MODEL *DUAL-CHANNEL SUPPLY CHAIN* BERDASARKAN WAKTU TRANSAKSI JUAL-BELI DENGAN MEMERHATIKAN FAKTOR DISRUPSI RISIKO

DUAL-CHANNEL SUPPLY CHAIN MODEL BASED ON TIME TRANSACTION OF DEALING BY NOTICE DISRUPTION RISK FACTOR

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ABSTRAK

Era revolusi industri 4.0 menuntut efektifitas dan efisiensi pelaksanaan kegiatan industri, salah satunya minimisasi waktu transaksi yang terdiri dari waktu pelayanan dan waktu pengiriman. Penelitian ini bertujuan untuk mengkalkulasikan keuntungan industri dengan menggunakan model *dual-channel supply chain* berdasarkan pada waktu transaksi jual-beli serta memperhatikan faktor disrupsi risiko yang terjadi pada pengecer sebagai akibat berubahnya pola pikir konsumen. Pada penelitian ini dikonstruksikan model maksimisasi suatu sistem keuntungan dari pemanufaktur-multiretailer. Kegiatan ekonomi pengecer mempunyai faktor disrupsi dalam pelaksanaan proses retailnya. Kemudian, ditentukan penyelesaian optimumnya dengan menggunakan metode Newton, sehingga diperoleh bahwa sistem mempunyai keuntungan optimum sebesar $620372. Keadaan tersebut dicapai pada saat harga produk dari pemanufaktur, retailer 1, dan retailer 2 secara berturut-turut sebesar $318.99, $352.48, dan $345.43 serta probabilitas disrupsi sebesar 9.15%. Berdasarkan analisis senstitivitas keuntungan sistem, keuntungan meningkat secara signifikan menjadi $1010948. Hal tersebut terjadi pada saat prioritas perpindahan permintaan konsumen kepada pengecer 1 sebesar 9.3 unit per perubahan harga dari pengecer 2.

Kata Kunci : faktor disrupsi risiko, waktu pengiriman, masalah optimasi, waktu pelayanan, *supply chain*, waktu transaksi.

ABSTRACT

The fourth industrial revolution era requires an effectiveness and efficiency to enforce the industrial activities, one of them, such as minimization of transaction time of dealing that consists of service and delivery time. The purpose of this research is to calculate the industrial profit using *dual-channel supply chain* model based on the transaction time of dealing by notice disruption risk factor on retailers as the effect of mindset changing of consumers. In this research, we construct the maximization model of profit in the system between manufacture and multi-retailer. Multi-retailer's economical activities have some disruption risk factors on the retail engagement. Furthermore, we determine the optimum solution using Newton method so we get the optimum profit of the system is $620372. That kind of situation is reached when the offered price of manufacturer, retailer 1, and retailer 2 is $318.99, $352.48, and $345.43 respectively with the probability of disruption is 9.15%. Depend on sensitivity analysis of profit system, the profit increase significantly to $1010948. It occur when priority of consumers demand to retailer 1 is missing to 9.3 units per price changing of retailer 2.

Kata Kunci : disruption risk factor, lead time, optimization problem, service time, supply chain, time of transaction.

Introduction

The globalization era is developing along with technological development, that is the implementation of technology in the education aspect, cultural aspect, economic aspect, industrial aspect, etc. In the industrial aspect, technological developments cause the economic activity system has changed, which at this time is often known as the industrial revolution 4.0. Industrial revolution 4.0 is an industrial transformation by digitizing and exploiting all of the potential renewable technology, so there could be obtained the customized flexibility product (Andreja R. 2007). Because of it is run by machine with the controlling system, the level of effectiveness and efficiency of working becomes more competitive, as well as resource efficiency.

In the era of industrial revolution 4.0, the entire industrial activity is running automatically and technology-based. In the digital age, the more competitive sectors that could be the media of competition for businessmen is the length of time in transaction so the goods or services can be delivered to consumers (Ding Y. *et al.* 2017). Calculation of the length of time in transaction consists of the length of service time and the lead time of goods in a period of transaction and the aim of the research is the lower of service time and lead time of goods to consumers, the higher the demand for goods to businesses in integrated media. More than that, the social pressure will continuously gain the increment of affection to service time and lead time of the product (Hanyeong K. *et al.* 2018).

