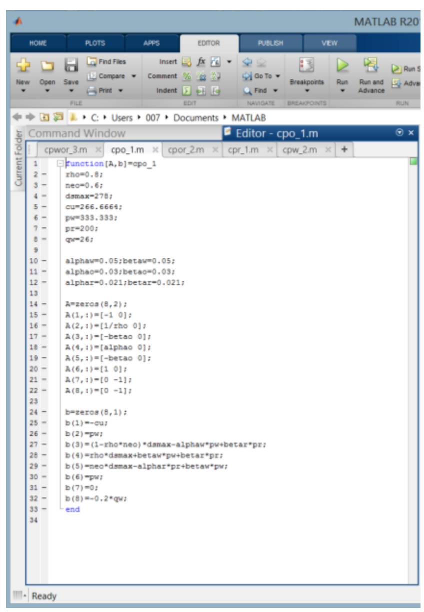

Figure 5.8 Verification Process for Constrains Matrix in Online Channel Scenario 1

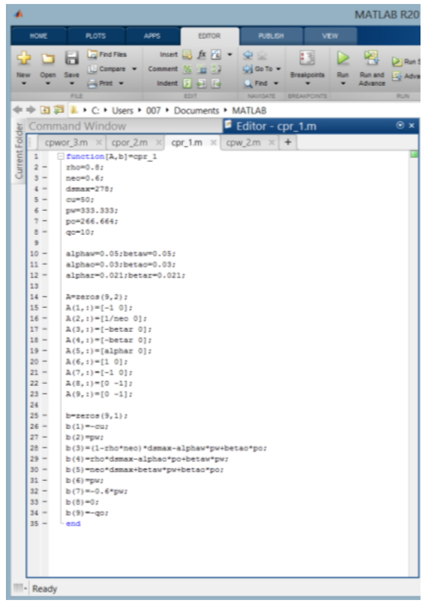

Figure 5.9 Verification Process for Constrains Matrix in Reseller Channel Scenario 1

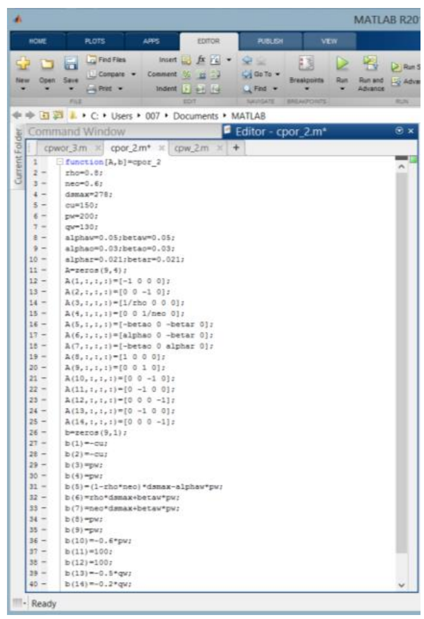

Figure 5.10 Verification Process for Constrains Matrix in Online and Reseller Channel Scenario 2

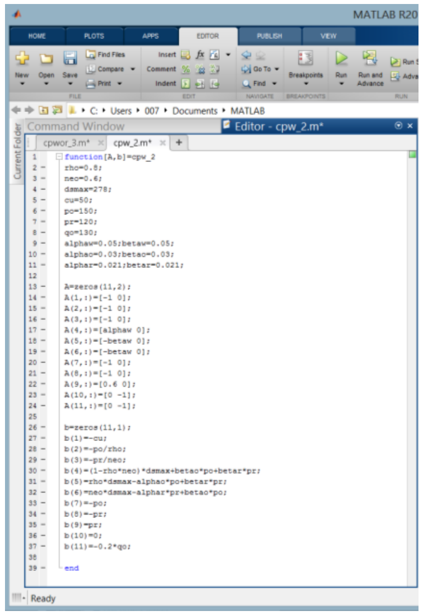

Figure 5.11 Verification Process for Constrains Matrix in Offline Channel Scenario 2

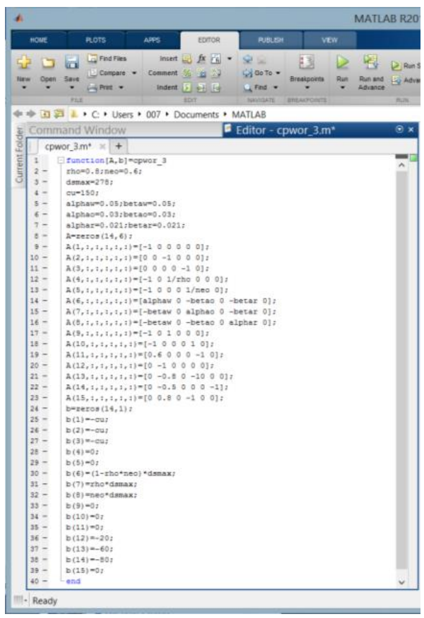

Figure 5.12 Verification Process for Constrains Matrix in Scenario 3

Constrains matrix development algorithm will help the numerical experiment processes. The tests will be done by using *optimtool* function in MATLAB software. It is seen from Figure 5.7 to Figure 5.12 above that the algorithm for constrains matrix is also verified. It is showed by the green box at the top-right corner of the window. There is no such error in its m-file, and this algorithm is ready to being recalled for optimization process.

In this research, according to those figures which shown before, it is said that all the algorithm that developed in m-file are verified. The main function in MATLAB software to find the optimal prices and order quantities in each scenario is *optimtool*. Verifying the results of this function can be done by seeing the result as shown at the figures below.

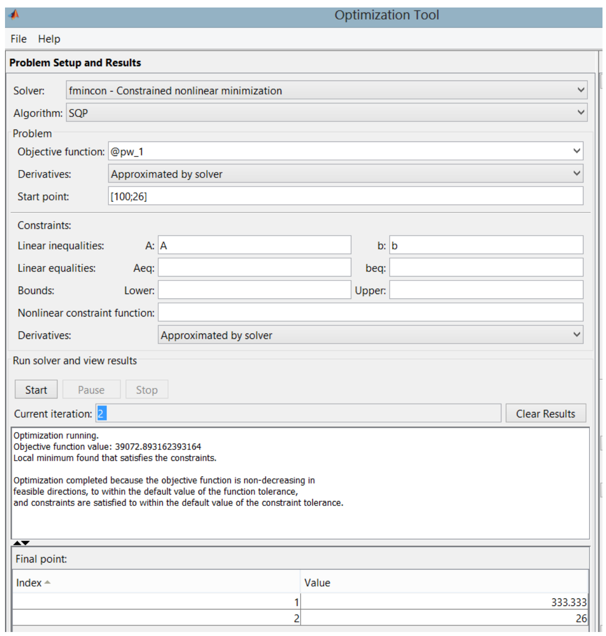

Figure 5.13 Optimtool Window in MATLAB Software

According to Figure 5.13 above, it is seen that to find optimal prices and order quantities in each scenario using objective function algorithm by considering constraints (AB matrix development algorithm) is reached the local minimum result. Based on the description at the window, it can be concluded that the results are verified since the optimum value is in a feasible region and also all the constraints are satisfied.

5.1.2 Model Validation

Validation processes are model checking and evaluating by comparing with the real system condition. It will be done by using the real data or existing data into the gain function and the demand function which had been developed. The validation process is to check the influence of the model parameters into system behavior, which evaluated from gain function and demand function of the system.

These validation processes are also done frequently, since there are some parameters are used in the model development. Recall the parameters will be used in this research, such as $\rho, \eta, \alpha, \beta, d^s_{max}, cu, s_c, h_c$. However, not all of the parameter tests result will be shown in this sub chapter, only some parameters which have some significant influence in the system behavior and comparing its behavior to the real condition of the current system observed.

5.1.2.1 Price Influence to Demand Function Behavior

In DCSC system for this research, prices offered in offline, online, and reseller channel are exactly the same. Theoretically, higher value of price will decrease the amount of demand. In the test, the other parameter will be tested at the same values and only changing the value of $P_w, P_o,$ and P_r. These following parameters are the values of definition for each parameter tested in this validation processes for price influence to demand function behavior.

Table 5.1 Data Input for Parameters Value in Pricing Influence Tests

ρ	η	α_w, β_w	α_o, β_o	α_r, β_r	d_s^{max}
0.8	0.6	0.05	0.03	0.021	278

5.1.2.1.1 Offline Price Influences to Offline Demand Behavior

In offline price influence test to offline demand behavior, the parameters values mentioned in Table 5.1 remain the same, while offline price (P_w) will changed in different values until reaching the current cu (cost of production). System behavior tests for this validation process result can be seen at the following figure.

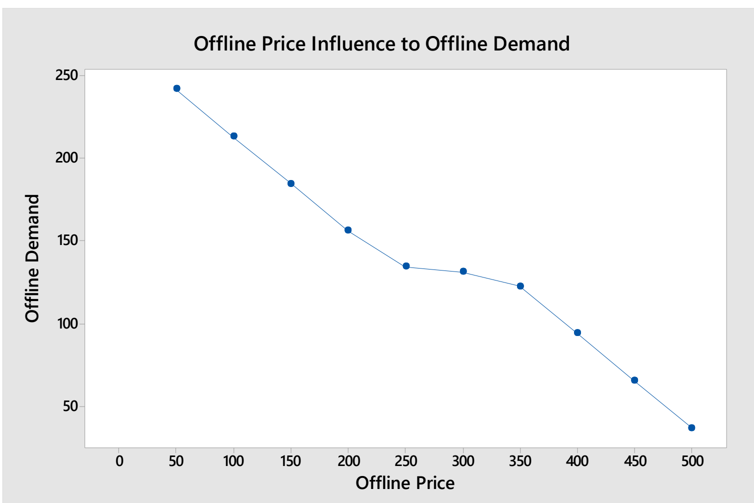

Figure 5.14 Validation Process for Offline Price Influence to Offline Demand

Figure 5.14 shows how the changes in offline price influence to the amount of offline demand. It can be seen that the higher price set for P_w value, then the lower demand in offline channel will be achieved. It shows that the offline demand function is able to represent the real system. When the product in offline channel is offered in higher price, then the total demand in that channel will decrease. Hence it can be concluded that the offline demand function is logically valid.

5.1.2.1.2 Online Price Influences to Online Demand Behavior

In online price influence test to online demand behavior, the parameters values mentioned in Table 5.1 remain the same, while online price (P_o) will changed in different values until reaching the current cu (cost of production). System behavior tests for this validation process result can be seen at the following figure.

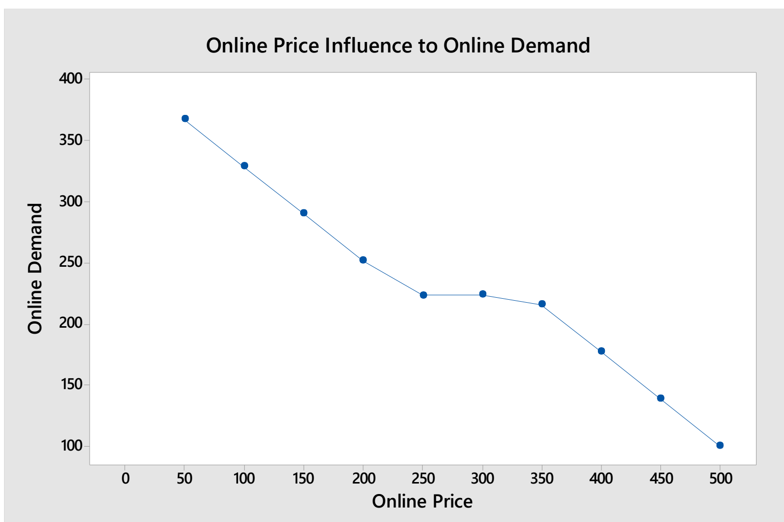

Figure 5.15 Validation Process for Online Price Influence to Online Demand

Figure 5.15 shows how the changes in online price influence to the amount of online demand. It can be seen that the higher price set for P_o value, then the lower demand in online channel will be achieved. It shows that the online demand function is able to represent the real system. When the product in online channel is offered in higher price, then the total demand in that channel will decrease. Hence it can be concluded that the online demand function is logically valid.

5.1.2.1.3 Reseller Price Influences to Reseller Demand Behavior

In reseller price influence test to reseller demand behavior, the parameters values mentioned in Table 5.1 remain the same, while reseller price (P_r) will changed in different values until reaching the current cu (cost of production). System behavior tests for this validation process result can be seen at the following figure.

Figure 5.16 Validation Process for Reseller Price Influence to Reseller Demand

Figure 5.16 shows how the changes in online price influence to the amount of reseller demand. It can be seen that the higher price set for P_r value, then the lower demand in reseller channel will be achieved. It shows that the reseller demand function is able to represent the real system. When the product in reseller channel is offered in higher price, then the total demand in that channel will decrease. Hence it can be concluded that the reseller demand function is logically valid.

5.1.2.2 Order Quantity Influence to Total Gain Function Behavior

Validation process for gain function can be done by checking the behavior of the system by changing the value of order quantity. Order quantity will be changed to see its impact to the total gain. Order quantity offered in offline, online, and reseller channel are exactly the same. Theoretically, assuming that there are not any changes in price, higher order quantity will generate higher total gain, whereas lower order quantity will generate lower total gain. These following parameters are the values of definition for each parameter tested in this validation processes for order quantity influence to total gain function behavior.

Table 5.2 Data Input for Parameters Value in Order Quantity Influence Tests

ρ	η	α_w, β_w	α_o, β_o	α_r, β_r	d_s^{max}	cu	s_c	h_c
0.8	0.6	0.05	0.03	0.021	278	50	5	2

5.1.2.2.1 Offline Order Quantity Influence to Offline Total Gain Function

In offline order quantity influence test to offline total gain behavior, the parameters values mentioned in Table 5.2 remain the same, while offline order quantity (Q_w) will changed in different values. System behavior tests for this validation process result can be seen at the following figure.

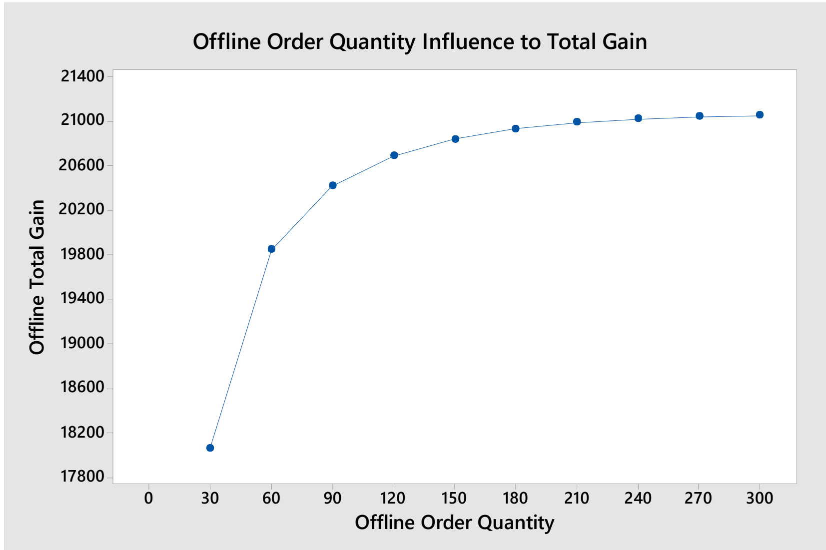

Figure 5.17 Offline Order Quantity Influence to Offline Total Gain

Figure 5.17 shows how the changes in offline order quantity influence to the amount of offline total gain. It can be seen that the higher order quantity set for Q_w value, then the higher total gain in offline channel will be achieved. It shows that the offline total gain is able to represent the real system. When the product in offline channel is sold in higher quantity, then the total gain in that channel will increase. Hence it can be concluded that the offline total gain function is logically valid.

5.1.2.2.2 Online Order Quantity Influence to Online Total Gain Function

In online order quantity influence test to online total gain behavior, the parameters values mentioned in Table 5.2 remain the same, while online order quantity (Q_o) will changed in different values. System behavior tests for this validation process result can be seen at the following figure.

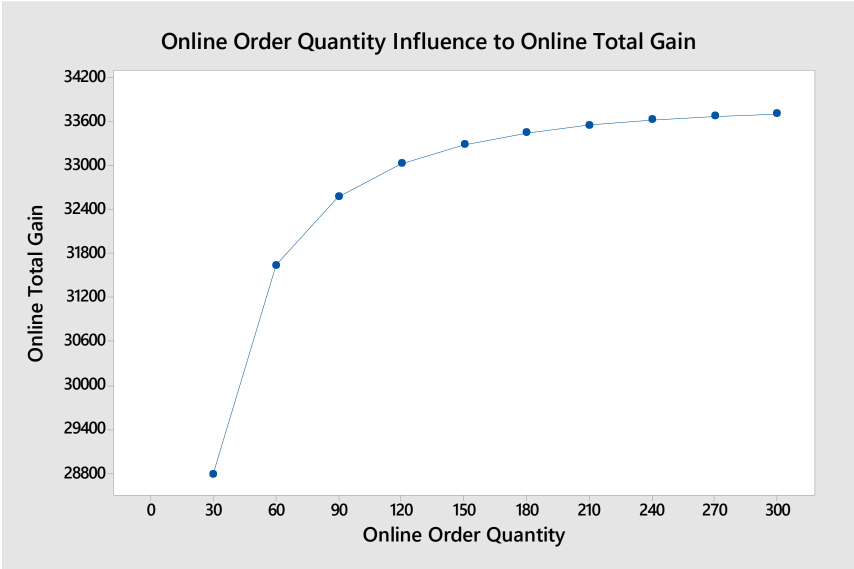

Figure 5.18 Online Order Quantity Influence to Online Total Gain

Figure 5.18 shows how the changes in online order quantity influence to the amount of online total gain. It can be seen that the higher order quantity set for Q_o value, then the higher total gain in online channel will be achieved. It shows that the online total gain is able to represent the real system. When the product in online channel is sold in higher quantity, then the total gain in that channel will increase. Hence it can be concluded that the online total gain function is logically valid.

