Integrated Green Supply Chain Model to Reduce Carbon Emission with Permissible Delay-in-Payment Consideration

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ABSTRACT

In practice, the policy of delaying payment periods is prevalent between players in a supply chain system. Generally, payments made at the end of the permitted period. Supply chain management is one of the keys to corporate sustainability that the activities have an impact on the environment. This paper aims to develop an integrated green supply chain model with a permissible delay in payment consideration. In this research, the author develops a mathematical model to find the effect of delay in payment on emissions costs without ignoring the economic performance of a supply chain. The author develops four different scenarios model. Furthermore, numerical experiments and sensitivity analysis tests were conducted. Result of the study shows that delay in payment is integrated players into the supply chain system. It has a positive impact on reducing supply chain emissions costs.

1. Introduction

The environmental effect of carbon emission often ignored in manufacturer and transportation activity. King and Lenox [1] Claimed that unplanned and irresponsible actions by industries are potential threats to sustainability. The Companies now are trying to minimize environmental impacts by integrating environmental concerns into their supply chain operations [2]. Several previous studies discussed the approaches to reducing carbon emissions. Zissis, et al. [3] and Peng, et al. [4] used a quantity discount as a medium in coordinating the supply chain to reduce carbon emission. Besides, revenue [5-7] and investment sharing [8] in the supply chain can reduce carbon emission. Supply Chain Management (SCM) become one of the centers of attention in a company with the aim of corporate sustainability. The supply chain is a very complex topic when it involves many functional areas inside and outside the company for improving company performance [9]. Besides, the supply chain is running to minimize costs. Aljazzar, et al. [10] explained that the order cost, storage cost, and setup cost are essential components in the supply chain costs. Waters [11] stated that these costs in the supply chain continue to increase. Inventory in the supply chain must be well maintained to ensure the

sustainability of the company. The efficient supply chain can occur with reasonable cooperation and coordination [12-17].

Some previous studies proved that coordinating the supply chain could minimize the cost [18-20]. With coordination in SCM, buyers and sellers can get the benefit. A good coordination scheme can coordinate sellers and buyers more flexible [18]. According to Sainathan and Groenevelt [19], there are several types of contracts that can coordinate supply chains, including quantity discounts, buyback, and revenue sharing. In the other studies, delay in payment contracts also successfully organized several players in the supply chain system [21]. Supply chain management always pays attention to improve company performance and maintain organizational sustainability [22]. The increase of global warming and changing biodiversity has brought the world's sustainability towards immediate danger. Researchers, academicians, practitioners, and scientists together suggest ways to maintain environmental sustainability. King and Lenox [23] Claim that unplanned and irresponsible actions by industry are a threat to sustainability. Companies now attempt to minimize the environmental impact by integrating environmental issues into their supply chain operations. According to Sarkis and Dou [24], the integration of supply chain elements with corporate environmental management that referred to as "Green Supply Chain." According to Jaber and Osman [25] and Ibrahim [26], delay in payment is a policy to coordinate players in the supply chain by allowing the customer to delay payments for a specified period without interest. Delay in payment also used as a strategy to increase sales and reduce inventory in the warehouse. Several previous studies have proven that the policy has a positive impact on companies [9, 14, 15, 21, 25, 27, 28]. When the delay in payment applied in a supply chain system, total supply chain costs can decrease [9].

Based on previous research, delay in payment policy have been studied. However, far too little attention has been paid to integrate the green supply chain model with permissible delay in payment with considering carbon emission. This paper aims to develop an integrated green supply chain model with permissible delay in payment considering carbon emission. The contribution of this paper is the integration of the two-echelon supply chain model with delays in payments to minimize emissions costs. In this paper, the author developed four different case scenarios under permissible delay in payment. The research result shows that delay in payment mechanisms successfully reduced carbon emission. It is proven by emission costs that are more compared minimally when no delay in payment mechanism. This paper also provides some insights for practitioners managerial. In this research, mathematical models developed into four case scenarios, according to a recent study by Ibrahim [21]. Some variables added with consideration of carbon emission. The numerical experiment conducted with several different case scenarios. Sensitivity analysis is carrying out on several variables that are considered significant to the total change of supply chain system cost. The organizing of this paper as follows: Section 2 is for presenting the notation, assumption, conceptual model, and mathematical model. Section 3 is for results and discussion, including numerical examples. Moreover, section 4 shows the conclusion.

2. Methods

In this section, the mathematical model was developed based on the conceptual model and several assumptions. The model is basic on Hill [29] and Ibrahim and Suparno [16]. In this paper, the model modified into four delays in payment policy and reducing carbon emission. This section also contains an explanation of the list of notations.

