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CLOSED-LOOP SUPPLY CHAIN DENGAN MEMPERTIMBANGKAN WAKTU TUNGGU PENGIRIMAN BARANG PADA MEDIA PENJUALAN LANGSUNG DAN TAK LANGSUNG

Closed-Loop Supply Chain with Delivery Lead Time on Direct and Indirect Channels

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Abstrak

Tanggung jawab untuk menjaga lingkungan berada di tangan semua pihak, termasuk pemanufaktur. Oleh sebab itu, pemanufaktur melakukan proses daur ulang produk bekas. Secara matematis, hal tersebut dapat dijelaskan dengan model *Closed-Loop Supply Chain* (*CLSC*). *CLSC* adalah sistem yang melakukan daur ulang atau *remanufacturing*. Dalam penelitian ini, *CLSC* melibatkan produsen dan dua pengecer. Pemanufaktur menjual produk secara langsung ke konsumen dan secara tidak langsung melalui pengecer. Tujuan dari penelitian ini adalah untuk mengonstruksikan fungsi keuntungan optimal dari masing-masing pelaku. Model yang dikonstruksikan merupakan fungsi harga tanpa kendala dan menggunakan sistem sentralisasi. Hasil menunjukkan bahwa waktu tunggu pengiriman barang berpengaruh pada keuntungan masing-masing pelaku. Semakin lama waktu tunggu pengiriman barang menyebabkan keuntungan semakin menurun.

Kata Kunci : *CLSC, remanufaktur, langsung, tak langsung, waktu tunggu pengiriman.*

Abstract

The responsbility of protecting the environment rest with all parties, including manufacturers. Therefore, manufacturers reprocess their used products. Mathematically, it can be explained by closed-loop supply chain (CLSC) model. CLSC is a system that is carried out recycling or remanufacturing. In this study, closed-loop supply chain involves manufacturer and two retailers. Manufacturers sell their product directly to consumers and indirectly through retailers. The purpose of this study is to construct an optimal profit function of each actor. With centralized system, the model is a function of price without constraints by notice delivery lead time. The result shows that delivery lead have an impact to profit each actor. The longer delivery lead time decreases the profit.

Keywords: *CLSC, remanufacture, direct, indirect, delivery lead time.*

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1. INTRODUCTION

The responsibility of protecting the environment rests with all parties. People are increasingly aware that environment must be safeguarded for the better future. Therefore, humans do their activities not only in terms of economic benefits but also social and environmental impacts. Large companies in the world also take part in protecting the environment by recycling used products and residual production waste. Several top suppliers, such as Xerox, ReCellular, IBM, and Dell participated in the collection of used products from collectors or from users [13].

Manufacturers who carry out the recycling process means implementing a Closed-Loop Supply Chain (CLSC) system. Closed-loop is a system that is carried out by producers by recycling their used products. The system has a good impact on the environment and an effort to save production materials. This type of supply chain provides the benefit of saving production costs and fulfill consumer demand because of the availability of goods [9].

The stock of goods owned by manufacturers can be obtained by collecting used products from consumers. There are two types of CLSC, first is through third parties or collectors and the second one is direct from consumers [1]. Manufacturer's profit is maximum when closed-loop direct from consumers or without through a third party [1]. The centralized system applied to CLSC will produce maximum profits when the used product are obtained by the manufacturer directly from consumers [8]. For example, Xerox Corporation provides prepaid mailboxes so that customers can easily return their used copy or print cartridges to Xerox. [10].

On the other hand, the rapid development of the internet has caused the supply chain system is no longer single traditional channel, but many manufacturers set up direct channels [12]. Manufacturers sell their products directly to consumers through online media and sell their products to retailers for resale. Consumers can buy products directly from manufacturers and indirectly through retailers. The rapid development of the internet also has an effect on the system of buying and selling, both manufacturer and retailers can sell products online. The online channel cannot be separated from delivery lead time. Price and delivery lead time are two things that consumers consider in determining their choices that affect the amount of demand [5]. Service quality determines consumer preferences where the quality of service is represented by the delivery lead time [2].

The rapid development of the internet causes industry players to change their product marketing strategy, from only through traditional channel then set up through online channel. The strategy carried out by industry players is not only for economical profit, but also must be beneficial to environmental. Therefore, industry players begin to think about the product recycling process. Many researchers are developing ways to get used products for recycling. There are three models of returning used products from consumers [10]. The choices include producers can take directly from consumers, producers take used products from retailers, or involve third parties (collectors) in collecting used products.