5.1.2.2.3 Reseller Order Quantity Influence to Reseller Total Gain Function

In reseller order quantity influence test to reseller total gain behavior, the parameters values mentioned in Table 5.2 remain the same, while reseller order quantity (Q_r) will changed in different values. System behavior tests for this validation process result can be seen at the following figure.

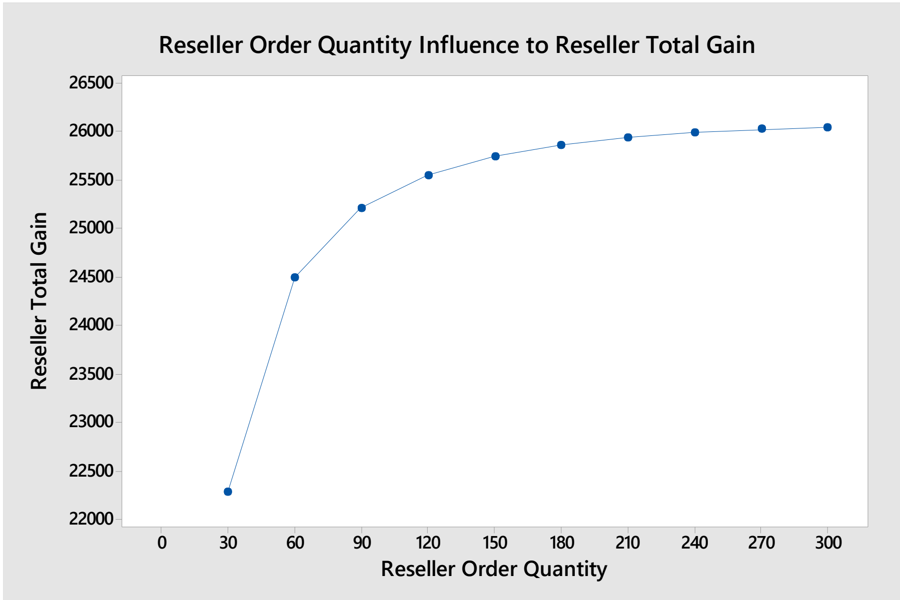

Figure 5.19 Reseller Order Quantity Influence to Reseller Total Gain

Figure 5.19 shows how the changes in reseller order quantity influence to the amount of reseller total gain. It can be seen that the higher order quantity set for Q_r value, then the higher total gain in reseller channel will be achieved. It shows that the reseller total gain is able to represent the real system. When the product in reseller channel is sold in higher quantity, then the total gain in that channel will increase. Hence it can be concluded that the reseller total gain function is logically valid.

5.1.2.3 Cost of Production Influence to Total Gain Function Behavior

The other function which developed in this research is the function in order to gain profit in offline, online, and reseller channel which will gain the total profit achieved by DCSC system itself. The parameter which is influence total gain is cost of production (cu). Parameter cu will be changed to see the impact to the total gain. Theoretically, assuming that there are not any changes in price, lower unit cost will generate higher gain, whereas higher unit cost will generate lower gain. Below is the validation process for cost of production influence to total gain function behavior.

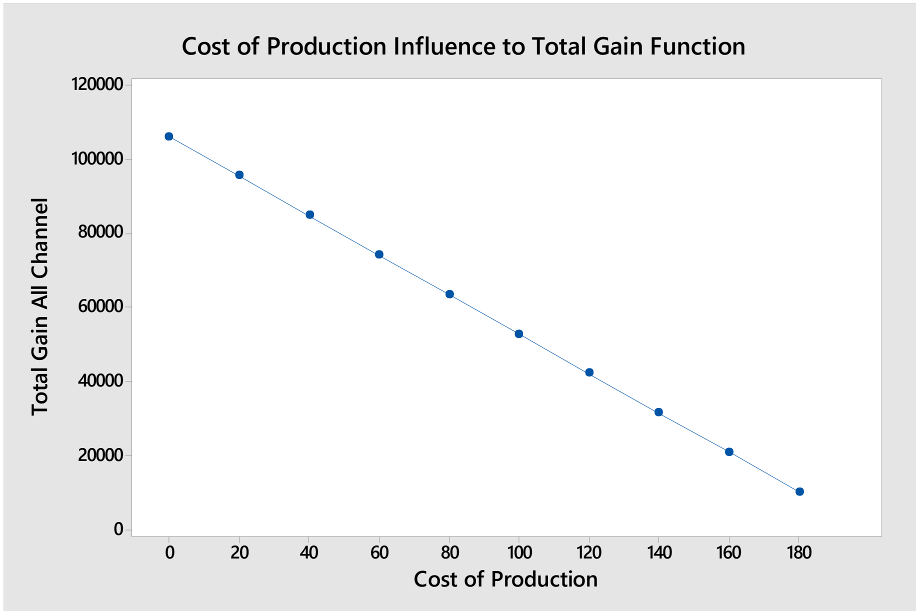

Figure 5.20 Validation Process for Cost of Production to Total Gain Function

From Figure 5.20, it shows that cost of production value has significant influence to total gain achieved by all channel. The higher cost of production spent, the lower gain or profit that can be achieved. While the lower cost of production spent, the higher total gain or profit that can be achieved. When the cost of production is set equal to 0, it increases the total gain to be maximum, whereas the higher cost of production decreases the total gain to be reach minimum. It can be concluded that the model is able represent the real system and logically valid.

5.2 Numerical Experiment

In this section, numerical experiment will be performed to see which scenario provides the best financial performance. The output of this experiment is the optimal price and optimal order quantity in each channel that generates the highest gain. In order to find the optimal prices and order quantities for offline, online, and reseller channel, the method will be used is Non-linear programming. Numerical experiment is done using MATLAB software with optimtool function. Each scenario has different script in MATLAB with some adjustment based on the characteristic of the scenario.

The numerical experiment in finding the optimal price and order quantity follows the theory of Stackelberg Leadership. Stackelberg Leadership brought the concept of price leader and price follower. A price follower expects that the price of the other party is fixed, therefore it will determine its own optimal price and a price leader determines its own optimal price by assuming that the other parties behave as follower (Schoonbeek, 1990). In this research, the channel with highest market (indicated by the number of sales) is assumed to be the price leader. In this case, it means that the offline, online, and reseller channel have the highest to lowest price leadership respectively.

5.2.1 Numerical Experiment for Scenario 1 (Non-cooperative)

In the scenario 1 (non-cooperative), each channel works independently in meeting customer demand. Based on the theory of Stackelberg Leadership above, offline channel is the first channel to be evaluated to find its optimal price and optimal order quantity by assuming that $P_o, P_r, Q_o, and\ Q_r$ have fixed value. Finding optimal prices and order quantities by using optimtool function requiring some definition to convert the developed model for this research into default language in MATLAB software. This following table is showing conclusion of constraints used to define the characteristic of observed DCSC system converted into MATLAB language.

Table 5.3 Constraints for Offline Channel in Scenario 1

No	Linear Constraint [A]		Vector [b]	Annotation
1	$-P_w$	$\leq$	$-cu$	Offline price is higher than cost of production
2	$-P_w$	$\leq$	$-\frac{P_o}{\rho}$	Demand interplay
3	$-P_w$	$\leq$	$-\frac{P_r}{\eta}$	
4	$\alpha_w P_w$	$\leq$	$(1-\rho\eta)d_s^{max} + \beta_o P_o + \beta_r P_r$	Demand each channel must be positive
5	$-\beta_w P_w$	$\leq$	$\rho d_s^{max} - \alpha_o P_o + \beta_r P_r$	
6	$-\beta_w P_w$	$\leq$	$\eta d_s^{max} - \alpha_r P_r + \beta_o P_o$	
7	$-P_w$	$\leq$	$-P_o$	Price leadership
8	$-P_w$	$\leq$	$-P_r$	
9	$0.6P_w$	$\leq$	P_r	Reseller policy
10	$-Q_w$	$\leq$	0	Quantity must be positive
11	$-Q_w$	$\leq$	$-0.2Q_o$	Offline' quantity policy

Finding optimal prices and order quantities by using optimtool function requiring some definition to convert the developed model for this research into default language in MATLAB software. This following table is showing conclusion of constraints used to define the characteristic of observed DCSC system converted into MATLAB language.

Table 5.3 shows the constrains used to find the optimal price and order quantity in offline channel in order to represent the real system. Column A shows the linear constraint matrix for inequality constraints and column b is the corresponding vectors. The optimization processes are done in several times in order to find not only the optimum but also it is a logical solution by changing the initial point. By inputting parameter with the same value as the existing condition that already mentioned in Chapter 4, the experiment generates optimal value of offline price (P_w) and offline order quantity (Q_w) to be NT$ 333.33 and 26 units.

The second channel to be evaluated in order to find its optimal price and order quantity is online channel. In this experiment, the input for offline price (P_w) and offline order quantity (Q_w) are the optimal value from previous experiment. Numerical experiment for online channel is done with some constraints as below.

Table 5.4 Constraints for Online Channel in Scenario 1

No	Linear Constraint [A]		Vector [b]	Annotation
1	$-P_o$	$\leq$	$-cu$	Online price is higher than cost of production
2	$\frac{P_o}{\rho}$	$\leq$	P_w	Demand interplay
3	$-\beta_o P_o$	$\leq$	$(1-\rho\eta)d_s^{max} - \alpha_w P_w + \beta_r P_r$	Demand each channel must be positive
4	$\alpha_o P_o$	$\leq$	$\rho d_s^{max} + \beta_w P_w + \beta_r P_r$	
5	$-\beta_o P_o$	$\leq$	$\eta d_s^{max} - \alpha_r P_r + \beta_w P_w$	
6	P_o	$\leq$	P_w	Price leadership
7	$-Q_o$	$\leq$	0	Quantity must be positive
8	$-0.2Q_o$	$\leq$	$-Q_w$	Offline' quantity policy

Table 5.4 shows the constrains used to find the optimal price and order quantity in online channel in order to represent the real system. Column A shows the linear constraint matrix for inequality constraints and column b is the corresponding vectors. The optimization processes are done in several times in order to find not only the optimum but also it is a logical solution by changing the initial point. By inputting parameter with the same value as the existing condition that already mentioned in Chapter 4, the experiment generates optimal value of online price (P_o) and online order quantity (Q_o) to be NT$ 266.664 and 15 units.

The third channel to be evaluated in order to find its optimal price and order quantity is reseller channel. In this experiment, the input for P_w, P_o, Q_w and Q_o are the optimal value from previous experiment. Numerical experiment for reseller channel is done with some constraints as below.

Table 5.5 Constraints for Reseller Channel in Scenario 1

No	Linear Constraint [A]		Vector [b]	Annotation
1	$-P_r$	$\leq$	$-cu$	Reseller price is higher than cost of production
2	$\frac{P_r}{\eta}$	$\leq$	P_w	Demand interplay
3	$-\beta_r P_r$	$\leq$	$(1-\rho\eta)d_s^{max} - \alpha_w P_w + \beta_o P_o$	Demand each channel must be positive
4	$-\beta_r P_r$	$\leq$	$\rho d_s^{max} - \alpha_o P_o + \beta_w P_w$	
5	$\alpha_r P_r$	$\leq$	$\eta d_s^{max} + \beta_w P_w + \beta_o P_o$	
6	P_r	$\leq$	P_w	Price leadership
7	$-P_r$	$\leq$	$-0.6P_w$	Reseller policy
8	$-Q_r$	$\leq$	0	Quantity must be positive

Table 5.5 shows the constrains used to find the optimal price and order quantity in reseller channel in order to represent the real system. Column A shows the linear constraint matrix for inequality constraints and column b is the corresponding vectors. The optimization processes are done in several times in order to find not only the optimum but also it is a logical solution by changing the initial point. By inputting parameter with the same value as the existing condition that already mentioned in Chapter 4, the experiment generates optimal value of reseller price (P_r) and reseller order quantity (Q_r) to be NT$ 200 and 10 units.

5.2.2 Numerical Experiment for Scenario 2 (Semi-cooperative)

In the scenario 2 (semi-cooperative), the online and reseller channel form a coordination and work complementary in meeting customer demand, while the offline channel works independently. The coordination of the online and reseller channel is possible because both channel are not as strong as offline channel. The numerical experiment is done for coordination online and reseller channel then offline channel. Coordination between online and reseller channel is the first to be evaluated to find the optimal prices and order quantities that evaluated simultaneously where both prices are derived from one objective function, by assuming that offline price (P_w) and offline order quantity (Q_w) have fixed value. Numerical experiment for coordination between online and reseller channel is done with some constraints as below.

Table 5.6 Constraints for Coordination between Online and Reseller Channel in Scenario 2

No	Linear Constraint [A]		Vector [b]	Annotation
1	$-P_o$	$\leq$	$-cu$	Online price is higher than cost of production
2	$-P_r$	$\leq$	$-cu$	Reseller price is higher than cost of

				production
3	$\frac{P_o}{\rho}$	≤	P_w	Demand interplay
4	$\frac{P_r}{\eta}$	≤	P_w	
5	$-\beta_o P_o - \beta_r P_r$	≤	$(1-\rho\eta)d_s^{max} - \alpha_w P_w$	Demand each channel must be positive
6	$\alpha_o P_o - \beta_r P_r$	≤	$\rho d_s^{max} + \beta_w P_w$	
7	$-\beta_o P_o + \alpha_r P_r$	≤	$\eta d_s^{max} + \beta_w P_w$	
8	P_o	≤	P_w	Price leadership
9	P_r	≤	P_w	
10	$-P_r$	≤	$-0.6P_w$	Reseller policy
11	$-Q_o$	≤	0	Quantity must be positive
12	$-Q_r$	≤	0	
13	$-0.2Q_o$	≤	$-Q_w$	Offline' quantity policy

Table 5.6 shows the constrains used to find the optimal price and order quantity in online and reseller channel in order to represent the real system. Column A shows the linear constraint matrix for inequality constraints and column b is the corresponding vectors. The optimization processes are done in several times in order to find not only the optimum but also it is a logical solution by changing the initial point. By inputting parameter with the same value as the existing condition that already mentioned in Chapter 4, the experiment generates optimal value of online price (P_o) and online order quantity (Q_o) to be NT$ 150 and 65 units and optimal value of reseller price (P_r) and reseller order quantity (Q_r) to be NT$ 120 and 26 units respectively.

The second channel to be evaluated in order to find its optimal price and order quantity is offline channel. In this experiment, the input for prices and order quantities in online and reseller channel are the optimal value from previous experiment. Numerical experiment for offline channel is done with some constraints as below.

Table 5.7 Constraints for Offline Channel in Scenario 2

No	Linear Constraint [A]		Vector [b]	Annotation
1	$-P_w$	$\leq$	$-cu$	Offline price is higher than cost of production
2	$-P_w$	$\leq$	$-\frac{P_o}{\rho}$	Demand interplay
3	$-P_w$	$\leq$	$-\frac{P_r}{\eta}$	
4	$\alpha_w P_w$	$\leq$	$(1-\rho\eta)d_s^{max} + \beta_o P_o + \beta_r P_r$	Demand each channel must be positive
5	$-\beta_w P_w$	$\leq$	$\rho d_s^{max} - \alpha_o P_o + \beta_r P_r$	
6	$-\beta_w P_w$	$\leq$	$\eta d_s^{max} - \alpha_r P_r + \beta_o P_o$	
7	$-P_w$	$\leq$	$-P_o$	Price leadership
8	$-P_w$	$\leq$	$-P_r$	
9	$0.6P_w$	$\leq$	P_r	Reseller policy
10	$-Q_w$	$\leq$	0	Quantity must be positive
11	$-0.8Q_w$	$\leq$	$-Q_o$	Offline' quantity policy

Table 5.7 shows the constrains used to find the optimal price and order quantity in offline channel in order to represent the real system. Column A shows the linear constraint matrix for inequality constraints and column b is the corresponding vectors. The optimization processes are done in several times in order to find not only the optimum but also it is a logical solution by changing the initial point. By inputting parameter with the same value as the existing condition that already mentioned in Chapter 4, the experiment generates optimal value of offline price (P_w) and offline order quantity (Q_w) to be NT$ 200 and 26 units.

5.2.3 Numerical Experiment for Scenario 3 (Fully-cooperative)

In the scenario 3 (fully-cooperative), all channels form a coordination and work complementary in meeting customer demand. The numerical experiment is done for all three channels simultaneously, where all prices and order quantities are derived from one objective function. Numerical experiment for all of the channel is done with some constraints as below.