Besides, the time of transactions in economic activities, the loss is becomes a serious threat or often known as a disruption factor. The disruption factors can be divided into various types, one of those is the disruption risk factor (Milan K. *et al.* 2018). The disruption risk factor is the probability for a business to have a loss based on risks that may occur during economic activities, such as the cost of product damage, returned stuff and consumers complaints.

Both of those could be factors that influence the supply chain model as a standard to determining business profits. Supply chain is any system that involves a series of product delivery from the production process until the hands of consumers (Kumar N. and Kumar R. 2012). If we pay attention on the market share potential, the supply chain model could be developed into dual-channel supply chain that consist of direct channel and indirect channel also the implementation by using Stackelberg Leader (Chen J. *et al.* 2012).

Based on the research about the time of transactions (Ding Y. *et al.* 2017) and the disruption risk factors (Milan K. *et al.* 2018), this research will develop on the pricing policy for each channel or business actors, there are producers and distributors in order to obtain maximum profits based on the length of service time and lead time of goods to consumers using the dual-channel supply chain model (Chen J. *et al.* 2012). Not only that, there is also concerns about business losses that might be arisen due to the risk disruption factor in terms of the number of consumer demand to distributors.

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Literature Review

In 2009, there was conducted a study on determining the level of supply chain disruption risk by using a Monte Carlo simulation to find out how important to control the disruption factors, especially risk disruption in SC activities (Amanda J. S. and Mahender S. 2009). The result of the research is that forecasting the value of the disruption factor will not reach an accurate calculation because in its course, the risk will change naturally (in dynamic) without knowing which factors can predict or encourage the risk to emerge. In the same year, it was examined the supply chain inventory model by observing the lead time of goods and service levels as form as constraint function (Jha J. K. and Shanker K. 2009). The result is when the service level increase, it will affect the profit rate indirectly.

In 2011, there was conducted a research on the effect of risk disruption on demand for goods in an inventory system (Amanda J. S. 2011). The conclusion is to handle the possibility of high disruption, it can be done by providing the alternative inventory of goods to anticipate the shocking gain in demand for the same goods. Then, in 2012, there is conducted a study on the analysis of disruption risk in multi-echelon supply chains in uncertainty market demand (Amanda J. S. and Mahender S. 2012). The research concluded that the disruption risk of a SC may increase or decrease at a time. In

2014, there is conducted a study on cost optimization and the service level by notice the risk disruption factors in the supply chain model (Tadeusz S. 2014). The results of this study reveal that consumer's demand tends to increase on suppliers at lower prices and higher service levels.

In 2017, there was conducted a study of a competition between multi-retailers in heterogeneous markets related to service time (Ding Y. *et al.* 2017). The study concluded that when competition at each retailer has more competitive, service time becomes a chaos factor to consider, it is able to compete with other retailers.

In 2018, there was conducted research on the strategy of determining policies and procurement of goods in multi-retailer competitive by taking into the account of risk disruption factor (Milan K. *et al.* 2018). The results of this study is the profit of a channel will decrease with increment probability of a risk disruption factor or in another words the risk disruption factor is inversely proportional to the total gain of channel. There are three main factors that become the main focus in this research, namely the potential market (market potential), relative price advantage (relative cost advantage), and the risk disruption factor (probability of disruption risk). These three things are the most influential and integration factors each other, for example if potential market increases along with relative cost high advantage then it will expand market share that can be reached by a channel.

At the same year, when the market demand is spread out and the disruption risk factors increased then the sustainable strategy to face that economical phenomenon is by using procurement strategy at the first option and the option purchase on the second one (Kelei X. *et al.* 2018). In the same year, there was conducted a study about the complexity and entropy analysis of a multi-channel supply chain considering channel cooperation and service (Qiuxiang L. *et al.* 2018). The result is when the manufacturer or the retailer keeps service level in the appropriate value which is conducive to maximizing her/his profit, the manufacturer should carefully set the service level of online-to-store channel to ensure the system's profit.

Assumptions and Notations

In constructing a mathematical model of the problems that have been described, parameters and decision variables are formed as seen at Table 1.