Zhang explained CLSC with the remanufacturing process [13]. In that study, the actors of the system consisted of one manufacturer and retailer. Both the decentralized and centralized systems, retailer services affect the amount of demand through retailers. Service quality determines consumer preferences where the quality of service is represented by the delivery lead time [3].

Focus on Arshad’s research [1] remanufacturing process is carried out directly by the manufacturer and from Hua’s research [4] that manufacturers sell their products directly and notice by delivery lead time. Both of these studies can be a reference for determining the price strategy of the CLSC system by direct selling and notice by delivery lead time. In this study, CLSC involved manufacturer and two retailers. The remanufacturing process is carried out manufacturer by getting used products from consumers without going through a third party. Manufacturers sell their products in two ways, namely directly to consumers and indirectly through retailers. With a centralized system, the profit function constructed is a function of selling price of each actor. The profit of centralized system is a function of price and without constraints. From the function, optimal profit can be determined by delivery lead time.

The contribution of this study is mainly reflected in the following: Under the centralized system, the offline retailers have extended the traditional dual-channel supply chain to the online closed-loop supply chain of remanufacturing based on the manufacturer’s direct recycling model. The impact of delivery lead time is introduced in the pricing strategies and we analyze the impact of delivery lead time to profit each actor.

2. RESEARCH METHOD

2.1 Notations and Assumptions

Manufacturers have the freedom to sell their products directly to consumers, because the development of the internet makes it easy for manufacturers to reach consumers directly. In the era of increasingly rapid technological development, making all things online, including buying and selling transactions. In this study, all manufacturers and two retailers sell products online to consumers. The model scheme is shown in Figure 1.

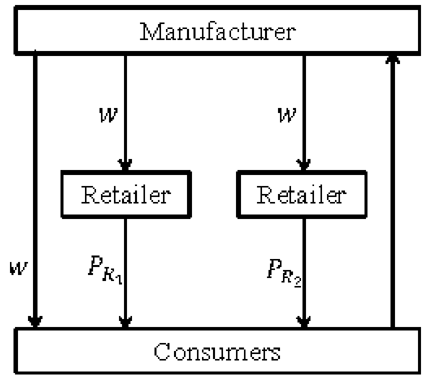

Figure 1. The Scheme of CLSC with one manufactur and two retailers

The aim of this study is to construct the model of CLSC notice by delivery lead time, find the optimal solution of the system, and investigate the effect of delivery lead time on the profit function system. In this study, we will analyze the behavior of this system when the decision is centralized.
The specific notations are described on Table 1. All parameters are positive.
The following are the assumptions used to construct the model.

a. Manufacturer only producing one product.
b. The production cost of the new product is higher than remanufacturer product, so $c_m > c_r$. Manufacturer buy used product directly form consumer with price A and equal to λ from the total of all new product that will remanufactured. The used product from consumers become stock, so that storage cost arise. The total cost of manufacturer is
$$\bar{c} = c_m D + (A + c_r + c_s)\lambda D \tag{1}$$
with D is consumer demand which is the sum of direct and indirect
c. Delivery lead time by manufacturer to consumers is longer than delivery lead time by retailers, so $l_m > l_{R_1}, l_{R_2}$.
d. Elasticity of demand through the Retailer 1 is equal to sensitivity of delivery lead time by Retailer 2.
e. Cross prices sensitivity are ignored.
f. Selling price from manufacturer to consumers is equal to selling price from manufacturer to retailers.
g. Assuming that the proportion of direct demand and indirect demand is $0 \leq \theta \leq 1$.
h. When used product are returned and the manufacturing process is carried out, the quality of the remanufactured products is equal to manufactured products [11].