Table 5.8 Constrains for All of Channels in Scenario 3

No	Linear Constraint [A]		Vector [b]	Annotation
1	$-P_w$	$\leq$	$-cu$	Price in each channel must be higher than cost of production
2	$-P_o$	$\leq$	$-cu$	
3	$-P_r$	$\leq$	$-cu$	
4	$-P_w + \frac{P_o}{\rho}$	$\leq$	0	Demand interplay
5	$-P_w + \frac{P_r}{\eta}$	$\leq$	0	
6	$\alpha_w P_w - \beta_o P_o - \beta_r P_r$	$\leq$	$(1-\rho\eta)d_s^{max}$	Demand each channel must be positive
7	$\alpha_o P_o - \beta_w P_w - \beta_r P_r$	$\leq$	ρd_s^{max}	
8	$\alpha_r P_r - \beta_w P_w - \beta_o P_o$	$\leq$	ηd_s^{max}	
9	$-P_w + P_o$	$\leq$	0	Price leadership
10	$-P_w + P_r$	$\leq$	0	
11	$0.6P_w - P_r$	$\leq$	0	Reseller policy
12	$-Q_w$	$\leq$	0	Quantity must be positive
13	$-Q_o$	$\leq$	0	
14	$-Q_r$	$\leq$	0	
15	$0.8Q_w - Q_o$	$\leq$	0	Offline' quantity policy

Table 5.8 shows the constraints used in finding optimal prices and order quantities in offline, online, and reseller price in order to represent the real system. For this numerical experiment, no constraints are violated, hence there is no need of constraints relaxation. α and β trial is done to find the best result until the experiment generates

optimal value of offline price (P_w) and offline order quantity (Q_w) to be NT$ 252 and 75 units, online price (P_o) and online order quantity (Q_o) to be NT$ 150 and 50 units, reseller price (P_r) and reseller order quantity (Q_r) to be NT$ 150 and 43 units.

5.2.4 Comparison of Scenarios

After evaluating each scenario, the results of the numerical experiments are summarized below.

Table 5.9 Comparison of Numerical Experiment Results

	Scenario 1 (Non-cooperative)	**Scenario 2 (Semi-cooperative)**	**Scenario 3 (Fully-cooperative)**
P_w	333	200	252
P_o	267	150	150
P_r	200	120	150
Q_w	26 units	26 units	75 units
Q_o	6 units	65 units	50 units
Q_r	10 units	26 units	43 units
G_w	31,576.09	17,126.96	
G_o	8,502.45		
G_r	14,035.75		
G_{or}		31,286.48	
G_{wor}			63,154.89
G_{total}	54,114.29	48,413.45	63,154.89

Table 5.9 shows the results of the numerical experiments in each scenario. The result of numerical experiments shows that there is a huge gap in total gain between scenarios. It is caused by the price difference in each scenario generated from optimization process done with MATLAB. Based on the result above, it can be concluded that Scenario 3 (fully-cooperative) generates the best financial performance. However, this decision can be changed in the future due to the changes in parameters that will be explained in sensitivity analysis.

5.2.5 Sensitivity Analysis

Sensitivity analysis is the technique used to analyze how the different values of a set of independent variables affect a specific dependent variable under certain specific conditions so we can evaluate which parameter has significant influence to the total gain achieved by the system. The purpose of sensitivity analysis is to see how the changes of a parameter affect the total gain that will cause the decision maker to change the decision regarding the choice of scenario. The sensitivity analysis is done by changing evaluated parameters in different value while the other parameter values remain the same. The effect or the behavior that can be seen from sensitivity analysis into total gain can be evaluated through a graphic. In this research, the parameters evaluated are $d_s^{max}, cu, \rho, \eta, s_c, and\ h_c$.

5.2.5.1 Sensitivity Analysis of d_s^{max} Parameter

In this section, d_s^{max} parameter is evaluated to see how the changes on its value affect the total gain. The value of d_s^{max} parameter defined in this part is the maximum total demand estimated when product price reaches as same as cost of production for each month. The following table is showing recapped result of the sensitivity analysis of d_s^{max} parameter.

Table 5.10 Sensitivity Analysis Result of dsmax Parameter

No	d_s^{max}	$G_{total\ 1}$	$G_{total\ 2}$	$G_{total\ 3}$	Best Scenario
1	100	20.232,16	18.016,52	23.450,11	3
2	200	39.525,48	35.093,45	45.756,17	3
3	300	58.818,80	52.170,37	68.062,23	3
4	400	78.112,12	69.247,29	90.368,29	3

No	d_s^{max}	$G_{total\ 1}$	$G_{total\ 2}$	$G_{total\ 3}$	Best Scenario
5	500	97.405,44	86.324,22	112.674,35	3
6	600	116.698,76	103.401,14	134.980,40	3
7	700	135.992,08	120.478,06	157.286,46	3
8	800	155.285,40	137.554,98	179.592,52	3
9	900	174.578,72	154.631,91	201.898,58	3
10	1000	193.872,04	171.708,83	224.204,64	3
11	1100	213.165,36	188.785,75	246.510,70	3
12	1200	232.458,68	205.862,68	268.816,76	3
13	1300	251.752,00	222.939,60	291.122,82	3
14	1400	271.045,32	240.016,52	313.428,88	3
15	1500	290.338,63	257.093,45	335.734,93	3

Table 5.10 shows the summary of sensitivity analysis done towards d_s^{max} parameter. In order to make the comparison between each scenario result is more attractive and easier, then the following is graphic illustration for sensitivity analysis of d_s^{max} parameter.

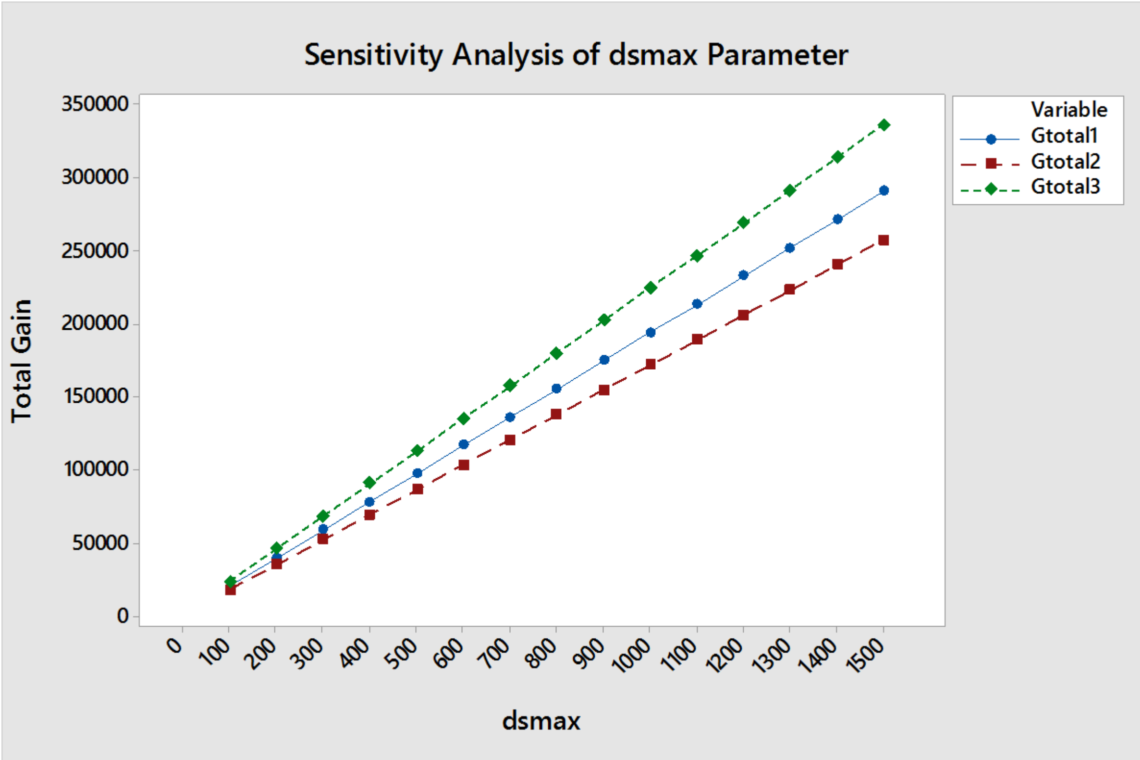

Figure 5.21 Graphic Illustration of dsmax Parameter

Figure 5.21 is the graphic illustration of sensitivity analysis of d_s^{max} parameter. The result shows that d_s^{max} parameter has significant influence to the total profit achieved by the system. However, from this sensitivity analysis can be concluded that the lower d_s^{max} parameter, the lower profit can be achieved by the system. It also show that no changes of d_s^{max} parameter makes other scenarios provide a better financial performance, hence Scenario 3 (fully-cooperative) remains the best scenario.

5.2.5.2 Sensitivity Analysis of cu Parameter

In this section, cu parameter is evaluated to see how the changes on its value affect the total gain. The value of cu parameter defined in this part is unit cost of production. The values of cu parameter will be changes while other at the same values. In order to evaluate the effect of cu parameter into total profit achieved, the test is resulting as recapped below.

Table 5.11 Sensitivity Analysis Result of cu Parameter

No	cu	$G_{total\ 1}$	$G_{total\ 2}$	$G_{total\ 3}$	Best Scenario
1	10	64.414,60	67.271,35	83.167,70	3
2	20	61.954,52	62.556,88	78.164,50	3
3	30	59.494,44	57.842,40	73.161,30	3
4	40	57.034,35	53.127,92	68.158,10	3
5	50	54.574,27	48.413,45	63.154,89	3
6	60	52.114,19	43.698,97	58.151,69	3
7	70	49.654,11	38.984,49	53.148,49	3
8	80	47.194,03	34.270,02	48.145,29	3
9	90	44.733,95	29.555,54	43.142,09	1
10	100	42.273,86	24.841,06	38.138,88	1
11	110	39.813,78	20.126,58	33.135,68	1
12	120	37.353,70	15.412,11	28.132,48	1
13	130	34.893,62	10.697,63	23.129,28	1
14	140	32.433,54	5.983,15	18.126,07	1
15	150	29.973,46	1.268,68	13.122,87	1

Table 5.11 shows the summary of sensitivity analysis done towards cu parameter. In order to make the comparison between each scenario result is more attractive and easier, then the following is graphic illustration for sensitivity analysis of cu parameter.

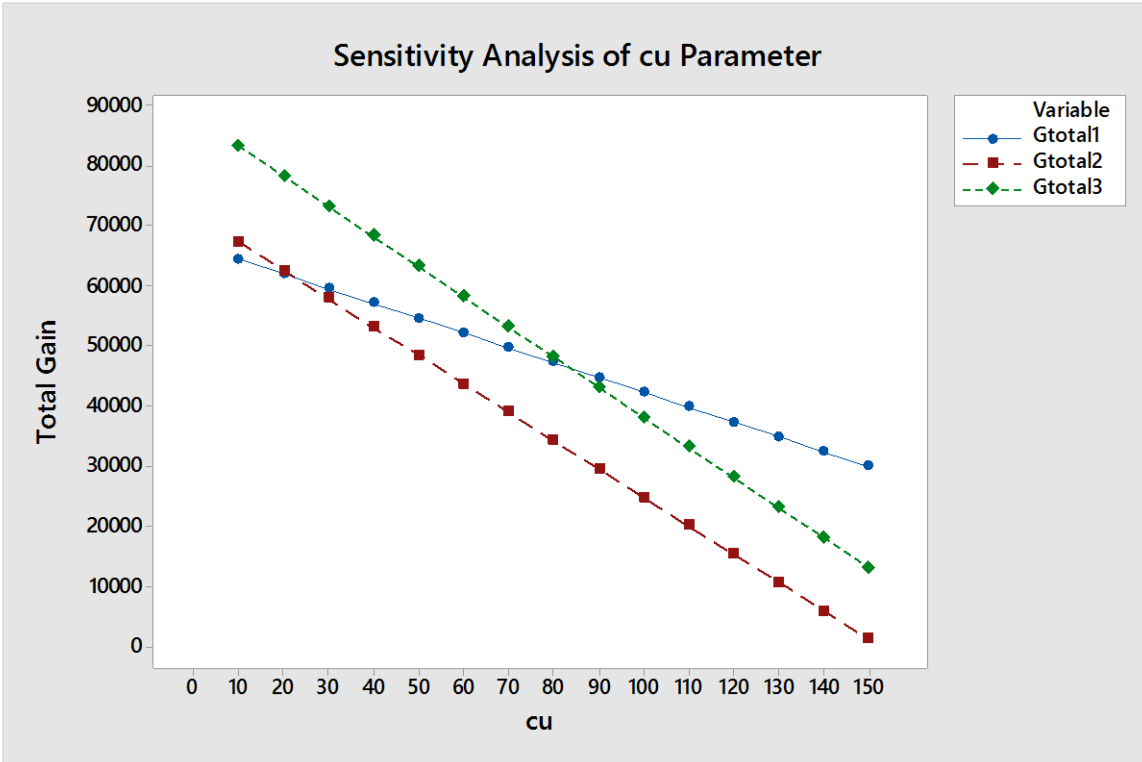

Figure 5.22 Graphic Illustration of cu Parameter

Figure 5.22 is the graphic illustration for sensitivity analysis of cu parameter. It is seen that the higher cu parameter values, the lower total gain can be achieved. This condition happens since profit achieved by the system for offline, online, and reseller channel were generated from the differences values between price set multiplies by total demand. That is why; the smaller gap between price set and cost of production of product, the lower profit can be achieved and vice versa.

It also shows that when the value of cu parameter is less than NT$ 90, the Scenario 3 (fully-cooperative) remains the best scenario. However, when the value of cu parameter reaches NT$ 90 and more, the maximum total gain occurs in Scenario 1 (non-cooperative).

5.2.5.3 Sensitivity Analysis of ρ Parameter

In this section, ρ parameter is evaluated to see how the changes on its value affect the total gain. The value of ρ parameter defined in this part is customer acceptance ratio in online channel compared to the offline channel. The values of ρ parameter will be changes while other at the same values. In order to evaluate the effect of ρ parameter into total profit achieved, the test is resulting as recapped below.

Table 5.12 Sensitivity Analysis Result of ρ Parameter

No	ρ	$G_{total\ 1}$	$G_{total\ 2}$	$G_{total\ 3}$	Best Scenario
1	0,1	74.256,28	44.596,29	67.654,05	1
2	0,2	71.444,57	45.141,60	67.011,31	1
3	0,3	68.632,85	45.686,91	66.368,57	1
4	0,4	65.821,14	46.232,22	65.725,84	1
5	0,5	63.009,42	46.777,52	65.083,10	3
6	0,6	60.197,70	47.322,83	64.440,37	3
7	0,7	57.385,99	47.868,14	63.797,63	3
8	0,8	54.574,27	48.413,45	63.154,89	3
9	0,9	51.762,56	48.958,75	62.512,16	3
10	1	48.950,84	49.504,06	61.869,42	3

Table 5.12 shows the summary of sensitivity analysis done towards ρ parameter . In order to make the comparison between each scenario result is more attractive and easier, then the following is graphic illustration for sensitivity analysis of ρ parameter.

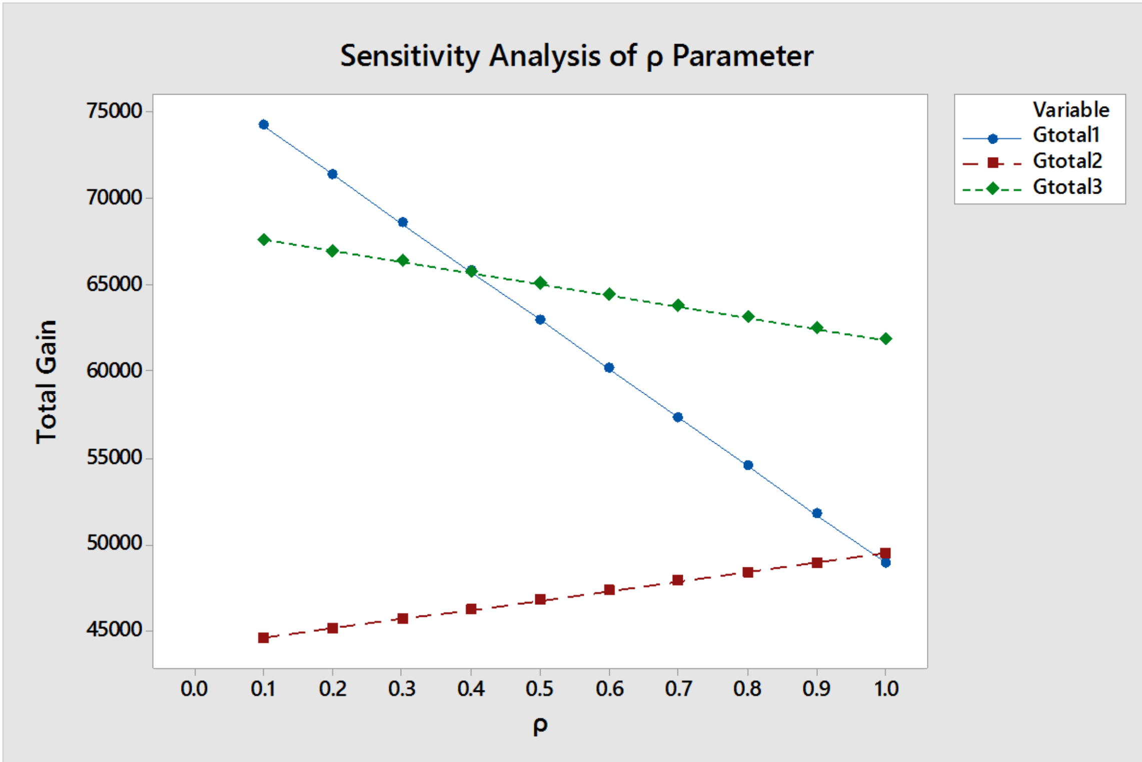

Figure 5.23 Graphic Illustration of ρ Parameter

Figure 5.23 is the graphic illustration of sensitivity analysis of ρ parameter. The result shows that ρ parameter has significant influence to the total profit achieved by the system. The result of the sensitivity analysis of ρ parameter shows that when the value of ρ is equal to 0.5 or above, the Scenario 3 (fully-cooperative) remains the best scenario. However, when the value of ρ is less than 0.4, the maximum total gain occurs in the Scenario 1 (non-cooperative).