Table 1. Notations of Parameters and Variables

Parameters in the model			
L_M	manufacture's lead time	ρ_M	sensitivity of manufacture's prices
L_{R1}	retailer 1's lead time	ϕ_{R1M}	sensitivity of ret 1-manuf prices
L_{R2}	retailer 2's lead time	ϕ_{R2M}	sensitivity of ret 2-manuf prices
β_M	sensitivity of manufacture's lead time	ϕ_{MR1}	sensitivity of manuf-ret 1prices
β_{R1}	sensitivity of retailer 1's lead time	ρ_{R1}	sensitivity of retailer 1's price
β_{R2}	sensitivity of retailer 2's lead time	ϕ_{R2R1}	sensitivity of ret 2 -ret 1 prices
S_M	manufacture's service time	ϕ_{MR2}	sensitivity of manuf-ret 2 prices
S_{R1}	retailer 1's service time	ϕ_{R1R2}	sensitivity of ret 1-ret 2 prices
S_{R2}	retailer 2's service time	ρ_{R2}	sensitivity of retailer 2's price
γ_M	sensitivity of manufacture's service time	λ	secondary proportion of demand
γ_{R1}	sensitivity of retailer 1's service time	α	homogeneity of retailers
γ_{R2}	sensitivity of retailer 2's service time	σ	disruption risk coefficient
a	initial demand of goods	δ	disruption risk factor coefficient
θ	primary proportion of demand	c	production cost

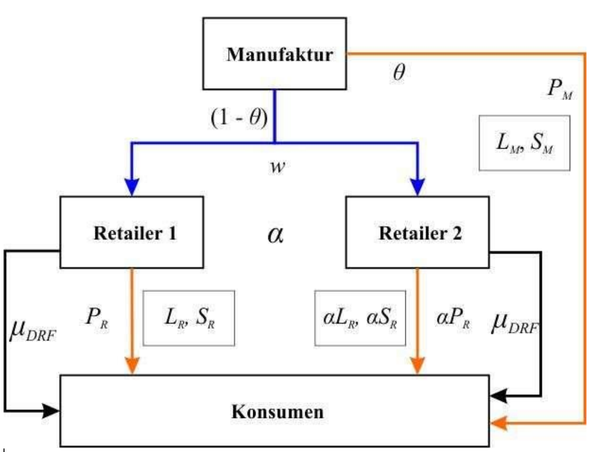

Figure 1. *Dual-channel supply chain* scheme.

As known as on Figure 1., assumptions are built for price decision on the dual-channel supply chain model which elaborated from the research of the time of transactions (Ding Y. *et al.* 2017) and disruption risk factors (Milan K. *et al.* 2018) as following,

i. the amount of the market demand for good traded does not exceed the amount of production from the manufacturer or in other words there is no mechanism of goods shortage,

ii. producers and distributors set policies together (*centralized decision making*) and the aim is to obtain optimal profits,

iii. production process has a perfection production principle, so there isn't invalid product during the production process,

iv. distribution activities are carried out by manufacturer and multi-retailer which be hold on online channel so there is a service time and lead time product,

v. elasticity of prices that offered to consumers, both from producers and distributors have bigger value than sensitivity of price,

vi. demand function of each businessmen is affected by transaction time of dealing.,

vii. price offered by one distributor to another can be expressed by the level of homogeneity of the distributor which indicates if the level of homogeneity is close to one, then the price offered by the distributors is the same,

viii. the probability of loss is triggered by disruption risk on the retailers which represent by μ_{DRF}. The disruption risk gains depend on the indirect demand independently,

ix. probability of loss due to disruption risk factors that may be arise by distributors fluctuates in open interval between 0 to 1,

x. disruption risk factor only occur in the retailers is caused by inconsistence market demand to retailers of each period of production with coefficient independency of disruption risk is σ.

Model Construction

1. Demand Function

Based on the literature review, assumptions, and notations that have been explained, we construct a demand function that development from previous research. The initial demand of a period of distribution is denoted by a. We assume that the primary demand market is denoted by θ-proportion and the secondary demand market between retailers is denoted by α-proportion. The demand function of each media is affected by service and lead time aspect. As we know from the previous research, the increment of service and lead time of a distribution media affect the number of demand market as the decrement of it.