Table 1. Notations

Parameters	
D_d	the consumer demand from the direct sale channel
D_i	the consumer demand from the indirect sale channel
D_{R_1}	the consumer demand from the Retailer 1
D_{R_2}	the consumer demand from the Retailer 2
l_m	delivery lead time by manufacturer
l_{R_1}	delivery lead time by the Retailer 1
l_{R_2}	delivery lead time by the Retailer 2
a	basic consumer demand
θ	the proportion of direct and indirect demand
γ	proportion of demand through the Retailer 1 and the Retailer 2
λ	the proportion of used product sold by consumers to manufacturers or the proportion of remanufactured products
c_m	manufacturing costs
c_r	remanufacturing costs
c_s	storage costs
A	purchase price of used products from consumers
α_m	sensitivity of delivery lead time by Manufacturer
α_{R_1}	sensitivity of delivery lead time by the Retailer 1
α_{R_2}	sensitivity of delivery lead time by the Retailer 2
β	elasticity of demand through manufacturer
β_1	elasticity of demand through the Retailer 1
β_2	elasticity of demand through the Retailer 2
Decision Variable	
P_{R_1}	selling price of the Retailer 1
P_{R_2}	selling price of the Retailer 2
w	selling price of manufacturer

2.2. Model Construction

Demand Function

Consumers are divided into two, consumers who buy products directly to manufacturers and consumers who buy products through retailers. Demand through manufacturer is called direct demand denoted D_d and the demand that through retailers is called indirect demand denoted D_r.

The proportion of direct channel demand to manufacturer is θ with basic demand a, so the number of initial direct channel demand units is θa. The initial demand unit decreases as the increase in selling price of manufacturer changes according to the elasticity parameter of manufacturer demand. Then, the longer the delivery time, the direct demand will decrease along with the sensitivity of the delivery lead time multiplied by the length of time of delivery. When l_m are increase, indirect channel demand through the Retailer 1 and the Retailer 2 are increases. These changes are illustrated by the sensitivity of the delivery time. Thus, the direct channel demand function is

$$D_d = \theta a - w\beta - l_m\alpha_m + l_{R_1}\alpha_{R_1} + l_{R_2}\alpha_{R_2}. \quad (2)$$

Demand through indirect channel by consumers to Retailers is the sum of demand for the Retailer 1 and the Retailer 2. Demand through the Retailer 1 is the multiplication of the of the proportion of the Retailer 1 demand $(1-\theta)$ basic demand a, and proportion indirect channel demand through the Retailer 1 γ, so we get $\gamma(1-\theta)$. The initial demand through the Retailer 1 are decreases as long as the length of delivery lead time that changes according to parameter of sensitivity of delivery lead time, The demand decreases as long as selling price by the Retailer 1 that changes according to parameter of elasticity of demand through Retailer 1. The longer delivery lead time, direct channel demand and demand through Retailer 2 will increases as long as parameter of sensitivity of delivery lead time. Thus, demand function through the Retailer 1 is

$$D_{R_1} = \gamma(1-\theta)a - l_{R_1}\alpha_{R_1} - P_{R_1}\beta_1 + l_m\alpha_m + l_{R_2}\alpha_{R_2}. \quad (3)$$

Initial demand through the Retailer 2 is $(1-\gamma)(1-\theta)a$. The demand are decreases as long as the length delivery lead time that changes according to parameter of sensitivity of delivery lead time. The demand also decreases as long selling price the Retailer 2 that changes according to parameter of elasticity the Retailer

2's demand. The longer delivery lead time, direct channel demand and demand through the Retailer 1 will increases as long as parameter of sensitivity of delivery lead time. So, demand function through the Retailer 2 is

$$D_{R_2} = (1-\gamma)(1-\theta)a - l_{R_2}\alpha_2 - P_{R_2}\beta_2 + l_m\alpha_m + l_{R_1}\alpha_{R_1}. \quad (4)$$

Indirect channel demand function are the sum of demand function through the Retailer 1 (3) and demand function through the Retailer 2 (4), so that

$$D_r = D_{R_1} + D_{R_2} = (1-\theta)a + 2l_m\alpha_m - P_{R_1}\beta_1 - P_{R_2}\beta_2. \quad (5)$$

Manufacture Profit Function

The manufacturing profit function is total revenue minus total manufacturing costs. Costs incurred by manufacturer include manufacturing cost, remanufacture, purchase price of used products from consumers, and storage product cost, with the cost of unit in order c_r, A, dan c_s. Remanufacturing process is done to process used products into new products. The proportion of used products remanufactured is equal to λ. So the total manufacturing cost is

$$TC_m = (c_m + (A + c_r + c_s)\lambda)D \quad (6)$$

with D is the sum of (2) and (5).
Manufacturer's revenue from direct channel indirect channel is $wD_d + wD_i$. Total manufacturer's revenue is

$$TR_m = wD_d + wD_i. \quad (7)$$

Manufacturer profit are total revenue of manufacturer (7) minus total costs by manufacturer (6), so

$$\Pi_m = TR_m - TC_m. \quad (8)$$

Retailer Profit Function

Cost incurred by Retailer 1 is manufacture's selling price w multiplied by indirect channel demand through the Retailer 1, so that

$$TC_{R_1} = wD_{R_1} = w\gamma a - w\gamma\theta a + wl_m\alpha_m + wl_{R_2}\alpha_{R_2} - wl_{R_1}\alpha_{R_1} - w\beta_1 P_{R_1}. \quad (9)$$