5.2.5.4 Sensitivity Analysis of η Parameter

In this section, η parameter is evaluated to see how the changes on its value affect the total gain. The value of η parameter defined in this part is customer acceptance ratio in reseller channel compared to the offline channel. The values of η parameter will be changes while other at the same values. In order to evaluate the effect of η parameter into total profit achieved, the test is resulting as recapped below.

Table 5.13 Sensitivity Analysis Result of η Parameter

No	η	$G_{total\,1}$	$G_{total\,2}$	$G_{total\,3}$	Best Scenario
1	0,1	69.596,94	54.026,91	71.836,08	3
2	0,2	66.592,40	52.904,22	70.099,84	3
3	0,3	63.587,87	51.781,52	68.363,61	3
4	0,4	60.583,34	50.658,83	66.627,37	3
5	0,5	57.578,81	49.536,14	64.891,13	3
6	0,6	54.574,27	48.413,45	63.154,89	3
7	0,7	51.569,74	47.290,75	61.418,66	3
8	0,8	48.565,21	46.168,06	59.682,42	3
9	0,9	45.560,68	45.045,37	57.946,18	3
10	1	42.556,14	43.922,68	56.209,95	3

Table 5.13 shows the summary of sensitivity analysis done towards η parameter . In order to make the comparison between each scenario result is more attractive and easier, then the following is graphic illustration for sensitivity analysis of η parameter .

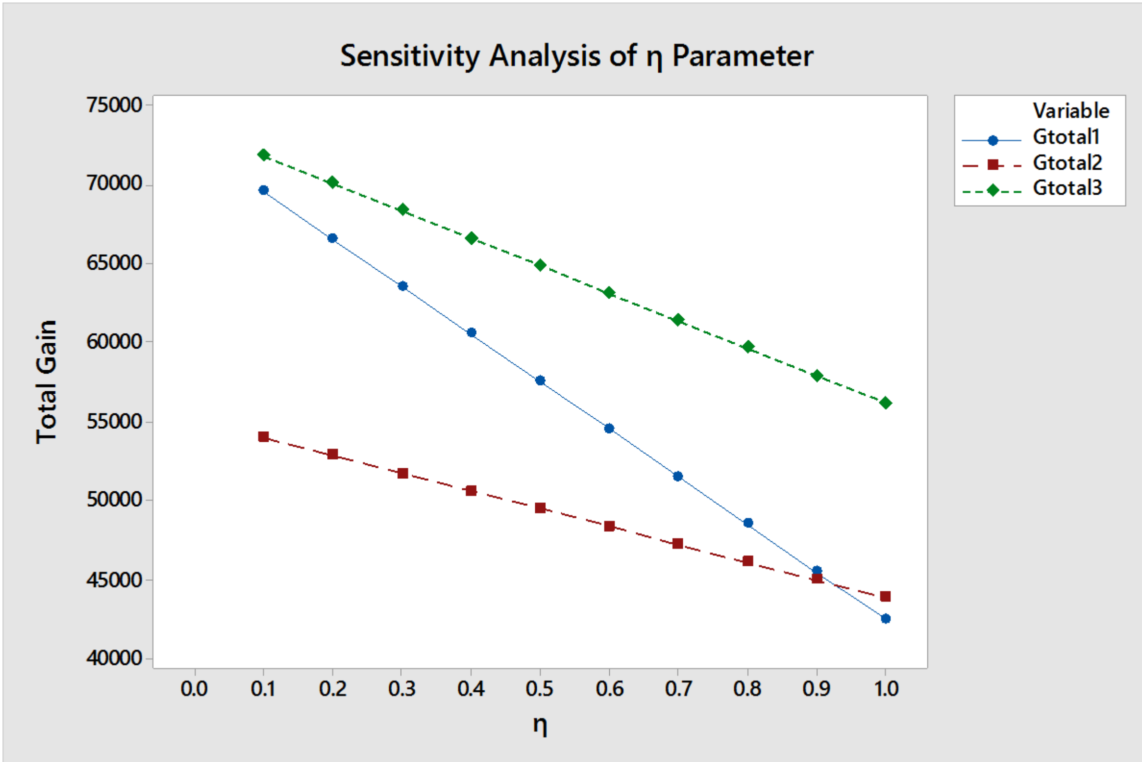

Figure 5.24 Graphic Illustration of η Parameter

Figure 5.24 is the graphic illustration of sensitivity analysis of η parameter. The result shows that η parameter has significant influence to the total profit achieved by the system. It also show that no changes of η parameter makes other scenarios provide a better financial performance, hence Scenario 3 (fully-cooperative) remains the best scenario.

5.2.5.5 Sensitivity Analysis of s_c Parameter

In this section, s_c parameter is evaluated to see how the changes on its value affect the total gain. The value of s_c parameter defined in this part is fixed setup cost per order. The values of s_c parameter will be changes while other at the same values. In order to evaluate the effect of s_c parameter into total profit achieved, the test is resulting as recapped below.

Table 5.14 Sensitivity Analysis Result of sc Parameter

No	s_c	$G_{total\ 1}$	$G_{total\ 2}$	$G_{total\ 3}$	Best Scenario
1	1	105.951,73	55.023,97	68.209,55	1
2	2	93.107,36	53.371,34	66.945,89	1
3	3	80.263,00	51.718,71	65.682,22	1
4	4	67.418,64	50.066,08	64.418,56	1
5	5	54.574,27	48.413,45	63.154,89	3
6	6	41.729,91	46.760,82	61.891,23	3
7	7	28.885,54	45.108,18	60.627,56	3
8	8	16.041,18	43.455,55	59.363,90	3
9	9	3.196,82	41.802,92	58.100,23	3
10	10	(9.647,55)	40.150,29	56.836,57	3
11	11	(22.491,91)	38.497,66	55.572,90	3
12	12	(35.336,28)	36.845,03	54.309,24	3
13	13	(48.180,64)	35.192,40	53.045,57	3
14	14	(61.025,00)	33.539,77	51.781,91	3
15	15	(73.869,37)	31.887,14	50.518,24	3

Table 5.14 shows the summary of sensitivity analysis done towards s_c parameter. In order to make the comparison between each scenario result is more attractive and easier, then the following is graphic illustration for sensitivity analysis of s_c parameter.

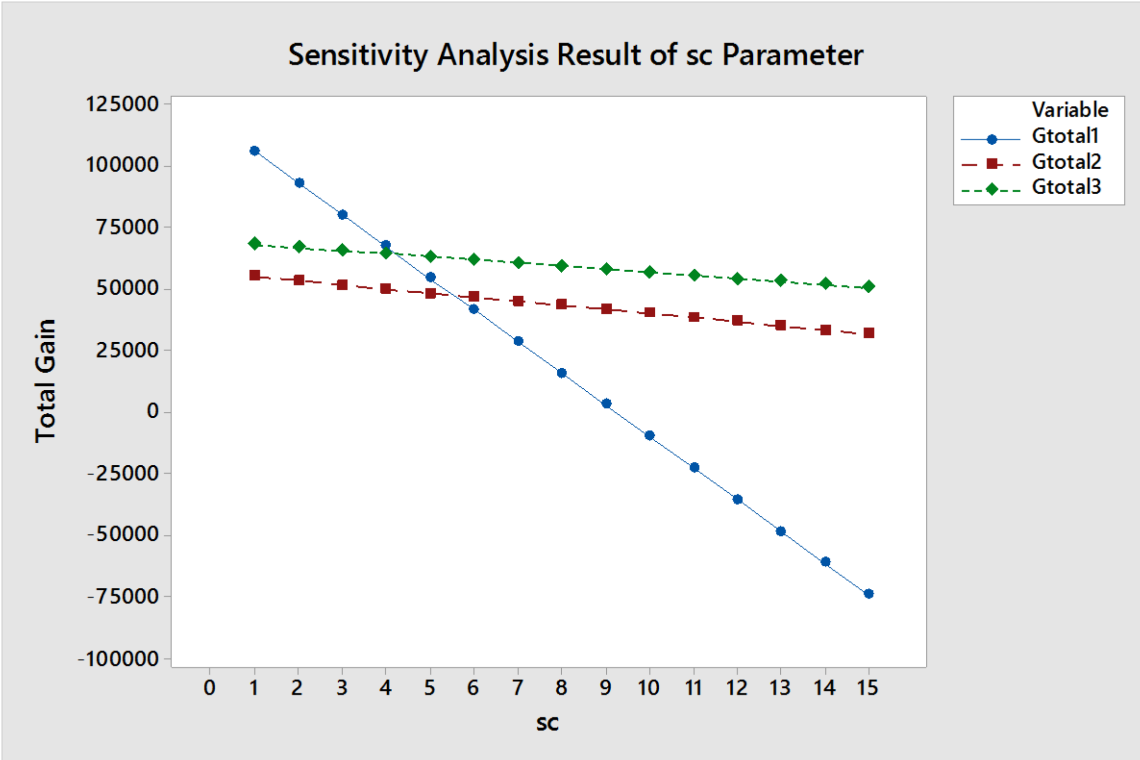

Figure 5.25 Graphic Illustration of sc Parameter

Figure 5.25 is the graphic illustration of sensitivity analysis of s_c parameter. The result shows that s_c parameter has significant influence to the total profit achieved by the system. However, from this sensitivity analysis can be concluded that the lower d_s^{max} parameter, the higher total gain can be achieved by the system. It also shows that when the value of s_c parameter is equal to NT$ 5 or above, the Scenario 3 (fully-cooperative) remains the best scenario. However, when the value of s_c parameter is less than NT$ 4, the maximum total gain occurs in the Scenario 1 (non-cooperative).

5.2.5.6 Sensitivity Analysis of h_c Parameter

In this section, h_c parameter is evaluated to see how the changes on its value affect the total gain. The value of h_c parameter defined in this part is unit holding cost. The values of h_c parameter will be changes while other at the same values. In order to evaluate the effect of h_c parameter into total profit achieved, the test is resulting as recapped below.

Table 5.15 Sensitivity Analysis Result of hc Parameter

No	h_c	$G_{total\ 1}$	$G_{total\ 2}$	$G_{total\ 3}$	Best Scenario
1	2	54.574,27	48.413,45	63.154,89	3
2	4	54.532,27	48.296,45	62.986,89	3
3	6	54.490,27	48.179,45	62.818,89	3
4	8	54.448,27	48.062,45	62.650,89	3
5	10	54.406,27	47.945,45	62.482,89	3
6	12	54.364,27	47.828,45	62.314,89	3
7	14	54.322,27	47.711,45	62.146,89	3
8	16	54.280,27	47.594,45	61.978,89	3
9	18	54.238,27	47.477,45	61.810,89	3
10	20	54.196,27	47.360,45	61.642,89	3
11	22	54.154,27	47.243,45	61.474,89	3
12	24	54.112,27	47.126,45	61.306,89	3
13	26	54.070,27	47.009,45	61.138,89	3
14	28	54.028,27	46.892,45	60.970,89	3
15	30	53.986,27	46.775,45	60.802,89	3

Table 5.15 shows the summary of sensitivity analysis done towards $\mathrm{h_c}$ parameter. In order to make the comparison between each scenario result is more attractive and easier, then the following is graphic illustration for sensitivity analysis of $\mathrm{h_c}$ parameter.

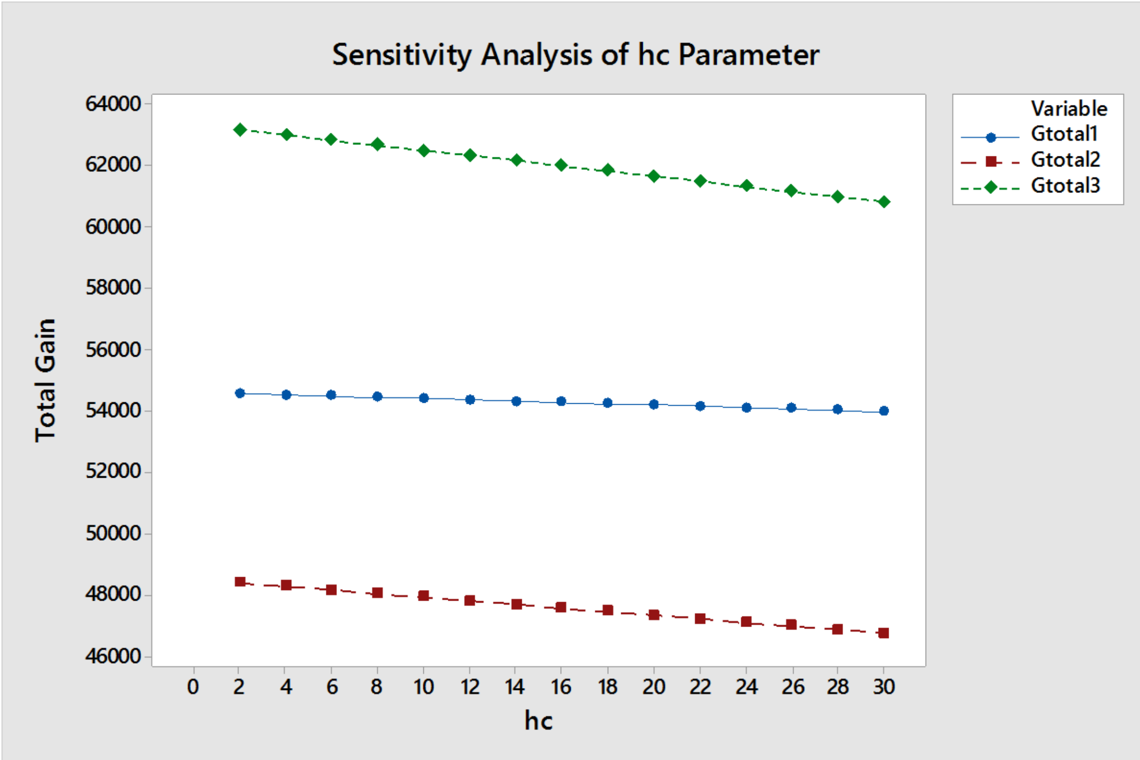

Figure 5.26 Graphic Illustration of hc Parameter

Figure 5.26 is the graphic illustration of sensitivity analysis of h_c parameter. The result shows that h_c parameter has significant influence to the total gain achieved by the system. However, from this sensitivity analysis can be concluded that the lower h_c parameter, the higher profit can be achieved by the system. It also show that no changes of h_c parameter makes other scenarios provide a better financial performance, hence Scenario 3 (fully-cooperative) remains the best scenario.

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CHAPTER 6

CONCLUSION AND RECOMMENDATION

The chapter is closing part of the research which is explaining about the conclusion of the whole research conducted and also suggestions proposed from the research.

6.1 Conclusions

These followings are conclusions or the summary of this research which have to answer all the objectives of this research.

Model development in this research is started by the development of model in determining total demand for offline and online channel then addition of reseller channel by considering customer sensitivity into price, and customer acceptance ratio into online and reseller channel instead of offline channel. Customer sensitivity into price is the parameter in order to accommodate the demand estimation by the changes of product price offered in all of channels. This parameter is also helping to accommodate in finding the optimal product prices for each channel to keep considering customer preferences into price setting in the market. The second stage is addition inventory policy in total gain function each channel. The type of inventory policy used are ordering cost and holding cost. The optimal order quantity is accommodated by the considering setup order and holding cost into total gain with EOQ basic model. The parameter in this research influences the demand amount in the system, because the model developed by considering price and order quantity.

By considering customer's channel preference based on the dual channel supply chain concept, three alternative scenarios are developed in order to see which scenario provides the best financial performance. The first scenario is Scenario 1 (non-cooperative), where each channel (offline, online, and reseller channel) works independently in meeting customer demand. The second scenario is Scenario 2 (semi-cooperative), where the online and reseller channel form a coordination and work complementary in meeting customer demand, while the offline channel works independently. The third scenario is Scenario 3 (fully-cooperative), where all channels form a coordination and work complementary in meeting customer demand. The Different gain function is developed for each scenario based on the characteristic of the scenario itself that considering inventory policy, resulting in different optimal price and order quantity for each channel in all scenarios.

Different pricing scenario provides different financial performance. In this research, it is shown that Scenario 3 (fully-cooperative) generates the best financial performance, resulting in the highest total gain. The optimal price suggested in this research for offline, online, and reseller channel are NT$ 252, NT$ 150, and NT$ 150. The optimal order quantity suggested in this research for offline, online, and reseller channel are 75 units, 50 units, and 43 units. However, the decision about the best scenario is not an absolute decision, since it can be changed in the future regarding the changes in system conditions. The sensitivity analysis is done to see which parameter is critical to the total gain. The research shows that the parameter that affects the total gain the most are in the following order: fixed setup cost per order (s_c), customer acceptance ratio of product in online channel compared to the offline channel (ρ), cost of production (cu), maximum demand when price is set near unit cost (d_{max}^{s}), customer acceptance ratio of product in reseller channel compared to the offline channel (η), and holding cost (h_c).