Service time of each media has a sensitivity value defined as the number of customers that move to another media per price of goods that was risen. Beside, the service time itself is the length of customer's time to be queuer that are denoted by S_M and S_{Ri} for $i = 1, 2$ that represent the manufacturer's service time and retailer i 's service time. The sensitivity of service time are denoted by γ_M, γ_{Ri} that represent the manufacturer's sensitivity and i^{th}-retailer's sensitivity for $i = 1,2$ respectively

Lead time of each media have a sensitivity value defined as the number of customers that move to another media per price of goods that was risen. Beside, the lead time itself is time from receipt of a customer order to the product is received by the customer that are denoted by L_M and L_{Ri} for $i = 1,2$ that represent the manufacturer's lead time and retailer i's lead time. The sensitivity of lead time is denoted by β_M, L_{Ri} for $i = 1,2$ that represent the manufacturer's sensitivity and retailer i's sensitivity for $i = 1,2$ respectively.

Moreover, the demand functions of each media can be written as,

$$\begin{aligned} D_D = {} & \theta a - \beta_M L_M - \gamma_M S_M - \rho_M P_M + \beta_{R1} L_{R1} \\ & + \gamma_{R1} S_{R1} + \phi_{R1M} P_R + \beta_{R2} L_{R2} + \gamma_{R2} S_{R2} \\ & + \phi_{R2M} \alpha P_R \\ D_I = {} & (1-\theta) a + 2(\beta_M L_M + \gamma_M S_M) \\ & + P_M(\phi_{MR1} + \phi_{MR2}) + P_R(\phi_{R1R2} \\ & + \alpha \phi_{R2R1} - \rho_{R1} + \alpha \rho_{R2}) \qquad (1) \end{aligned}$$

The function of retailers can be separated to retailer i. The demand function of retailer i is represented as

$$\begin{aligned} D_{IR1} = {} & (1-\theta)\lambda a + \beta_M L_M + S_M + \phi_{MR1} P_M \\ & - \beta_{R1} L_{R1} - \gamma_{R1} S_{R1} + \beta_{R2} L_{R2} \\ & + \gamma_{R2} S_{R2} - P_R(\rho_{R1} - \alpha \phi_{R2R1}) \\ D_{IR2} = {} & (1-\theta)(1-\lambda) a + \beta_M L_M + S_M \\ & + \phi_{MR2} P_M + \beta_{R1} L_{R1} + \gamma_{R1} S_{R1} \\ & - \beta_{R2} L_{R2} - \gamma_{R2} S_{R2} - P_R(\alpha \rho_{R2} - \\ & \phi_{R1R2}) \qquad (2) \end{aligned}$$

The D_D and D_I represent the demand function of direct channel and indirect channel respectively. The D_{IR1} and D_{IR2} represent the demand function of first retailer, and second retailer respectively. The sum between demand function of first and second retailer is denoted by D_I. The price of goods which offered by manufacturer and retailer is denoted by P_M and P_R respectively. The first retailer's price denoted by P_R and the second retailer's price can be defined as αP_R as written as above.

At the end, we have obtained the demand function from direct channel and indirect channel as distribution media. Furthermore, we use the demand function to formulate global profit function of the centralized system.

2. Disruption Risk Factor

Disruption risk factor is influenced by inconsistence demand of consumers to indirect channel itself because of change of costumer's mindset who move to substitute cheaper product. According to the equation, we obtain the amount of demand for each retailer. However, the disruption risk factor only has a point of interest, it is the scope of retailers so the service time (S_M), lead time (L_M) and the prices (P_M) of manufacture are not effected to disruption risk. Therefore, the disruption risk of retailer can be represented as a function as follows,

$$E_{DRF} = ((1-\theta)a - \rho_{R1}P_R + \phi_{R2R1}\alpha P_R - \rho_{R2}\alpha P_R + \phi_{R1R2}P_R)/(1-\theta)a \quad (3)$$

Then the probability of disruption risk that may occur on indirect channel is a multiplication between the exponential function of independent retailer demand and coefficient independency of disruption (σ). Furthermore, we can obtain the value of disruption risk factor below,

$$\mu_{DRF} = (1 - e^{-\sigma E_{DRF}}) \quad (4)$$

3. Profit Function

2.1. Profit Function of Direct Channel

The profit function on the direct channel can be obtained from total revenue minus total cost of production. The manufacturer's total revenue comes from direct selling to consumers and grocery selling to retailers. Direct selling to consumers is a multiplication between the prices of goods (P_M) and demand on direct channel (D_D). Grocery selling to retailers in a multiplication between the prices of grocery goods from manufacture $(\omega \mathrm{P}_M)$ and demand on indirect channel (D_I). On the other side, total cost of production is a multiplication between initial demand (a) and the cost of production per unit (C). Thus we can obtain the profit function of direct channel below,