The Retailer 1 sell their product with price P_{R_1} as much as indirect channel demand through the Retailer 1, so we got revenue function

$$TR_{R_1} = P_{R_1}D_{R_1} = P_{R_1}\gamma a - P_{R_1}l_m\alpha_m + P_{R_2}l_{R_2}\alpha_{R_2} - P_{R_1}l_{R_1}\alpha_{R_1} - {P_{R_1}}^2\beta_1. \quad (10)$$

So, the profit function of Retailer 2 is

$$\Pi_{R_1} = TR_{R_1} - TC_{R_1}. \quad (11)$$

Cost incurred by the Retailer 2 is manufacturer's selling price w multiplied by indirect channel demand through the Retailer 2, so that

$$TC_{R_2} = wD_{R_2} = wa - w\theta a - w\gamma a - w\gamma\theta a + wl_m\alpha_m + wl_{R_1}\alpha_{R_1} - wl_{R_2}\alpha_{R_2} - w\beta_2 P_{R_1}. \quad (12)$$

The Retailer 2 sell their products with price P_{R_2} as much as indirect channel demand through Retailer 2, so the revenue function is

$$\begin{aligned} TR_{R_2} &= P_{R_2}D_{R_2} \\ &= P_{R_2}a - P_{R_2}\theta a - P_{R_2}\gamma a - P_{R_2}\gamma\theta a + P_{R_2}l_m\alpha_m + P_{R_2}l_{R_1}\alpha_{R_1} - P_{R_2}l_{R_2}\alpha_{R_2} - {P_{R_1}}^2\beta_1. \end{aligned} \quad (13)$$

So, the profit function of Retailer 2 is

$$\Pi_{R_2} = TR_{R_2} - TC_{R_2}. \quad (14)$$

Profit Function

Profit function of the system is sum of manufacturer's profit (8), the Retailer 1's profit (11), and the Retailer 2's profit (14), so that

$$\begin{aligned} \Pi(P_{R_1}, P_{R_2}, w) = {} & (P_{R_2} - w)\left(l_m\alpha_m + l_{R_1}\alpha_{R_1} - l_{R_2}\alpha_{R_2} - P_{R_2}\beta_2 + a(-1+\gamma)(-1+\theta)\right) \\ & (P_{R_1} - w)(l_m\alpha_m - l_{R_1}\alpha_{R_1} + l_{R_2}\alpha_{R_2} - P_{R_1}\beta_1 + a\gamma - a\gamma\theta) + (a + l_m\alpha_m + \\ & l_{R_1}\alpha_{R_1} - w\beta - P_{R_1}\beta_1 - P_{R_2}\beta_2)(-c_m + w - (c_r + c_s + A)\lambda). \end{aligned} \quad (15)$$

2.3. Optimal Solution

According to Equation (15), will determine the second partial derivative of $\Pi(P_{R_1}, P_{R_2}, w)$ to P_{R_1}, P_{R_2}, and w so we get Hessian matrix

$$H = \begin{pmatrix} -2\beta_1 & 0 & 0 \\ 0 & -2\beta_2 & 0 \\ 0 & 0 & -2\beta \end{pmatrix}$$

with matrix determinant H is $-8\beta_1\beta_2\beta$. From the Hessian matrix we get leading principal minor,

$$\Delta_1 = -2\beta_1, \Delta_2 = \begin{vmatrix} -2\beta_1 & 0 \\ 0 & -2\beta_2 \end{vmatrix} = 4\beta_1\beta_2, \Delta_3 = \begin{vmatrix} -2\beta_1 & 0 & 0 \\ 0 & -2\beta_2 & 0 \\ 0 & 0 & -2\beta \end{vmatrix} = -8\beta_1\beta_2\beta.$$