6.2 Recommendations

The recommendations proposed from this research are mentioned at the points below.

1. To capture the reality, the setting of demand function is better off in non-stationary condition.
2. Price setting and order quantity decision suggested in this research is unable to be implemented in all periods, it has to be regularly evaluated for the current market and company conditions. Different parameter values in the system changes the decision both for product pricing and order quantity.
3. Other inventory policy cost such as inventory storage cost and cost of capital could also be considered. Since those costs are influenced the total gain.
4. Evaluating a bigger scope of the supply chain system, where the reseller channel expands their channel by adding the offline and online channel.

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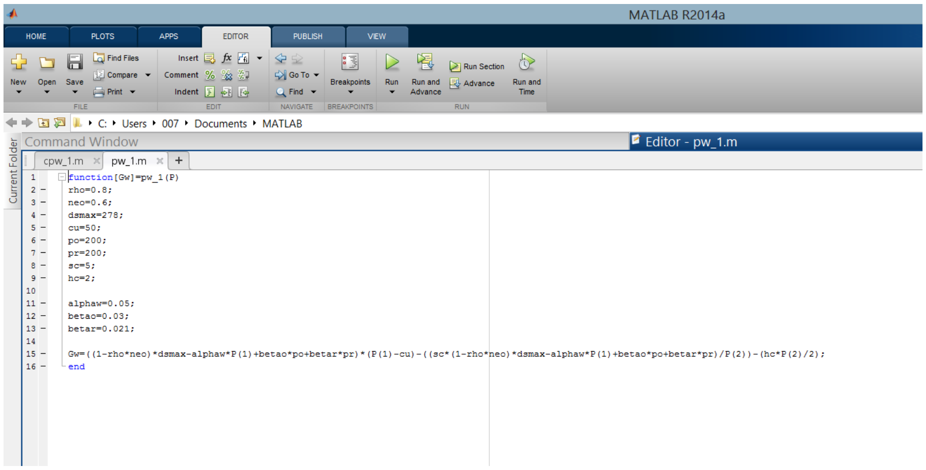
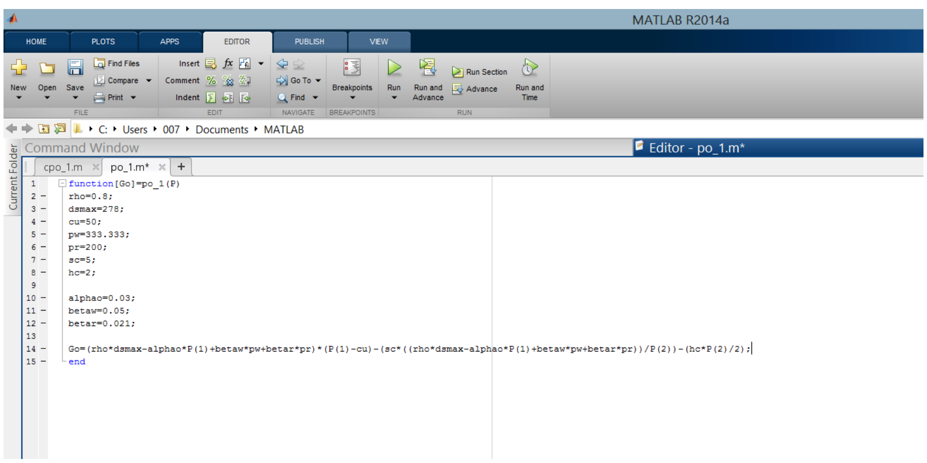
ENCLOSURE

Enclosure 1 - MATLAB m-file Script of Gain Function

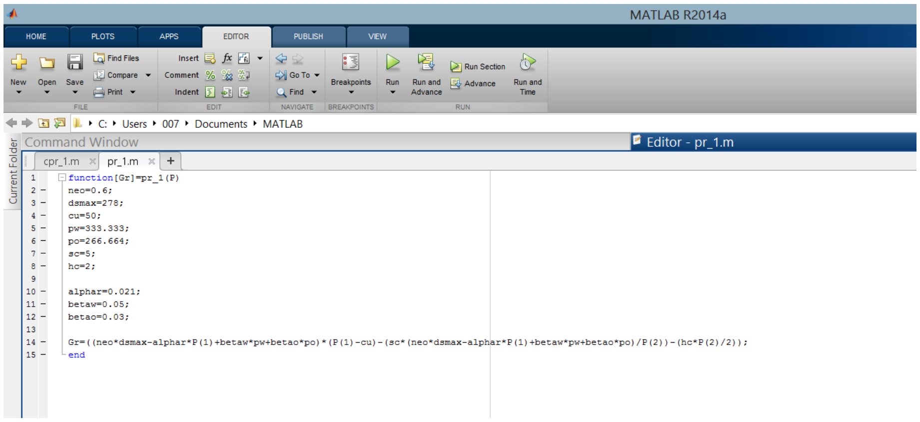
- **Scenario 1 (Offline Channel)**



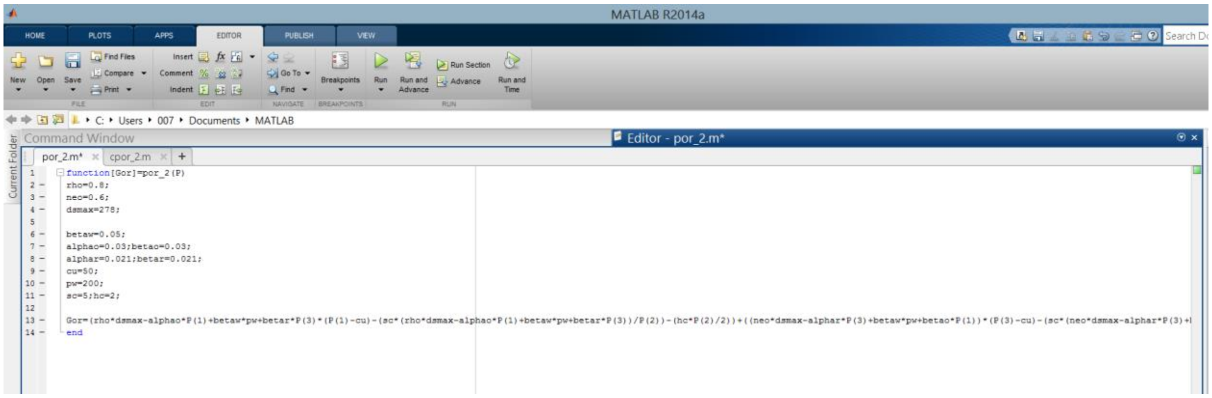
- **Scenario 1 (Online Channel)**



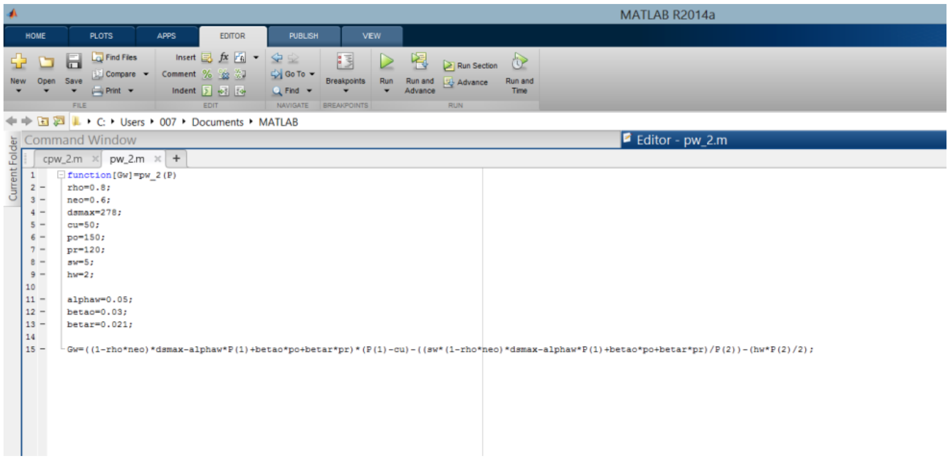
❖ Scenario 1 (Reseller Channel)



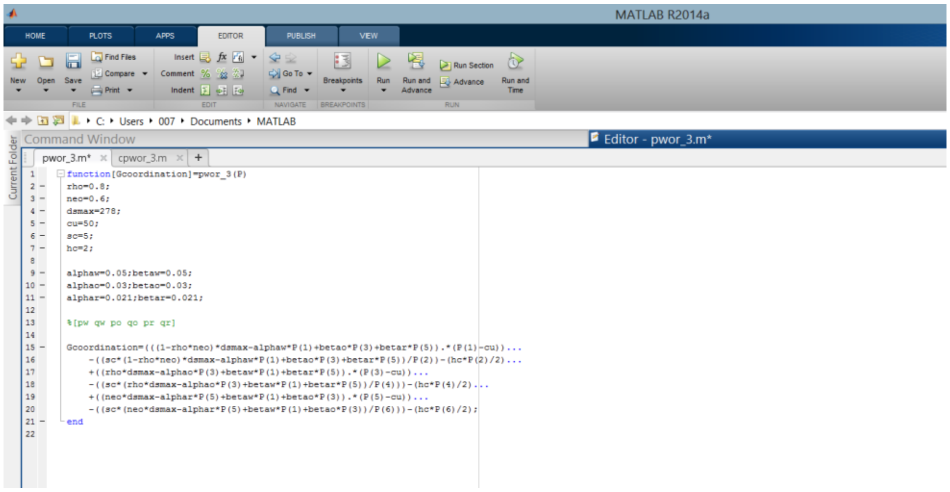
❖ Scenario 2 (Coordination Online and Reseller Channel)



❖ Scenario 2 (Offline Channel)

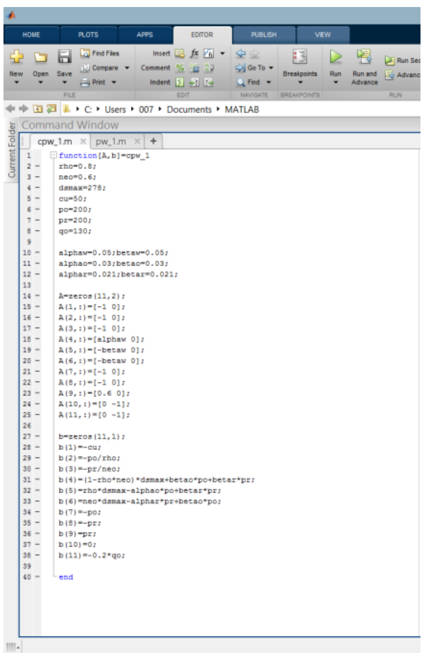


❖ Scenario 3 (Offline, Online, and Reseller Channel)

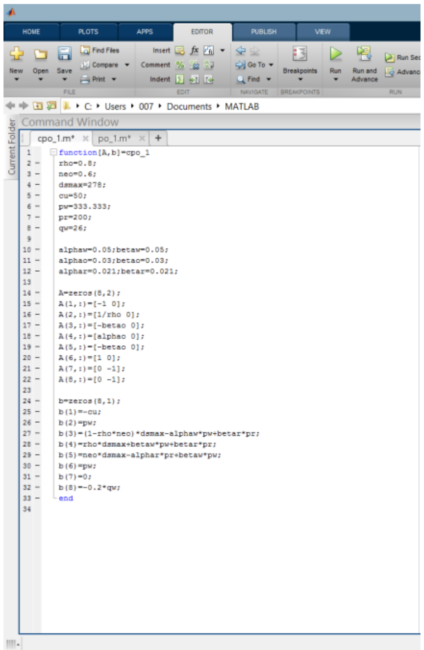


Enclosure 2 - MATLAB m-file Script of Constrains Matrix

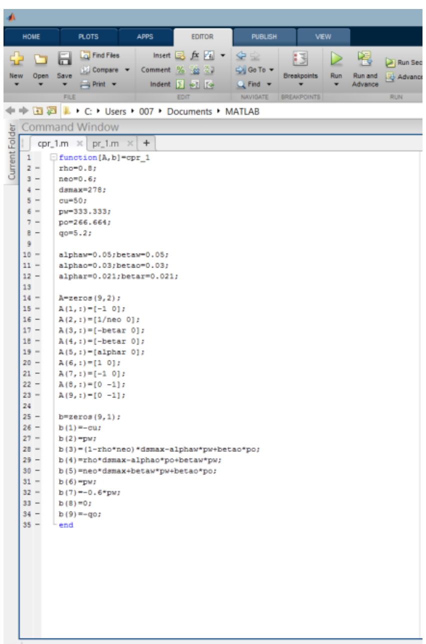
❖ Scenario 1 (Offline Channel)



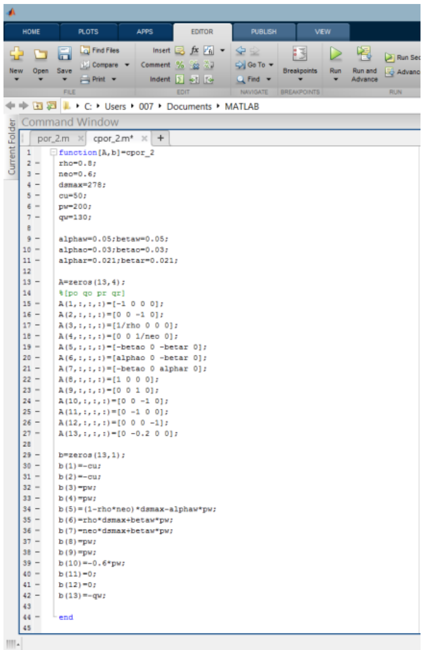
❖ Scenario 1 (Online Channel)



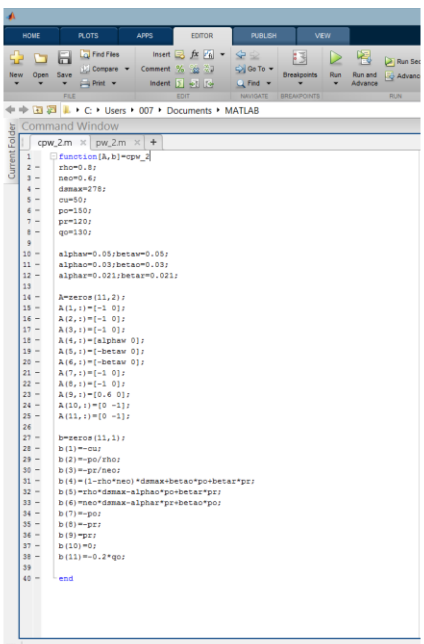
❖ Scenario 1 (Reseller Channel)



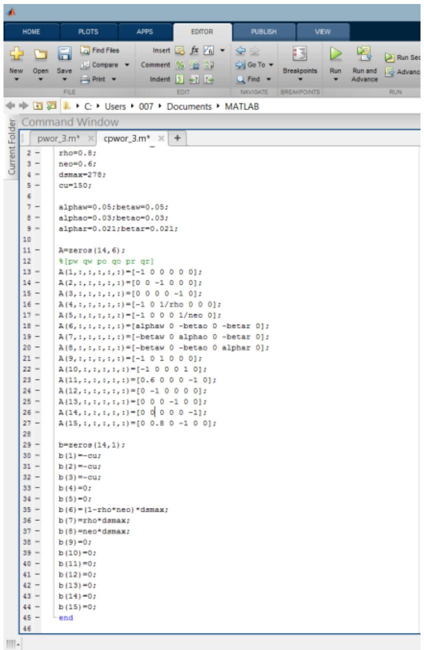
❖ Scenario 2 (Coordination Online and Reseller Channel)



❖ Scenario 2 (Offline Channel)

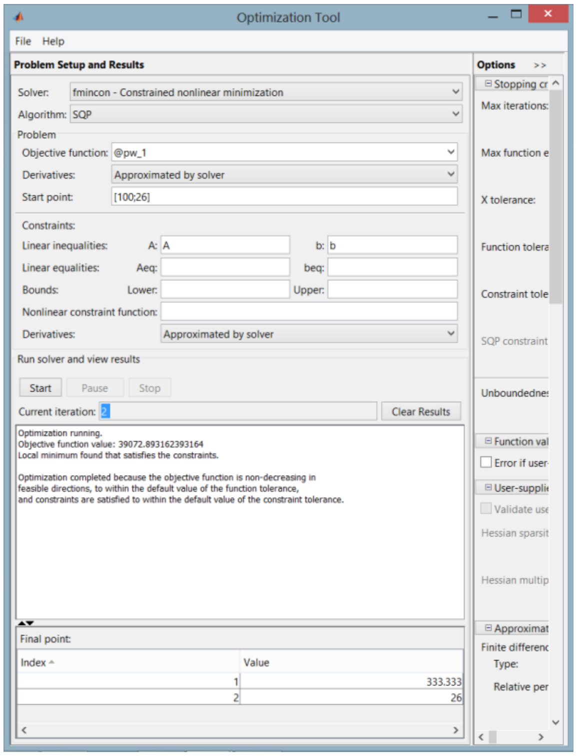


❖ Scenario 3 (Offline, Online, and Reseller Channel)