$$\pi_D = (P_M - c)D_D + (\delta P_M - c)D_I \quad (5)$$

2.2. Profit Function of Indirect Channel

The profit function on the indirect channel can be obtained from total revenue minus total procurement cost. The retailer's total revenue comes from direct selling to consumers. Direct selling to consumers is a multiplication between the prices of both first retailer (P_R) and also second retailer (αP_R) with each partial demand on indirect channel, there are (D_{IR1}) for the first retailer and (D_{IR2}) for the second retailer. On the other side, total procurement cost is a multiplication between initial demand (D_I) and the procurement cost per unit (δP_M) .So the profit function on indirect channel is follow,

$$\pi_I = \pi_{R1} + \pi_{R2}$$
$$= (1 - \mu_{DRF})(P_R D_{IR1} + \alpha P_R D_{IR2}) - \delta P_M D_I \quad (6)$$

4. Centralized Profit Function and Optimization Problem

In a centralized scenario, the businessmen of *dual-channel supply chain* make decisions together in all of the integrated system. This causes the gained profits will be focused on the entire system. The function of the profits system is the sum of the profits of manufacture and the retailers. Then, the problem that may appear in a centralized system is maximization problem with two variable nonlinear equation system. Profit function in centralized system can be written as follows,

$$\Pi_{max}(P_M, P_R) = \pi_D + \pi_I$$
$$= P_M D_D + (1 - \mu_{DRF})(P_R D_{IR1} + \alpha P_R D_{IR2}) - c(D_D + D_I) \quad (7)$$

5. Optimal Solution

The model of *DCSC* can be proved by using Sylverster Criterion that $\Pi(P_M, P_R)$ is a strictly concave function [16]. The function is strictly concave if the value of principal minor determinant of the Hessian matrix which is obtained from the *DCSC* model is definite negative. Strictly concave function only has a global maximum point or a value of (P_M, P_R) so the system has a maximum value on $\Pi(P_M, P_R)$.

Sylvester Criterion is proofed by determining the *principal minor determinant* of the Hessian matrix of the equation system (Taha H. A. 2007). The Hessian matrix system obtained as below,

$$\boldsymbol{H} = \begin{pmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{pmatrix}$$

with

$$h_{11} = -2\phi_M$$
$$h_{12} = \phi_{R1M} + \alpha\phi_{R2M} + (1 - \mu_{DRF})(\phi_{MR1} + \alpha\phi_{MR2}) + \mu_{DRF} P_R (\phi_{MR1} + \alpha\phi_{MR2})\sigma(\rho_{R1} - \phi_{R1R2} + \alpha(\rho_{R2} + \phi_{R2R1}))/a(\theta - 1)$$
$$h_{21} = h_{12}$$
$$h_{22} = 2\alpha\phi_{R2R1} + (A + \mu_{DRF}(A - 2a^2 (\theta - 1)^2 \alpha\phi_{R2R1} + 2a(\theta - 1) B(C - D)\sigma + P_R c^2 C\sigma^2)) / a^2(\theta - 1)^2$$

and

$$A = 2a^2(\theta - 1)^2(\rho_{R1} + \alpha(\alpha\rho_{R2} - \phi_{R1R2}))$$
$$B = \rho_{R1} - \phi_{R1R2} + \alpha(\rho_{R2} - \phi_{R2R1})$$

$$C = \gamma_M S_M - \alpha\beta_M L_M - \gamma_{R1}S_{R1} - \beta_{R1}L_{R1} + \gamma_{R2}S_{R2} + \beta_{R2}L_{R2} + \alpha(\theta - 1)(\alpha(\lambda - 1) - \lambda) + P_M\phi_{MR1} - 2P_R\rho_{R1} + \alpha(\beta_{R1}L_{R1} - \beta_{R2}L_{R2} + \gamma_M S_M + \gamma_{R1}S_{R1} - \gamma_{R2}S_{R2} + P_M\phi_{R2M} + 2P_R(\phi_{R!R2} + \phi_{R2R1} - \alpha\rho_{R2}))$$

Based on the *Sylverster Criterion*, if *principal minor determinant* of the Hessian matrix of the function is $(-1)^j$ with $j = 1, 2, 3, \dots, n$ then the function is a strictly concave function which has single maximum global point. If

$$H_{11} = det(h_{11})$$

$$H_{22} = det\begin{pmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{pmatrix}$$

so it can be determined that $H_{11} < 0$ and $H_{22} > 0$ so $\frac{H_{11}}{H_{22}} < 0$. It is proofed that the model has single optimal solution. The optimal solution could be obtained by using Newton method as written on the Apendix A.