According to Sylvester's Criterion ([3], [6]) a function is said to be negative definit if $\frac{1}{\Delta_1}, \frac{\Delta_1}{\Delta_2}$, dan $\frac{\Delta_2}{\Delta_3}$ has negative value. From the result in this study, $\frac{1}{\Delta_1} = \frac{1}{-2\beta_1}, \frac{\Delta_1}{\Delta_2} = \frac{-2\beta_1}{4\beta_1\beta_2}$, dan $\frac{\Delta_2}{\Delta_3} = \frac{4\beta_1\beta_2}{-8\beta_1\beta_2\beta}$. This prove that Π is stricly concave function with a single (P_{R_1}, P_{R_2}, w) so that we get the optimum value of P_{R_1}, P_{R_2}, dan w.
The solution of equation (15) is first partial derivative that made equal to zero, we get

$$\frac{\partial \Pi}{\partial P_{R_1}} = l_m\alpha_m - l_{R_1}\alpha_{R_1} + l_{R_2}\alpha_{R_2} - 2P_{R_1}\beta_1 + w\beta_1 + a\gamma - a\gamma\theta - \beta_1(-c_m + w - (c_r + c_s + A)\lambda) = 0,$$

$$\frac{\partial \Pi}{\partial P_{R_2}} = l_m\alpha_m + l_{R_1}\alpha_{R_1} - l_{R_2}\alpha_{R_2} - 2P_{R_2}\beta_2 + w\beta_2 + a(-1+\gamma)(-1+\theta) - \beta_2(-c_m + w - (c_r + c_s + A)\lambda) = 0,$$

$$\frac{\partial \Pi}{\partial w} = a - l_m\alpha_m + l_{R_1}\alpha_{R_1} + l_{R_2}\alpha_{R_2} - 2w\beta - a\lambda - a(-1+\gamma)(-1+\theta) + a\gamma\theta - \beta(-c_m + w - (c_r + c_s + A)\lambda) = 0.$$

From the result, the optimum solution of each variables using Cramer Method is

$$P_{R_1}{}^* = -\frac{1}{2\beta_1}(-l_m\alpha_m + l_{R_1}\alpha_{R_1} - l_{R_2}\alpha_{R_2} - a\gamma - a\gamma\theta - \beta_1(-c_m + (c_r + c_s + A)\lambda) \quad (16)$$

$$P_{R_2}{}^* = -\frac{1}{2\beta_2}(l_m\alpha_m + l_{R_1}\alpha_{R_1} - l_{R_2}\alpha_{R_2} - a(-1+\gamma)(-1+\theta) + \beta_2(c_r + c_s + A)\lambda) \quad (17)$$

$$w^* = -\frac{1}{2\beta}(l_m\alpha_m - l_{R_1}\alpha_{R_1} - l_{R_2}\alpha_{R_2} - a\theta - \beta(c_m + c_r + c_s + A)\lambda) \quad (18)$$

3. RESULT AND DISCUSSION

3.1. NUMERICAL SIMULATION AND ANALYSIS

In this section, numerical examples are presented to verify analytical result and to analyze the delivery lead time parameter. The value of each parametes are obtained from numerical simulation using Wolfram Mathematica.

Given that basic consumer demand in one year is 50000 units. The proportion of direct demand is 0.4. Consumer demand decreases with price increases in the media that changes according to the selling price elasticity parameters direct channel 200.

The length of delivery lead time also affecting the demand. This is because of consumer sensitivity. Both manufacturer and retailers sell their product through online channel. Consumer who buy product through direch channel take 10 days. The longer delivery lead time cause consumers change their purchases to other channel, thereby reducing purchases in direct channel purchases as much as 150 unit/day and increasing purchases in Retailer 1 as much as 100 unit/day and Retailer 2 as much as 100 unit/day.

Manufacturers do the manufactur and remanufacturing process. The manufacturer cost are manufacturing cost, remanufacturing cost, storage cost, and purchase cost used product from consumers. Those are 45$, 30$, 15$, and 5$ respectively.

Based in these illustrations, the CLSC management carried out to maximize the profit. The numerical example are given in Table 2.

Furthermore, the parameter values in Table 2 are substituted for the equation (16), (17), and (18) to get the optimal price.

Table 2. Numerical example

Parameter	Value	Unit
l_m	10	Day
l_{R_1}	4	Day
l_{R_2}	2	Day
a	50000	Unit
θ	0.4	-
γ	0.5	-
λ	0.01	-
c_m	45	$ per unit
c_r	30	$ per unit
c_s	15	$ per unit
A	5	$ per unit
α_m	150	Unit/day
α_{R_1}	100	Unit/day
α_{R_2}	100	Unit /day
β	200	Unit/$
β_1	100	Unit/$
β_2	100	Unit/$

The result of simulation are present on Table 3.