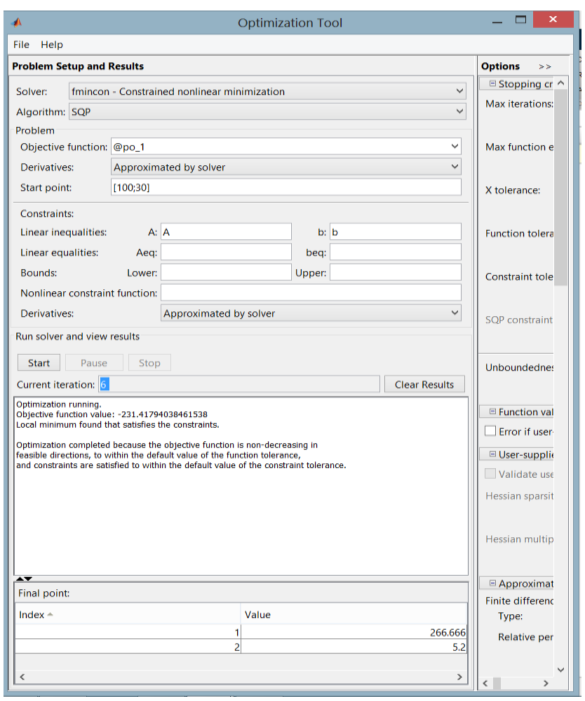

HOME
PLOTS
APPS
EDITOR
PUBLISH
VIEW
New
Open
Save
Find Files
Compare
Print
Insert
Comment
Indent
Go To
Find
Breakpoints
Run
Run and Advance
FILE
EDIT
NAVIGATE
C: ▸ Users ▸ 007 ▸ Documents ▸ MATLAB
Command Window
Current Folder
pwor_3.m*
cpwor_3.m*
rho=0.8;
neo=0.6;
dsmax=278;
cu=150;
alphaw=0.05;betaw=0.05;
alphao=0.03;betao=0.03;
alphar=0.021;betar=0.021;
A=zeros(14,6);
%[pw qw po qo pr qr]
A(1,:,:,:,:,:)=[-1 0 0 0 0 0];
A(2,:,:,:,:,:)=[0 0 -1 0 0 0];
A(3,:,:,:,:,:)=[0 0 0 0 -1 0];
A(4,:,:,:,:,:)=[-1 0 1/rho 0 0 0];
A(5,:,:,:,:,:)=[-1 0 0 0 1/neo 0];
A(6,:,:,:,:,:)=[alphaw 0 -betao 0 -betar 0];
A(7,:,:,:,:,:)=[-betaw 0 alphao 0 -betar 0];
A(8,:,:,:,:,:)=[-betaw 0 -betao 0 alphar 0];
A(9,:,:,:,:,:)=[-1 0 1 0 0 0];
A(10,:,:,:,:,:)=[-1 0 0 0 1 0];
A(11,:,:,:,:,:)=[0.6 0 0 0 -1 0];
A(12,:,:,:,:,:)=[0 -1 0 0 0 0];
A(13,:,:,:,:,:)=[0 0 0 -1 0 0];
A(14,:,:,:,:,:)=[0 0 0 0 0 -1];
A(15,:,:,:,:,:)=[0 0.8 0 -1 0 0];
b=zeros(14,1);
b(1)=-cu;
b(2)=-cu;
b(3)=-cu;
b(4)=0;
b(5)=0;
b(6)=(1-rho*neo)*dsmax;
b(7)=rho*dsmax;
b(8)=neo*dsmax;
b(9)=0;
b(10)=0;
b(11)=0;
b(12)=0;
b(13)=0;
b(14)=0;
b(15)=0;
end

Enclosure 3 - MATLAB Result

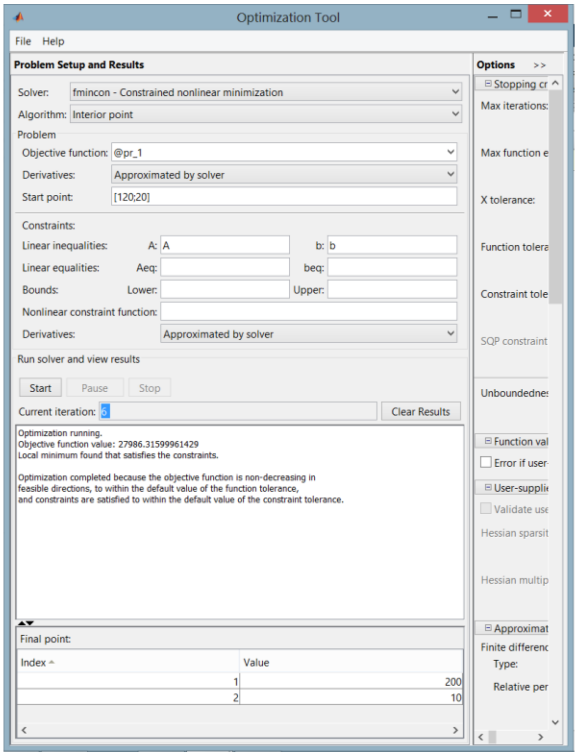
❖ Scenario 1 (Offline Channel)



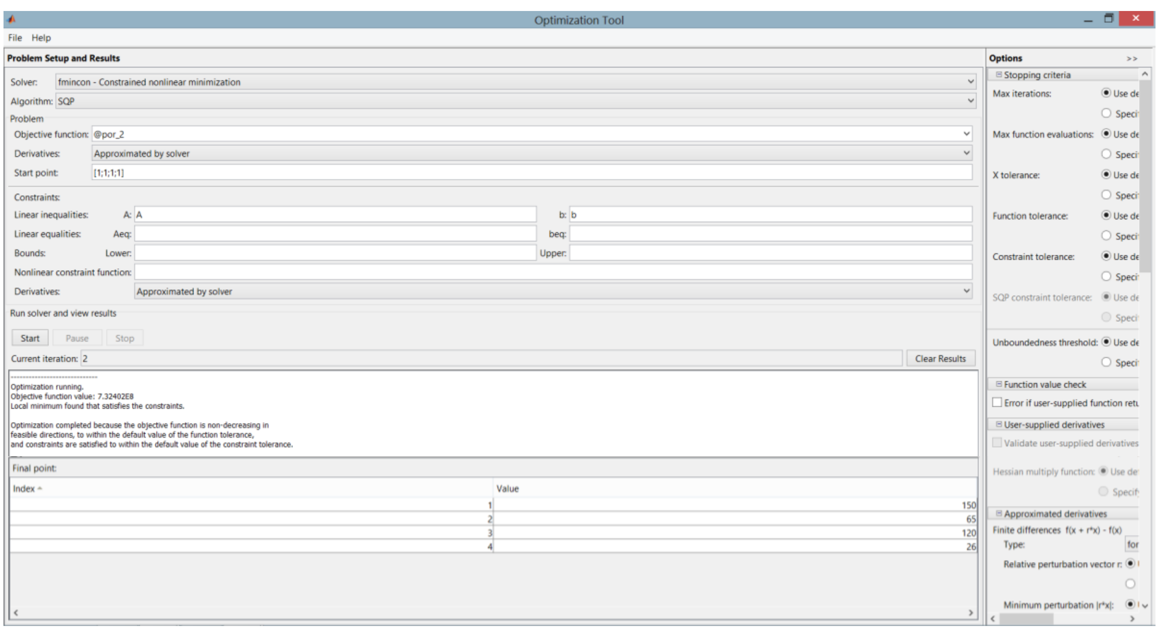
❖ Scenario 1 (Online Channel)



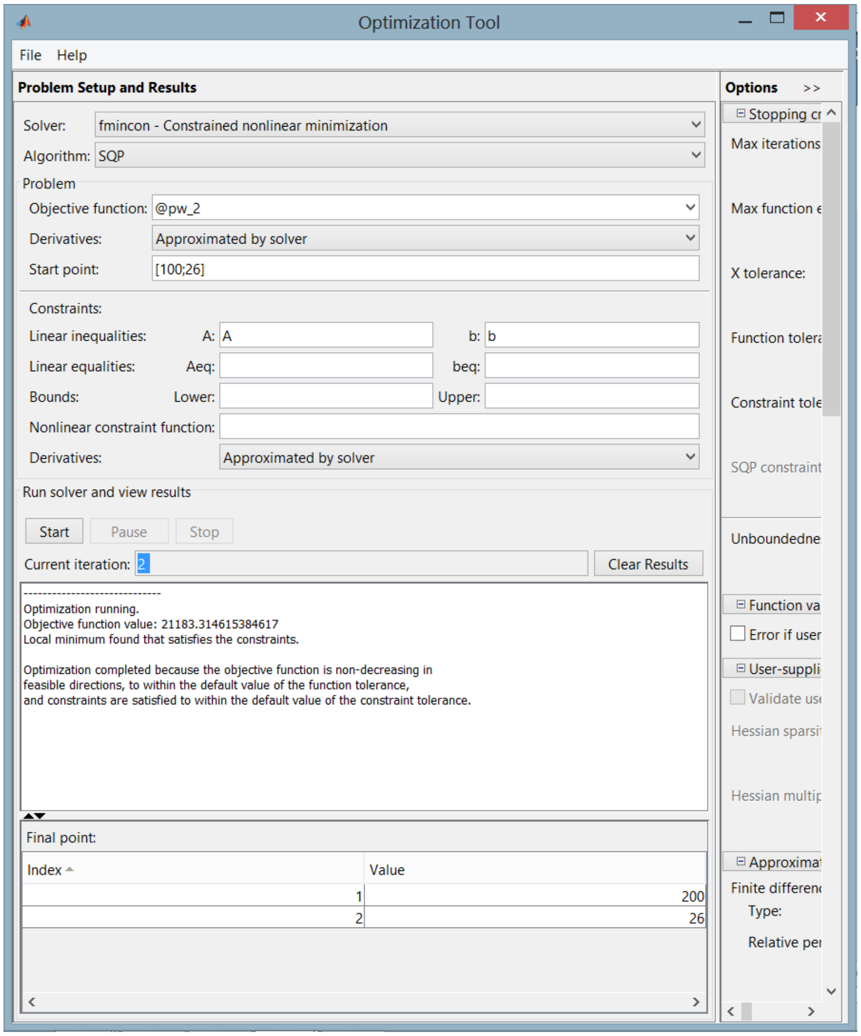
❖ **Scenario 1 (Reseller Channel)**



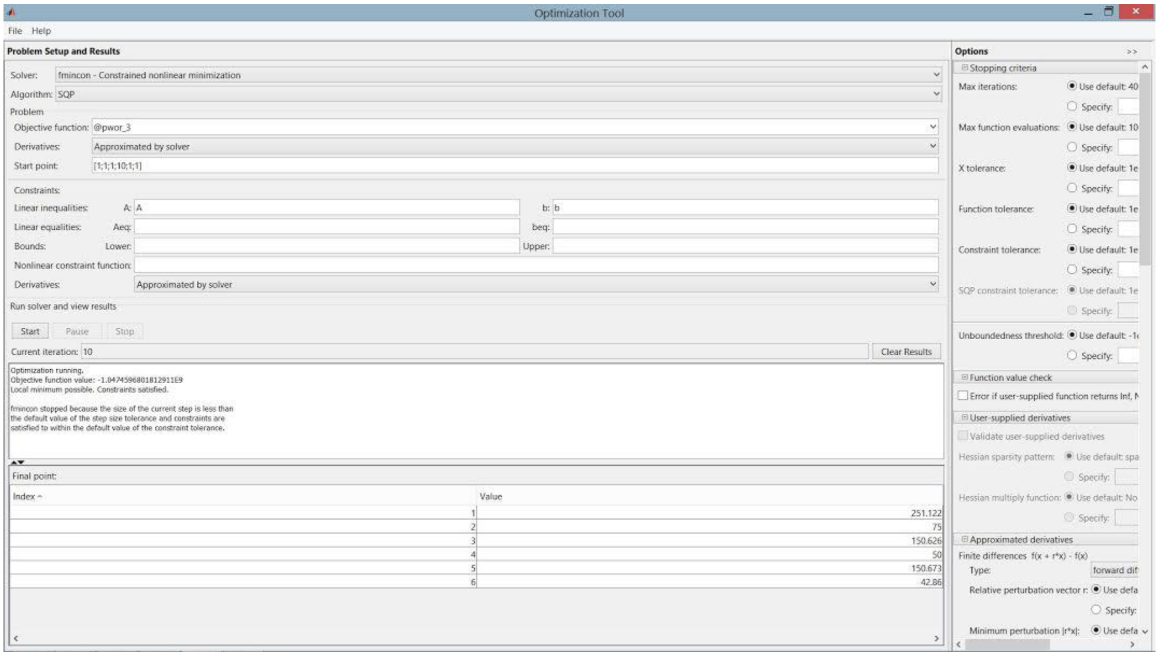
❖ **Scenario 2 (Coordination Online and Reseller Channel)**



❖ Scenario 2 (Offline Channel)



❖ Scenario 3 (Offline, Online, and Reseller Channel)



Enclosure 4 - Validation for Offline Price Influences to Offline Demand

No	Parameter											
	dsmax	**Dw**	**Do**	**Dr**	**Pw**	**Po**	**Pr**	**rho (ρ)**	**neo (η)**	**αw/βw**	**αo/βo**	**αr/βr**
1	100	37	107	87	500	200	200	0.8	0.6	0.05	0.03	0.021
2	150	66	144	114	450	200	200	0.8	0.6	0.05	0.03	0.021
3	200	94	182	142	400	200	200	0.8	0.6	0.05	0.03	0.021
4	250	123	219	169	350	200	200	0.8	0.6	0.05	0.03	0.021
5	262	131	226	174	300	200	200	0.8	0.6	0.05	0.03	0.021
6	263	134	225	172	250	200	200	0.8	0.6	0.05	0.03	0.021
7	300	156	252	192	200	200	200	0.8	0.6	0.05	0.03	0.021
8	350	185	289	219	150	200	200	0.8	0.6	0.05	0.03	0.021
9	400	213	327	247	100	200	200	0.8	0.6	0.05	0.03	0.021
10	450	242	364	274	50	200	200	0.8	0.6	0.05	0.03	0.021

Enclosure 5 - Validation for Online Price Influences to Online Demand

No	Parameter											
	dsmax	**Dw**	**Do**	**Dr**	**Pw**	**Po**	**Pr**	**rho (ρ)**	**neo (η)**	**αw/βw**	**αo/βo**	**αr/βr**
1	100	61	101	81	200	500	200	0.8	0.6	0.05	0.03	0.021
2	150	86	139	109	200	450	200	0.8	0.6	0.05	0.03	0.021
3	200	110	178	138	200	400	200	0.8	0.6	0.05	0.03	0.021
4	250	135	216	166	200	350	200	0.8	0.6	0.05	0.03	0.021
5	262	139	224	172	200	300	200	0.8	0.6	0.05	0.03	0.021
6	263	138	224	171	200	250	200	0.8	0.6	0.05	0.03	0.021
7	300	156	252	192	200	200	200	0.8	0.6	0.05	0.03	0.021
8	350	181	290	220	200	150	200	0.8	0.6	0.05	0.03	0.021
9	400	205	329	249	200	100	200	0.8	0.6	0.05	0.03	0.021
10	450	230	367	277	200	50	200	0.8	0.6	0.05	0.03	0.021

Enclosure 6 - Validation for Reseller Price Influences to Reseller Demand

No	Parameter											
	dsmax	**Dw**	**Do**	**Dr**	**Pw**	**Po**	**Pr**	**rho (ρ)**	**neo (η)**	**αw/βw**	**αo/βo**	**αr/βr**
1	100	59	86	66	200	200	500	0.8	0.6	0.05	0.03	0.021
2	150	83	127	97	200	200	450	0.8	0.6	0.05	0.03	0.021
3	200	108	168	128	200	200	400	0.8	0.6	0.05	0.03	0.021
4	250	133	209	159	200	200	350	0.8	0.6	0.05	0.03	0.021
5	262	139	219	167	200	200	300	0.8	0.6	0.05	0.03	0.021
6	263	138	221	169	200	200	250	0.8	0.6	0.05	0.03	0.021
7	300	156	252	192	200	200	200	0.8	0.6	0.05	0.03	0.021
8	350	181	293	223	200	200	150	0.8	0.6	0.05	0.03	0.021
9	400	206	334	254	200	200	100	0.8	0.6	0.05	0.03	0.021
10	450	231	375	285	200	200	50	0.8	0.6	0.05	0.03	0.021

Enclosure 7 - Validation for Offline Order Quantity Influence to Offline Total Gain

No	**Parameter**																**Offline Demand**	**Total Gain**
	dsmax	**Dw**	**Do**	**Dr**	**Pw**	**Po**	**Pr**	**rho (ρ)**	**neo (η)**	**αw/βw**	**αo/βo**	**αr/βr**	**cu**	**sc**	**hc**	**Qw**		
1	278	145	234	179	200	200	200	0.8	0.6	0.05	0.03	0.021	50	5	2	30	21,714	18,065.00
2	278	145	234	179	200	200	200	0.8	0.6	0.05	0.03	0.021	50	5	2	60	21,714	19,844.50
3	278	145	234	179	200	200	200	0.8	0.6	0.05	0.03	0.021	50	5	2	90	21,714	20,417.67
4	278	145	234	179	200	200	200	0.8	0.6	0.05	0.03	0.021	50	5	2	120	21,714	20,689.25
5	278	145	234	179	200	200	200	0.8	0.6	0.05	0.03	0.021	50	5	2	150	21,714	20,840.20
6	278	145	234	179	200	200	200	0.8	0.6	0.05	0.03	0.021	50	5	2	180	21,714	20,930.83
7	278	145	234	179	200	200	200	0.8	0.6	0.05	0.03	0.021	50	5	2	210	21,714	20,987.00
8	278	145	234	179	200	200	200	0.8	0.6	0.05	0.03	0.021	50	5	2	240	21,714	21,021.63
9	278	145	234	179	200	200	200	0.8	0.6	0.05	0.03	0.021	50	5	2	270	21,714	21,041.89
10	278	145	234	179	200	200	200	0.8	0.6	0.05	0.03	0.021	50	5	2	300	21,714	21,052.10