Numerical Example

The value of parameters is took from the research of *SC* management based on time transaction of dealing (Ding Y. *et al.* 2017) and disruption risk factors (Milan K. *et al.* 2018). This values are used to determine how is the behavior of the *dual-channel supply chain* would be described the global profit function. The value of parameters are shown as below at Table 2.

Table 2. The value of parameters which is used in the model

Parameters	Value	Unit	Parameters	Value	Unit	Parameters	Value	Unit
L_M	120	unit/ hours	ρ_M	14.6	unit/ $	λ	0.5	-
L_{R1}	24	unit/ hours	ρ_{R1}	12	unit/ $	α	0.98	-
L_{R2}	36	unit/ hours	ρ_{R2}	12.4	unit/ $	σ	10	-
β_M	5	unit/ hours	ϕ_{R1M}	2.2	unit/ $	δ	0.9	-
β_{R1}	4	unit/ hours	ϕ_{R2M}	2	unit/ $	c	200	$
β_{R2}	4.5	unit/ hours	ϕ_{MR1}	2	unit/ $	a	10000	unit
S_M	6	unit/ hours	ϕ_{R2R1}	6.5	unit/ $	θ	0.5	-
S_{R1}	3.5	unit/ hours	ϕ_{MR2}	1.5	unit/ $	γ_{R1}	22	unit/ hours
S_{R2}	4	unit/ hours	ϕ_{R1R2}	7	unit/ $	γ_{R2}	22	unit/ hours
γ_M	24	unit/ hours						

According to the values of parameters at Table 2 we get maximization problem such as,

$$\Pi_{max}(P_M, P_R) = 6759P_M - 14.6P_M^2 + 7889P_R -10.68P_R^2 + 7.63P_M P_R + P_R e^{0.02P_R}(-0.29 - 1.88 \times 10^{-4} P_M + 4.84 \times 10^{-4} P_R) \quad (8)$$

By using Newton method algorithm, the optimal solution of maximization problem (8) can be determine so that the maximum profit system in centralized scenario is $620372. The maximum profit is reached when offered price of manufacturer, retailer 1, and retailer 2 is $318.99, $352.48, and $345.43. We did sensitivity analysis as written on the next section.

Sensitivity Analysis

Sensitivity analysis is implemented to the value of significant parameters which affect to the price decision and optimum profit system. The parameters that we analyze consist of demand function parameters, service time parameters, lead time parameters, and coefficient of disruption parameter. The result of the sensitivity analysis is shown on Figure 2, Figure 3, Figure 4, and Figure 5,

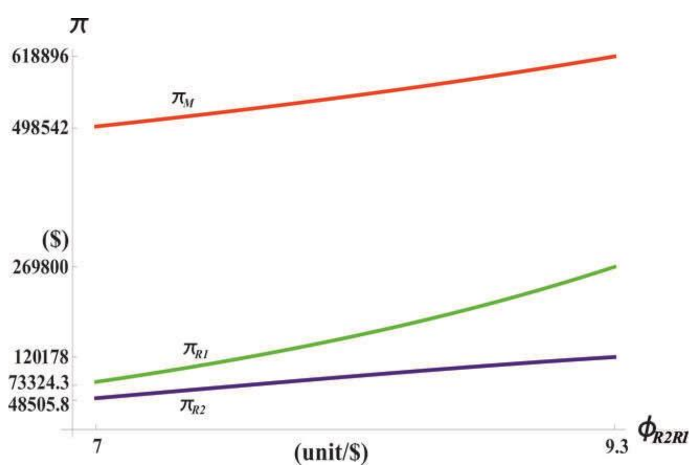

Figure 2. Curve of businessmen profit against sensitivity price of R2 with R1.