Table 3. The result of simulation

Decision variable	P_{R_1}	P_{R_2}	w
Value	104.75	106.25	70.5

The result on Table 3 are substituted to D_d and D_r, we get 5000 for D_d and 11950 for D_r. The profit of each actors are $\Pi_{R_1} = 199506\$, \Pi_{R_2} = 271181\$, \Pi_m = 422500\$$, and $\Pi = 839188\$$. When delivery lead time by manufacturer are 10 days, the total profit is $839188\$$.

Sensitivity Analysis

We did parameter analysis for l_m, l_{R_1}, l_{R_2}, and according to the assumption the value of $\alpha_{R_1} = \alpha_{R_2}$ and $\beta_{R_1} = \beta_{R_2}$.

The analysis of parameter l_{R_1} with value 1, 2, 3, 4, 5 days are shown in Table 4.

Table 4. Sensitivity analysis for l_{R_1}

l_{R_1}	P_{R_1}	P_{R_2}	w	D_r	D_d	Π_{R_1}	Π_{R_2}	Π_m	Π
1	105.75	104.75	69.75	119950	4850	216900	207375	407400	831675
2	105.25	105.25	70	119950	4900	210619	210619	412825	834063
3	104.75	105.75	70.25	119950	4950	204413	213888	418275	836575
4	104.25	106.25	70.5	119950	5000	198281	217181	423750	839213
5	103.75	106.75	70.75	119950	5050	192225	220500	429250	841975

From the Table 4, the selling price of Retailer 1 is decrease when the delivery lead time is incrased. It also makes the profit of Retailer 1 is decrases.

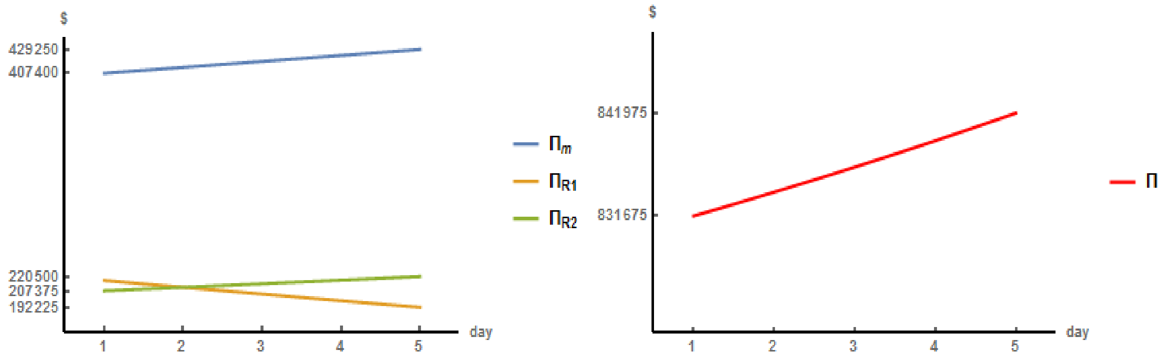

Figure 2. The relationship between l_{R_1} and optimal profit: each actors (left) and total profit (right)

Figure 2 show that the profit of Retailer 1 is decline as delivery lead time increase. It also appears that the profit of other actors dan total profit increase when the delivery lead time of Retailer 1 also increase.

The analysis of parameter l_{R_2} with value 1, 2, 3, 4, 5 days are shown in Table 5.

Table 5. Sensitivity analysis for l_{R_2}

l_{R_2}	P_{R_1}	P_{R_2}	w	D_r	D_d	Π_{R_1}	Π_{R_2}	Π_m	Π
1	103.75	106.75	70.25	119950	4950	195138	223563	418275	836975
2	104.25	106.25	70.5	11950	5000	198281	217181	423750	839213
3	104.75	105.75	70.75	11950	5050	201450	210875	429250	841575
4	105.25	105.25	71	11950	5100	204644	204644	434775	844063
5	105.75	104.75	71.25	11950	5150	207863	198488	440325	846675

From the Table 5, the selling price of Retailer 2 is decrease when the delivery lead time is incrased. It also makes the profit of Retailer 2 decreases.