Enclosure 8 - Validation for Online Order Quantity Influence to Online Total Gain

No	Parameter																Online Demand	Total Gain
	dsmax	Dw	Do	Dr	Pw	Po	Pr	rho (ρ)	neo (η)	αw/βw	αo/βo	αr/βr	cu	sc	hc	Qo		
1	278	145	234	179	200	200	200	0.8	0.6	0.05	0.03	0.021	50	5	2	30	34,590	28,795.00
2	278	145	234	179	200	200	200	0.8	0.6	0.05	0.03	0.021	50	5	2	60	34,590	31,647.50
3	278	145	234	179	200	200	200	0.8	0.6	0.05	0.03	0.021	50	5	2	90	34,590	32,578.33
4	278	145	234	179	200	200	200	0.8	0.6	0.05	0.03	0.021	50	5	2	120	34,590	33,028.75
5	278	145	234	179	200	200	200	0.8	0.6	0.05	0.03	0.021	50	5	2	150	34,590	33,287.00
6	278	145	234	179	200	200	200	0.8	0.6	0.05	0.03	0.021	50	5	2	180	34,590	33,449.17
7	278	145	234	179	200	200	200	0.8	0.6	0.05	0.03	0.021	50	5	2	210	34,590	33,556.43
8	278	145	234	179	200	200	200	0.8	0.6	0.05	0.03	0.021	50	5	2	240	34,590	33,629.38
9	278	145	234	179	200	200	200	0.8	0.6	0.05	0.03	0.021	50	5	2	270	34,590	33,679.44
10	278	145	234	179	200	200	200	0.8	0.6	0.05	0.03	0.021	50	5	2	300	34,590	33,713.50

Enclosure 9 - Validation for Reseller Order Quantity Influence to Reseller Total Gain

No	Parameter																Reseller Demand	Total Gain
	dsmax	Dw	Do	Dr	Pw	Po	Pr	rho (ρ)	neo (η)	αw/βw	αo/βo	αr/βr	cu	sc	hc	Qr		
1	278	145	234	179	200	200	200	0.8	0.6	0.05	0.03	0.021	50	5	2	30	26,790	22,295.00
2	278	145	234	179	200	200	200	0.8	0.6	0.05	0.03	0.021	50	5	2	60	26,790	24,497.50
3	278	145	234	179	200	200	200	0.8	0.6	0.05	0.03	0.021	50	5	2	90	26,790	25,211.67
4	278	145	234	179	200	200	200	0.8	0.6	0.05	0.03	0.021	50	5	2	120	26,790	25,553.75
5	278	145	234	179	200	200	200	0.8	0.6	0.05	0.03	0.021	50	5	2	150	26,790	25,747.00
6	278	145	234	179	200	200	200	0.8	0.6	0.05	0.03	0.021	50	5	2	180	26,790	25,865.83
7	278	145	234	179	200	200	200	0.8	0.6	0.05	0.03	0.021	50	5	2	210	26,790	25,942.14
8	278	145	234	179	200	200	200	0.8	0.6	0.05	0.03	0.021	50	5	2	240	26,790	25,991.88
9	278	145	234	179	200	200	200	0.8	0.6	0.05	0.03	0.021	50	5	2	270	26,790	26,023.89
10	278	145	234	179	200	200	200	0.8	0.6	0.05	0.03	0.021	50	5	2	300	26,790	26,043.50

Enclosure 10 - Validation for Cost of Production Influence to Total Gain

No	Parameter															Gain Offline	Gain Online	Gain Reseller	TOTAL GAIN
	dsmax	**dw**	**do**	**dr**	**pw**	**po**	**pr**	**rho (ρ)**	**neo (η)**	**α1/β3/β5**	**α2/β1/β6**	**α3/β2/β4**	**cu**	**so**	**ho**				
1	278	145	234	179	200	200	200	0.8	0.6	0.05	0.03	0.021	0	5	2	27,708.46	44,216.15	34,216.15	106,140.77
2	278	145	234	179	200	200	200	0.8	0.6	0.05	0.03	0.021	20	5	2	24,924.62	39,781.54	30,781.54	95,487.69
3	278	145	234	179	200	200	200	0.8	0.6	0.05	0.03	0.021	40	5	2	22,140.77	35,346.92	27,346.92	84,834.62
4	278	145	234	179	200	200	200	0.8	0.6	0.05	0.03	0.021	60	5	2	19,356.92	30,912.31	23,912.31	74,181.54
5	278	145	234	179	200	200	200	0.8	0.6	0.05	0.03	0.021	80	5	2	16,573.08	26,477.69	20,477.69	63,528.46
6	278	145	234	179	200	200	200	0.8	0.6	0.05	0.03	0.021	100	5	2	13,789.23	22,043.08	17,043.08	52,875.38
7	278	145	234	179	200	200	200	0.8	0.6	0.05	0.03	0.021	120	5	2	11,005.38	17,608.46	13,608.46	42,222.31
8	278	145	234	179	200	200	200	0.8	0.6	0.05	0.03	0.021	140	5	2	8,221.54	13,173.85	10,173.85	31,569.23
9	278	145	234	179	200	200	200	0.8	0.6	0.05	0.03	0.021	160	5	2	5,437.69	8,739.23	6,739.23	20,916.15
10	278	145	234	179	200	200	200	0.8	0.6	0.05	0.03	0.021	180	5	2	2,653.85	4,304.62	3,304.62	10,263.08

Enclosure 11 - Sensitivity Analysis of dsmax Parameter

No	SCENARIO 1																Gtotal1
	dsmax	Dw	Do	Dr	Pw	Po	Pr	Qw	Qo	Qr	Rw	Gw	Ro	Go	Rr	Gr	
1	100	48	100	80	333	267	200	26	6	10	13,459	10,845	20,146	3,352	12,069	6,025	20,221
2	200	100	180	140	333	267	200	26	6	10	28,175	22,731	37,506	6,245	21,069	10,525	39,501
3	300	152	260	200	333	267	200	26	6	10	42,891	34,617	54,866	9,138	30,069	15,025	58,780
4	400	204	340	260	333	267	200	26	6	10	57,607	46,503	72,226	12,032	39,069	19,525	78,059
5	500	256	420	320	333	267	200	26	6	10	72,323	58,389	89,586	14,925	48,069	24,025	97,339
6	600	308	500	380	333	267	200	26	6	10	87,039	70,275	106,946	17,818	57,069	28,525	116,618
7	700	360	580	440	333	267	200	26	6	10	101,755	82,161	124,306	20,712	66,069	33,025	135,897
8	800	412	660	500	333	267	200	26	6	10	116,471	94,047	141,666	23,605	75,069	37,525	155,177
9	900	464	740	560	333	267	200	26	6	10	131,187	105,933	159,026	26,498	84,069	42,025	174,456
10	1000	516	820	620	333	267	200	26	6	10	145,903	117,819	176,386	29,392	93,069	46,525	193,735
11	1100	568	900	680	333	267	200	26	6	10	160,619	129,705	193,746	32,285	102,069	51,025	213,015
12	1200	620	980	740	333	267	200	26	6	10	175,335	141,591	211,106	35,178	111,069	55,525	232,294
13	1300	672	1060	800	333	267	200	26	6	10	190,051	153,477	228,466	38,072	120,069	60,025	251,573
14	1400	724	1140	860	333	267	200	26	6	10	204,767	165,363	245,826	40,965	129,069	64,525	270,853
15	1500	776	1220	920	333	267	200	26	6	10	219,483	177,249	263,186	43,858	138,069	69,025	290,132
No	SCENARIO 2																Gtotal2
	dsmax	Dw	Do	Dr	Pw	Po	Pr	Qw	Qo	Qr	Rw	Gw	Ro	Go	Rr	Gr	
1	100	49	92	72	200	150	120	26	65	26	7,353	5,913	8,802	8,060	5,039	4,044	18,017
2	200	101	172	132	200	150	120	26	65	26	15,153	12,213	16,802	15,445	9,239	7,436	35,093
3	300	153	252	192	200	150	120	26	65	26	22,953	18,513	24,802	22,829	13,439	10,828	52,170
4	400	205	332	252	200	150	120	26	65	26	30,753	24,813	32,802	30,214	17,639	14,221	69,247
5	500	257	412	312	200	150	120	26	65	26	38,553	31,113	40,802	37,598	21,839	17,613	86,324
6	600	309	492	372	200	150	120	26	65	26	46,353	37,413	48,802	44,983	26,039	21,005	103,401
7	700	361	572	432	200	150	120	26	65	26	54,153	43,713	56,802	52,368	30,239	24,397	120,478
8	800	413	652	492	200	150	120	26	65	26	61,953	50,013	64,802	59,752	34,439	27,790	137,555

9	900	465	732	552	200	150	120	26	65	26	69,753	56,313	72,802	67,137	38,639	31,182	154,632
10	1000	517	812	612	200	150	120	26	65	26	77,553	62,613	80,802	74,521	42,839	34,574	171,709
11	1100	569	892	672	200	150	120	26	65	26	85,353	68,913	88,802	81,906	47,039	37,967	188,786
12	1200	621	972	732	200	150	120	26	65	26	93,153	75,213	96,802	89,291	51,239	41,359	205,863
13	1300	673	1052	792	200	150	120	26	65	26	100,953	81,513	104,802	96,675	55,439	44,751	222,940
14	1400	725	1132	852	200	150	120	26	65	26	108,753	87,813	112,802	104,060	59,639	48,144	240,017
15	1500	777	1212	912	200	150	120	26	65	26	116,553	94,113	120,802	111,445	63,839	51,536	257,093
No	**SCENARIO 3**																**Gtotal3**
	dsmax	**Dw**	**Do**	**Dr**	**Pw**	**Po**	**Pr**	**Qw**	**Qo**	**Qr**	**Rw**	**Gw**	**Ro**	**Go**	**Rr**	**Gr**	
1	100	47	94	74	252	150	150	75	50	43	9,504	8,795	9,125	8,163	7,395	6,492	23,450
2	200	99	174	134	252	150	150	75	50	43	20,008	18,599	17,125	15,363	13,395	11,794	45,756
3	300	151	254	194	252	150	150	75	50	43	30,512	28,403	25,125	22,563	19,395	17,097	68,062
4	400	203	334	254	252	150	150	75	50	43	41,016	38,207	33,125	29,763	25,395	22,399	90,368
5	500	255	414	314	252	150	150	75	50	43	51,520	48,010	41,125	36,963	31,395	27,701	112,674
6	600	307	494	374	252	150	150	75	50	43	62,024	57,814	49,125	44,163	37,395	33,004	134,980
7	700	359	574	434	252	150	150	75	50	43	72,528	67,618	57,125	51,363	43,395	38,306	157,286
8	800	411	654	494	252	150	150	75	50	43	83,032	77,422	65,125	58,563	49,395	43,608	179,593
9	900	463	734	554	252	150	150	75	50	43	93,536	87,225	73,125	65,763	55,395	48,911	201,899
10	1000	515	814	614	252	150	150	75	50	43	104,040	97,029	81,125	72,963	61,395	54,213	224,205
11	1100	567	894	674	252	150	150	75	50	43	114,544	106,833	89,125	80,163	67,395	59,515	246,511
12	1200	619	974	734	252	150	150	75	50	43	125,048	116,637	97,125	87,363	73,395	64,818	268,817
13	1300	671	1054	794	252	150	150	75	50	43	135,552	126,440	105,125	94,563	79,395	70,120	291,123
14	1400	723	1134	854	252	150	150	75	50	43	146,056	136,244	113,125	101,763	85,395	75,422	313,429
15	1500	775	1214	914	252	150	150	75	50	43	156,560	146,048	121,125	108,963	91,395	80,725	335,735

Enclosure 12 - Sensitivity Analysis of cu Parameter

No	SCENARIO 1													Gtotal1
	Pw	Po	Pr	cu	Qw	Qo	Qr	Rw	Gw	Ro	Go	Rr	Gr	
1	333	267	200	10	26	6	10	45259	36529	60457	10070	35579	17780	64379
2	333	267	200	20	26	6	10	43858	35397	58104	9678	33707	16843	61919
3	333	267	200	30	26	6	10	42456	34266	55752	9286	31834	15907	59459
4	333	267	200	40	26	6	10	41055	33134	53399	8894	29962	14971	56999
5	333	267	200	50	26	6	10	39654	32002	51047	8502	28089	14035	54539
6	333	267	200	60	26	6	10	38253	30870	48695	8110	26216	13098	52078
7	333	267	200	70	26	6	10	36852	29739	46342	7718	24344	12162	49618
8	333	267	200	80	26	6	10	35450	28607	43990	7326	22471	11226	47158
9	333	267	200	90	26	6	10	34049	27475	41637	6934	20599	10289	44698
10	333	267	200	100	26	6	10	32648	26344	39285	6542	18726	9353	42238
11	333	267	200	110	26	6	10	31247	25212	36933	6149	16853	8417	39778
12	333	267	200	120	26	6	10	29846	24080	34580	5757	14981	7480	37318
13	333	267	200	130	26	6	10	28444	22948	32228	5365	13108	6544	34858
14	333	267	200	140	26	6	10	27043	21817	29875	4973	11236	5608	32398
15	333	267	200	150	26	6	10	25642	20685	27523	4581	9363	4672	29937
No	SCENARIO 2													Gtotal2
	Pw	Po	Pr	cu	Qw	Qo	Qr	Rw	Gw	Ro	Go	Rr	Gr	
1	200	150	120	10	26	65	26	26900	21701	32259	29712	19666	15858	67271
2	200	150	120	20	26	65	26	25484	20558	29955	27585	17878	14414	62557
3	200	150	120	30	26	65	26	24069	19414	27650	25458	16090	12970	57842
4	200	150	120	40	26	65	26	22653	18270	25346	23331	14302	11526	53128
5	200	150	120	50	26	65	26	21237	17127	23042	21205	12515	10082	48413
6	200	150	120	60	26	65	26	19821	15983	20738	19078	10727	8638	43699
7	200	150	120	70	26	65	26	18405	14840	18434	16951	8939	7194	38984
8	200	150	120	80	26	65	26	16990	13696	16129	14824	7151	5750	34270

9	200	150	120	90	26	65	26	15574	12553	13825	12697	5363	4306	29556
10	200	150	120	100	26	65	26	14158	11409	11521	10570	3576	2862	24841
11	200	150	120	110	26	65	26	12742	10266	9217	8443	1788	1418	20127
12	200	150	120	120	26	65	26	11326	9122	6913	6316	0	-26	15412
13	200	150	120	130	26	65	26	9911	7979	4608	4189	-1788	-1470	10698
14	200	150	120	140	26	65	26	8495	6835	2304	2062	-3576	-2914	5983
15	200	150	120	150	26	65	26	7079	5692	0	-65	-5363	-4358	1269
No	**SCENARIO 3**													**Gtotal3**
	Pw	**Po**	**Pr**	**cu**	**Qw**	**Qo**	**Qr**	**Rw**	**Gw**	**Ro**	**Go**	**Rr**	**Gr**	
1	252	150	150	10	75	50	43	33786	31458	32711	29390	25305	22320	83168
2	252	150	150	20	75	50	43	32390	30155	30375	27287	23498	20722	78165
3	252	150	150	30	75	50	43	30993	28852	28038	25184	21690	19125	73161
4	252	150	150	40	75	50	43	29597	27549	25702	23081	19883	17528	68158
5	252	150	150	50	75	50	43	28201	26246	23365	20979	18075	15930	63155
6	252	150	150	60	75	50	43	26805	24943	21029	18876	16268	14333	58152
7	252	150	150	70	75	50	43	25409	23640	18692	16773	14460	12736	53148
8	252	150	150	80	75	50	43	24013	22337	16356	14670	12653	11138	48145
9	252	150	150	90	75	50	43	22617	21034	14019	12567	10845	9541	43142
10	252	150	150	100	75	50	43	21221	19731	11683	10464	9038	7944	38139
11	252	150	150	110	75	50	43	19825	18428	9346	8361	7230	6346	33136
12	252	150	150	120	75	50	43	18429	17125	7010	6259	5423	4749	28132
13	252	150	150	130	75	50	43	17032	15822	4673	4156	3615	3152	23129
14	252	150	150	140	75	50	43	15636	14519	2337	2053	1808	1554	18126
15	252	150	150	150	75	50	43	14240	13216	0	-50	0	-43	13123