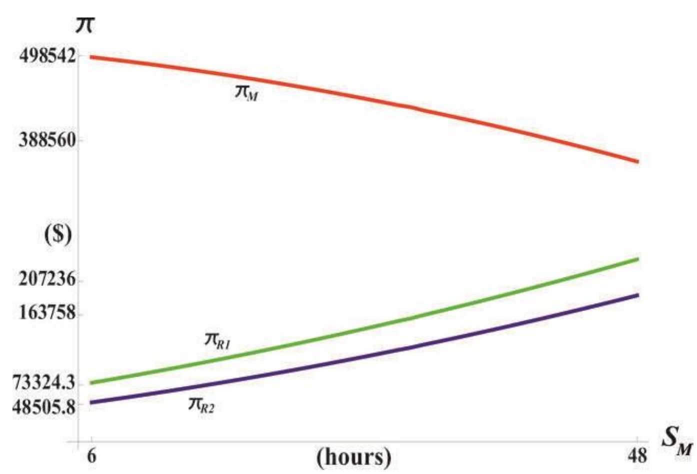

Figure 3. Curve of businessmen profit against service time of manufacturer.

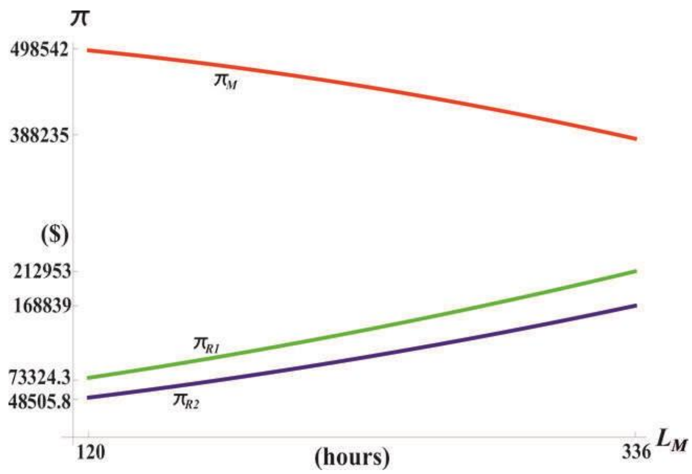

Figure 4. Curve of businessmen profit against lead time of manufacturer

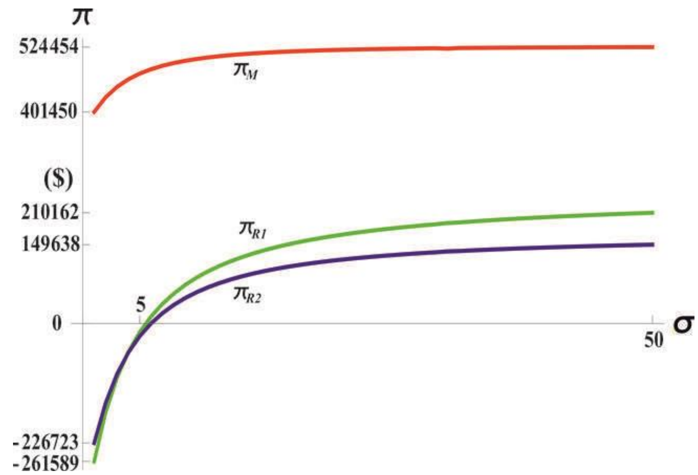

Figure 5. Curve of businessmen profit against coefficient of disruption

Depend on the Figure 2, Figure 3, Figure 4, and Figure 5, the most significant parameter that increase the profit of the system is ϕ_{R2R1}-parameter. The demand function parameter can increase \$1010948 in total profit. That profit can be reached when the price of manufacturer, retailer 1, and retailer 2 is \$341.76, \$441.97, and \$433.13 respectively.

Pricing Policy Based On Sensitivity Analysis

The manufacturer as *Stakelberg* leader should make some policy about the system such as the pricing, distributions, the amount of sales, etc. Because of that, there are some kind of situations that could be the consideration of the manufacturer to decide the most suitable pricing policy,

1. Pricing policy under market manipulation ability
   If manufacturer has an ability to manipulate market share with controlling the price of each businessmen, so the most effective policy that possible to be implemented is manufacturer make a regulation about the offered price from retailer 2 as on the Figure 2.
2. Pricing policy with upgradable human resource in service division
   If manufacturer has a capability to increase the service level of each businessmen, so the most effective policy that possible to be implemented is increasing the amount of human resource in service division of manufacturer as on the Figure 3.
3. Pricing policy with more financial budged in distributions

If manufacturer has a capability to develop the financial aspect in distribution sectors, so the most effective policy that possible to be implemented is enhance the budged of distribution sector of manufacturer as on the Figure 4.