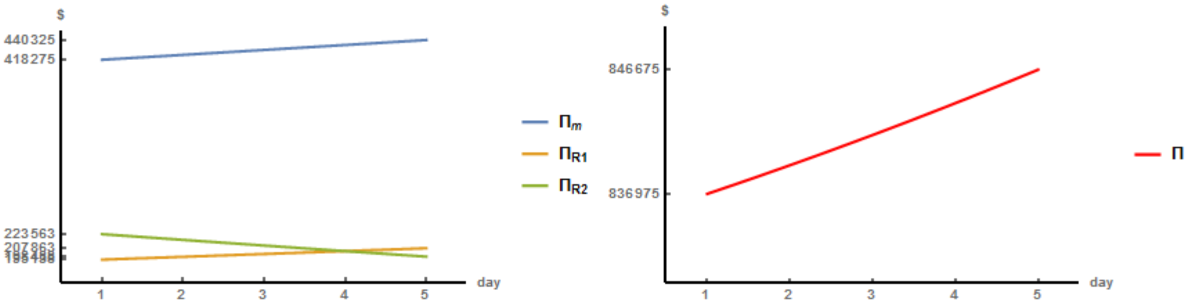

Figure 3. The relationship between l_{R_2} and optimal profit: each actors (left) and total profit (right)

Based on Figure 3 show that the profit of Retailer 2 is decline as delivery lead time increase. It also appears that the profit of other actors dan total profit increase when the delivery lead time of Retailer 2 also increase.

The analysis of parameter l_m with value 10, 11, 12, 13, 14 days are shown in Table 6.

Table 6. Sensitivity analysis for l_m

l_m	P_{R_1}	P_{R_2}	w	D_r	D_d	Π_{R_1}	Π_{R_2}	Π_m	Π
10	104.25	106.25	70.5	11950	5000	198281	217181	423750	839213
11	105	107	70.125	12100	4925	207506	226781	419241	853528
12	105.75	107.75	69.75	12250	4850	216900	236550	414675	868125
13	106.5	108.5	69.375	12400	4775	226463	246488	410053	883003
14	107.25	109.25	68.625	12550	4700	236194	256594	405375	898163

From the Table 6, the selling price of manufactur is decrease when the delivery lead time is incrased. It also makes the profit of manufactur decreases.

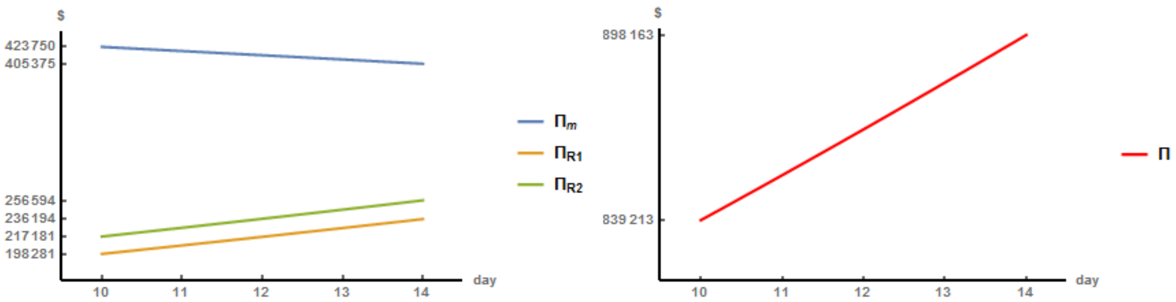

Figure 4. The relationship between l_m and optimal profit: each actors (left) and total profit (right)

Figure 4 show that the profit of manufactur is decline as delivery lead time increase. It also appears that the profit of other actors dan total profit increase when the delivery lead time of manufactur also increase.

From the Table 4, 5, and 6 the selling price of each actors is decrease when the delivery lead time is incrased. It also makes the profit decrases, although the system profits continue to increase. However, the profit of other channels are increase, this caused by a sensitivity of delivery lead time which causes the transfer of demand to other channels.

4. CONCLUSIONS

Closed-loop supply chain is one of the solution made by manufacturers as an effort to take responsibility for protecting the environment. Manufacturers sell their products directly to consumers and indirectly through retailers is a strategy to increase profits. The closed-loop supply chain model which has been constructed with delivery lead time affect the profits of each actor. The longer delivery lead time of product carried out by each actor, the less profit obtained. This is due to the sensitivity of delivery lead time which result is changes in demand and switches to other actors. As a result other actors have increased profits.

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