Enclosure 13 - Sensitivity Analysis of ρ Parameter

No	SCENARIO 1														Gtotal1
	Pw	Po	Pr	rho (ρ)	neo (η)	Qw	Qo	Qr	Rw	Gw	Ro	Go	Rr	Gr	
1	333	267	200	0.1	0.6	26	6	10	72,697	58,691	8,819	1,464	28,089	14,035	74,189
2	333	267	200	0.2	0.6	26	6	10	67,977	54,878	14,851	2,469	28,089	14,035	71,382
3	333	267	200	0.3	0.6	26	6	10	63,256	51,066	20,884	3,475	28,089	14,035	68,575
4	333	267	200	0.4	0.6	26	6	10	58,536	47,253	26,917	4,480	28,089	14,035	65,767
5	333	267	200	0.5	0.6	26	6	10	53,815	43,440	32,949	5,486	28,089	14,035	62,960
6	333	267	200	0.6	0.6	26	6	10	49,095	39,628	38,982	6,491	28,089	14,035	60,153
7	333	267	200	0.7	0.6	26	6	10	44,374	35,815	45,014	7,496	28,089	14,035	57,346
8	333	267	200	0.8	0.6	26	6	10	39,654	32,002	51,047	8,502	28,089	14,035	54,539
9	333	267	200	0.9	0.6	26	6	10	34,934	28,190	57,080	9,507	28,089	14,035	51,731
10	333	267	200	1	0.6	26	6	10	30,213	24,377	63,112	10,513	28,089	14,035	48,924

No	SCENARIO 2														Gtotal2
	Pw	Po	Pr	rho (ρ)	neo (η)	Qw	Qo	Qr	Rw	Gw	Ro	Go	Rr	Gr	
1	200	150	120	0.1	0.6	26	65	26	38,751	31,273	3,582	3,241	12,515	10,082	44,596
2	200	150	120	0.2	0.6	26	65	26	36,249	29,252	6,362	5,808	12,515	10,082	45,142
3	200	150	120	0.3	0.6	26	65	26	33,747	27,231	9,142	8,374	12,515	10,082	45,687
4	200	150	120	0.4	0.6	26	65	26	31,245	25,210	11,922	10,940	12,515	10,082	46,232
5	200	150	120	0.5	0.6	26	65	26	28,743	23,190	14,702	13,506	12,515	10,082	46,778
6	200	150	120	0.6	0.6	26	65	26	26,241	21,169	17,482	16,072	12,515	10,082	47,323
7	200	150	120	0.7	0.6	26	65	26	23,739	19,148	20,262	18,638	12,515	10,082	47,868
8	200	150	120	0.8	0.6	26	65	26	21,237	17,127	23,042	21,205	12,515	10,082	48,413
9	200	150	120	0.9	0.6	26	65	26	18,735	15,106	25,822	23,771	12,515	10,082	48,959
10	200	150	120	1	0.6	26	65	26	16,233	13,085	28,602	26,337	12,515	10,082	49,504

No	SCENARIO 3														Gtotal3
	Pw	Po	Pr	rho (ρ)	neo (η)	Qw	Qo	Qr	Rw	Gw	Ro	Go	Rr	Gr	
1	252	150	150	0.1	0.6	75	50	43	51,787	48,259	3,905	3,465	18,075	15,930	67,654

2	252	150	150	0.2	0.6	75	50	43	48,417	45,115	6,685	5,967	18,075	15,930	67,011
3	252	150	150	0.3	0.6	75	50	43	45,048	41,970	9,465	8,469	18,075	15,930	66,369
4	252	150	150	0.4	0.6	75	50	43	41,679	38,825	12,245	10,971	18,075	15,930	65,726
5	252	150	150	0.5	0.6	75	50	43	38,309	35,680	15,025	13,473	18,075	15,930	65,083
6	252	150	150	0.6	0.6	75	50	43	34,940	32,536	17,805	15,975	18,075	15,930	64,440
7	252	150	150	0.7	0.6	75	50	43	31,571	29,391	20,585	18,477	18,075	15,930	63,798
8	252	150	150	0.8	0.6	75	50	43	28,201	26,246	23,365	20,979	18,075	15,930	63,155
9	252	150	150	0.9	0.6	75	50	43	24,832	23,101	26,145	23,481	18,075	15,930	62,512
10	252	150	150	1	0.6	75	50	43	21,463	19,957	28,925	25,983	18,075	15,930	61,869

Enclosure 14 - Sensitivity Analysis of η Parameter

No	**SCENARIO 1**														**Gtotal1**
	Pw	**Po**	**Pr**	**rho (ρ)**	**neo (η)**	**Qw**	**Qo**	**Qr**	**Rw**	**Gw**	**Ro**	**Go**	**Rr**	**Gr**	
1	333	267	200	0.8	0.1	26	6	10	71124	57420	51047	8502	7239	3610	69531
2	333	267	200	0.8	0.2	26	6	10	64830	52336	51047	8502	11409	5695	66533
3	333	267	200	0.8	0.3	26	6	10	58536	47253	51047	8502	15579	7780	63534
4	333	267	200	0.8	0.4	26	6	10	52242	42169	51047	8502	19749	9865	60536
5	333	267	200	0.8	0.5	26	6	10	45948	37086	51047	8502	23919	11950	57537
6	333	267	200	0.8	0.6	26	6	10	39654	32002	51047	8502	28089	14035	54539
7	333	267	200	0.8	0.7	26	6	10	33360	26919	51047	8502	32259	16120	51540
8	333	267	200	0.8	0.8	26	6	10	27066	21835	51047	8502	36429	18205	48541
9	333	267	200	0.8	0.9	26	6	10	20772	16752	51047	8502	40599	20290	45543
10	333	267	200	0.8	1	26	6	10	14478	11668	51047	8502	44769	22375	42544
No	**SCENARIO 2**														**Gtotal2**
	Pw	**Po**	**Pr**	**rho (ρ)**	**neo (η)**	**Qw**	**Qo**	**Qr**	**Rw**	**Gw**	**Ro**	**Go**	**Rr**	**Gr**	
1	200	150	120	0.8	0.1	26	65	26	37917	30599	23042	21205	2785	2223	54027
2	200	150	120	0.8	0.2	26	65	26	34581	27905	23042	21205	4731	3795	52904

3	200	150	120	0.8	0.3	26	65	26	31245	25210	23042	21205	6677	5367	51782
4	200	150	120	0.8	0.4	26	65	26	27909	22516	23042	21205	8623	6938	50659
5	200	150	120	0.8	0.5	26	65	26	24573	19821	23042	21205	10569	8510	49536
6	200	150	120	0.8	0.6	26	65	26	21237	17127	23042	21205	12515	10082	48413
7	200	150	120	0.8	0.7	26	65	26	17901	14433	23042	21205	14461	11654	47291
8	200	150	120	0.8	0.8	26	65	26	14565	11738	23042	21205	16407	13225	46168
9	200	150	120	0.8	0.9	26	65	26	11229	9044	23042	21205	18353	14797	45045
10	200	150	120	0.8	1	26	65	26	7893	6349	23042	21205	20299	16369	43923
No	**SCENARIO 3**														**Gtotal3**
	Pw	**Po**	**Pr**	**rho (ρ)**	**neo (η)**	**Qw**	**Qo**	**Qr**	**Rw**	**Gw**	**Ro**	**Go**	**Rr**	**Gr**	
1	252	150	150	0.8	0.1	75	50	43	50664	47211	23365	20979	4175	3647	71836
2	252	150	150	0.8	0.2	75	50	43	46171	43018	23365	20979	6955	6103	70100
3	252	150	150	0.8	0.3	75	50	43	41679	38825	23365	20979	9735	8560	68364
4	252	150	150	0.8	0.4	75	50	43	37186	34632	23365	20979	12515	11017	66627
5	252	150	150	0.8	0.5	75	50	43	32694	30439	23365	20979	15295	13474	64891
6	252	150	150	0.8	0.6	75	50	43	28201	26246	23365	20979	18075	15930	63155
7	252	150	150	0.8	0.7	75	50	43	23709	22053	23365	20979	20855	18387	61419
8	252	150	150	0.8	0.8	75	50	43	19216	17860	23365	20979	23635	20844	59682
9	252	150	150	0.8	0.9	75	50	43	14724	13667	23365	20979	26415	23300	57946
10	252	150	150	0.8	1	75	50	43	10231	9474	23365	20979	29195	25757	56210

Enclosure 15 - Sensitivity Analysis of sc Parameter

No	SCENARIO 1													Gtotal1
	Pw	Po	Pr	sc	Qw	Qo	Qr	Rw	Gw	Ro	Go	Rr	Gr	
1	333	267	200	1	26	6	10	39654	38103	51047	42533	28089	25270	105906
2	333	267	200	2	26	6	10	39654	36578	51047	34025	28089	22461	93064
3	333	267	200	3	26	6	10	39654	35053	51047	25518	28089	19652	80222
4	333	267	200	4	26	6	10	39654	33527	51047	17010	28089	16843	67380
5	333	267	200	5	26	6	10	39654	32002	51047	8502	28089	14035	54539
6	333	267	200	6	26	6	10	39654	30477	51047	-6	28089	11226	41697
7	333	267	200	7	26	6	10	39654	28952	51047	-8514	28089	8417	28855
8	333	267	200	8	26	6	10	39654	27427	51047	-17022	28089	5608	16013
9	333	267	200	9	26	6	10	39654	25902	51047	-25530	28089	2799	3171
10	333	267	200	10	26	6	10	39654	24376	51047	-34037	28089	-10	-9671
10	333	267	200	11	26	6	10	39654	22851	51047	-42545	28089	-2819	-22513
10	333	267	200	12	26	6	10	39654	21326	51047	-51053	28089	-5628	-35355
10	333	267	200	13	26	6	10	39654	19801	51047	-59561	28089	-8437	-48197
10	333	267	200	14	26	6	10	39654	18276	51047	-68069	28089	-11246	-61039
10	333	267	200	15	26	6	10	39654	16751	51047	-76577	28089	-14055	-73880
No	SCENARIO 2													Gtotal2
	Pw	Po	Pr	sc	Qw	Qo	Qr	Rw	Gw	Ro	Go	Rr	Gr	
1	200	150	120	1	26	65	26	21237	20394	23042	22623	12515	12007	55024
2	200	150	120	2	26	65	26	21237	19577	23042	22268	12515	11526	53371
3	200	150	120	3	26	65	26	21237	18761	23042	21914	12515	11045	51719
4	200	150	120	4	26	65	26	21237	17944	23042	21559	12515	10563	50066
5	200	150	120	5	26	65	26	21237	17127	23042	21205	12515	10082	48413
6	200	150	120	6	26	65	26	21237	16310	23042	20850	12515	9601	46761
7	200	150	120	7	26	65	26	21237	15493	23042	20496	12515	9119	45108
8	200	150	120	8	26	65	26	21237	14677	23042	20141	12515	8638	43456

9	200	150	120	9	26	65	26	21237	13860	23042	19787	12515	8157	41803
10	200	150	120	10	26	65	26	21237	13043	23042	19432	12515	7675	40150
10	200	150	120	11	26	65	26	21237	12226	23042	19078	12515	7194	38498
10	200	150	120	12	26	65	26	21237	11409	23042	18723	12515	6713	36845
10	200	150	120	13	26	65	26	21237	10593	23042	18369	12515	6231	35192
10	200	150	120	14	26	65	26	21237	9776	23042	18014	12515	5750	33540
10	200	150	120	15	26	65	26	21237	8959	23042	17660	12515	5269	31887
No	**SCENARIO 3**													**Gtotal3**
	Pw	**Po**	**Pr**	**sc**	**Qw**	**Qo**	**Qr**	**Rw**	**Gw**	**Ro**	**Go**	**Rr**	**Gr**	
1	252	150	150	1	75	50	43	28201	27750	23365	22848	18075	17612	68210
2	252	150	150	2	75	50	43	28201	27374	23365	22380	18075	17191	66946
3	252	150	150	3	75	50	43	28201	26998	23365	21913	18075	16771	65682
4	252	150	150	4	75	50	43	28201	26622	23365	21446	18075	16351	64419
5	252	150	150	5	75	50	43	28201	26246	23365	20979	18075	15930	63155
6	252	150	150	6	75	50	43	28201	25870	23365	20511	18075	15510	61891
7	252	150	150	7	75	50	43	28201	25494	23365	20044	18075	15090	60628
8	252	150	150	8	75	50	43	28201	25118	23365	19577	18075	14669	59364
9	252	150	150	9	75	50	43	28201	24742	23365	19109	18075	14249	58100
10	252	150	150	10	75	50	43	28201	24366	23365	18642	18075	13829	56837
10	252	150	150	11	75	50	43	28201	23990	23365	18175	18075	13408	55573
10	252	150	150	12	75	50	43	28201	23614	23365	17707	18075	12988	54309
10	252	150	150	13	75	50	43	28201	23238	23365	17240	18075	12567	53046
10	252	150	150	14	75	50	43	28201	22862	23365	16773	18075	12147	51782
10	252	150	150	15	75	50	43	28201	22486	23365	16306	18075	11727	50518

Enclosure 16 - Sensitivity Analysis of hc Parameter

No	SCENARIO 1													Gtotal1
	Pw	Po	Pr	hc	Qw	Qo	Qr	Rw	Gw	Ro	Go	Rr	Gr	
1	333	267	200	2	26	6	10	39654	32002	51047	8502	28089	14035	54539
2	333	267	200	4	26	6	10	39654	31976	51047	8496	28089	14025	54497
3	333	267	200	6	26	6	10	39654	31950	51047	8490	28089	14015	54455
4	333	267	200	8	26	6	10	39654	31924	51047	8484	28089	14005	54413
5	333	267	200	10	26	6	10	39654	31898	51047	8478	28089	13995	54371
6	333	267	200	12	26	6	10	39654	31872	51047	8472	28089	13985	54329
7	333	267	200	14	26	6	10	39654	31846	51047	8466	28089	13975	54287
8	333	267	200	16	26	6	10	39654	31820	51047	8460	28089	13965	54245
9	333	267	200	18	26	6	10	39654	31794	51047	8454	28089	13955	54203
10	333	267	200	20	26	6	10	39654	31768	51047	8448	28089	13945	54161
10	333	267	200	22	26	6	10	39654	31742	51047	8442	28089	13935	54119
10	333	267	200	24	26	6	10	39654	31716	51047	8436	28089	13925	54077
10	333	267	200	26	26	6	10	39654	31690	51047	8430	28089	13915	54035
10	333	267	200	28	26	6	10	39654	31664	51047	8424	28089	13905	53993
10	333	267	200	30	26	6	10	39654	31638	51047	8418	28089	13895	53951
No	SCENARIO 2													Gtotal2
	Pw	Po	Pr	hc	Qw	Qo	Qr	Rw	Gw	Ro	Go	Rr	Gr	
1	200	150	120	2	26	65	26	21237	17127	23042	21205	12515	10082	48413
2	200	150	120	4	26	65	26	21237	17101	23042	21140	12515	10056	48296
3	200	150	120	6	26	65	26	21237	17075	23042	21075	12515	10030	48179
4	200	150	120	8	26	65	26	21237	17049	23042	21010	12515	10004	48062
5	200	150	120	10	26	65	26	21237	17023	23042	20945	12515	9978	47945
6	200	150	120	12	26	65	26	21237	16997	23042	20880	12515	9952	47828
7	200	150	120	14	26	65	26	21237	16971	23042	20815	12515	9926	47711
8	200	150	120	16	26	65	26	21237	16945	23042	20750	12515	9900	47594

9	200	150	120	18	26	65	26	21237	16919	23042	20685	12515	9874	47477
10	200	150	120	20	26	65	26	21237	16893	23042	20620	12515	9848	47360
10	200	150	120	22	26	65	26	21237	16867	23042	20555	12515	9822	47243
10	200	150	120	24	26	65	26	21237	16841	23042	20490	12515	9796	47126
10	200	150	120	26	26	65	26	21237	16815	23042	20425	12515	9770	47009
10	200	150	120	28	26	65	26	21237	16789	23042	20360	12515	9744	46892
10	200	150	120	30	26	65	26	21237	16763	23042	20295	12515	9718	46775
No	**SCENARIO 3**													**Gtotal3**
	Pw	**Po**	**Pr**	**hc**	**Qw**	**Qo**	**Qr**	**Rw**	**Gw**	**Ro**	**Go**	**Rr**	**Gr**	
1	252	150	150	2	75	50	43	28201	26246	23365	20979	18075	15930	63155
2	252	150	150	4	75	50	43	28201	26171	23365	20929	18075	15887	62987
3	252	150	150	6	75	50	43	28201	26096	23365	20879	18075	15844	62819
4	252	150	150	8	75	50	43	28201	26021	23365	20829	18075	15801	62651
5	252	150	150	10	75	50	43	28201	25946	23365	20779	18075	15758	62483
6	252	150	150	12	75	50	43	28201	25871	23365	20729	18075	15715	62315
7	252	150	150	14	75	50	43	28201	25796	23365	20679	18075	15672	62147
8	252	150	150	16	75	50	43	28201	25721	23365	20629	18075	15629	61979
9	252	150	150	18	75	50	43	28201	25646	23365	20579	18075	15586	61811
10	252	150	150	20	75	50	43	28201	25571	23365	20529	18075	15543	61643
10	252	150	150	22	75	50	43	28201	25496	23365	20479	18075	15500	61475
10	252	150	150	24	75	50	43	28201	25421	23365	20429	18075	15457	61307
10	252	150	150	26	75	50	43	28201	25346	23365	20379	18075	15414	61139
10	252	150	150	28	75	50	43	28201	25271	23365	20329	18075	15371	60971
10	252	150	150	30	75	50	43	28201	25196	23365	20279	18075	15328	60803

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BIOGRAPHY

Sandra Oktavia Teguh, ST., MT., MBA gains her master with dual degree program in Industrial Management at National Taiwan University of Science and Technology and Industrial Engineering at Sepuluh Nopember Institute of Technology in 2018. Her bachelor degree Industrial Engineering at Sepuluh Nopember Institute of Technology in 2014. Her research interests are inventory and supply chain management, optimization problems, and pricing.