4. Pricing policy under disruption risk factor hold down

   If manufacturer has an ability to hold down the disruption risk between potential consumers and new substitute product, so the most effective policy that possible to be implemented is spreading out the market share so there is new market potential that could be produced as on the Figure 5

Conclusion

The *dual-channel supply chain* model can be used to solve optimization problem such as equation (8). Equation is a strictly concave function, so based on Sylverster Criterion there is single maximum solution.

The model can be implemented in real life such as an illustration problem on numerical example. The optimal solution of model with given parameters on Table 2, can be obtained by using Newton method algorithm so that we get the maximum profit of the system is \$620732. The profit is reached when the offered price of manufacturer, retailer 1, and retailer 2 is \$318.99, \$352.48, and \$345.43 respectively with the probability of disruption is 9.15%.

Furthermore, we did sensitivity analysis to know the behavior of each parameter to total profit of the system. Depend on sensitivity analysis of profit system, the profit increase significantly to \$1010948. It occur when priority of consumers demand to retailer 1 is missing to 9.3 units per price changing of retailer 2. The sensitivity analysis can be a consideration of the manufacturer to make some regulation or policy about pricing, amount of sales of each businessmen, distributions, etc. Moreover, the most effective regulation option is shown in pricing policy based on sensitivity analysis section.

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Apendix A

Suppose that nonlinear equation system for two variables x and y, with equation as below,

$$\begin{aligned} f(x,y) &= 0 \\ g(x,y) &= 0 \end{aligned} \tag{9}$$

Nonlinear equation system can be solved by Newton method using Taylor series so that for $f(x,y)$ we get

$$\begin{aligned} 0 &= f(x^*,y^*) \\ &= f(x+(x^*-x), y+(y^*-y)) \\ &= f(x,y)+(x^*-x)f_x(x,y)+(y^*-y) \\ &\quad f_y(x,y)+R_f \end{aligned}$$

with

$$\begin{aligned} R_f = &((x^*-x)2f_{xx}+2(x^*-x) \\ &(y^*-y)f_{xy}+(y^*-y)2f_{yy})(\eta;\epsilon)/2 \end{aligned}$$

is second derivative of Taylor series and so on $g(x,y)$ (Blyth W. F. 1992). The values of R_f and R_g could be ignored if the approximation of (x,y) is very close to (x^*,y^*) so

$$(x^*-x)f_x(x,y)+(y^*-y)f_y(x,y) \approx -f(x,y)$$
$$(x^*-x)g_x(x,y)+(y^*-y)g_y(x,y) \approx -g(x,y)$$

Because of $f(x,y)$, $g(x,y)$, and also first derivative from each independent variables can be solved with initial value approximation x_0 and y_0, so that the value of (x^*-x) and (y^*-y) can be determine. It cause the approximation of (x^*,y^*) as known as (x_{new},y_{new}) is obtained.

In the matrix form, equation system (9) can be written as,

$$\boldsymbol{J}(\boldsymbol{v})(\boldsymbol{v}^*-\boldsymbol{v}) \approx -h(\boldsymbol{v}) \qquad (10)$$

with

$$\boldsymbol{J}(\boldsymbol{v}) = \begin{pmatrix} f_x(x,y) & f_y(x,y) \\ g_x(x,y) & g_y(x,y) \end{pmatrix},$$

$$(\boldsymbol{v}^*-\boldsymbol{v}) = \begin{pmatrix} x^*-x \\ y^*-y \end{pmatrix},$$

$$h(\boldsymbol{v}) = \begin{pmatrix} f(x,y) \\ g(x,y) \end{pmatrix}.$$

Furthermore, equation (10) can be written as follow,

$$\boldsymbol{v}^* \approx \boldsymbol{v} - [\boldsymbol{J}(\boldsymbol{v})]^{-1}h(\boldsymbol{v}).$$

So that Newton method algorithm is shown as below,

1. define the correction vector $\boldsymbol{u}$ with solving,
$$\boldsymbol{J}(\boldsymbol{v}^{[m]})\boldsymbol{u}^{[m]} = -h(\boldsymbol{v}^{[m]})$$
2. determine the optimal approximation solution with iteration below,
$$\boldsymbol{v}^{[m+1]} = \boldsymbol{v}^{[m]} + \boldsymbol{u}^{[m]}$$
for $m = 1, 2, 3, ...$

Pustaka

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