2.1 Notations

The notation used in the model is presented below:

i : Supply chain player *(s: supplier, m: manufacturer, d: distributor)*

j : Type of inventory *(w: raw material, f: finished goods)*

$A_{i,j}$: Setup/order cost incurred by player-i to the item-j

$C_{i,j}$: Production/purchases cost per item issued by player-i for the item-j

$h_{i,j}$: Financial holding cost per item issued by player-i for the item-j

$S_{i,j}$: Physical (storage) holding cost per item issued by player-i for the item-j

Q : Distributor order quantity

n_1 : The number of shipments of the supplier to manufacturing per manufacturing material cycle.

n_2 : The number of shipments by manufacturing to the distributor per distributor cycle

α : The number of raw materials needed to produce one finished product

t_i : The time of the delay in payments offered by player-i

τ_i : The payment time made by player-i

k_i : Return on investment (ROI) for player-i

P : The annual production rate of manufacture

D : Distributor annual demand $D < P$

T : Common cycle length $= \frac{n_2 Q}{D}$

T_s : Supplier cycle length $= \frac{n_2 Q}{P}$

T_w : Manufacture raw material cycle length $= \frac{n_2 Q}{n_1 P}$

T_m : Manufacture finish product cycle length $= \frac{n_2 Q}{D}$

T_d : Distributor cycle length $= \frac{Q}{D}$

A_0 : Transport Cost at the start of an order point

T_e : Transport emission tax

T_{ci} : Emission tax rate

T_{cap} : Truck capability

n_t : Number of a truck per shipment (Q/T_{cap})

E_m : Manufacturing Emission $E_m = aP^2 - bP + c$, *(a,b,c are parameters)*

SC : Total annual cost of supplier

MC : Total annual cost of manufacturer

DC : Total annual cost of a distributor

TSC : Total annual cost of supply chain system

2.2 Assumptions

This study used several assumptions to limit the scope of the model, given below: 1). One type of product, one supplier, one manufacturer, and one distributor; 2). Demand is deterministic based on distributor information; 3). The supplier's production level is higher than the manufacturer raw material demand; 4). The manufacturer's production level is higher than distributor demand; 5). Holding cost components are divided into financial holding cost and physical holding cost; 6). Supplier and manufacturer offer delay in payment; 7). The period of delay in payment and order quantity becomes the decision variable; 8). Both manufacture and distributor invest their vendor owes in a risk-free investment during the allowed period; 9). Both manufacture and distributor pay debt with one payment; 10). An unlimited number of trucks; and 11). Routes are not considered.

2.3 Conceptual Model

In this study, formulation of mathematical models considering the length of the cycle, where overall cycle length is $T = \frac{n_2 Q}{D}$. The mathematical model in this study is the extension of Ibrahim and Suparno [16] model. They do not consider carbon emission cost. The players in the supply chain system are suppliers, manufacturers, and distributor. Coordination among the players does with the delay in consideration of the payment. In this study, the previous mathematical model was modified to determine the effect of delay in payment on reducing gas emissions. Fig. 1 shows the integration model between suppliers with manufacturer and producers with the distributor.
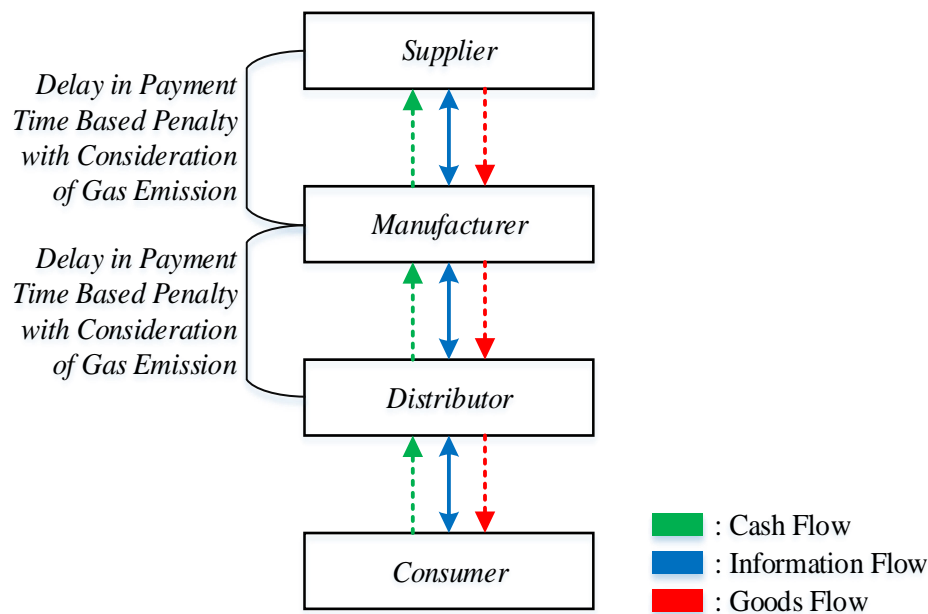

Fig. 1. Conceptual Model

Mathematical models were developed into several case scenarios. Every case is a combination of subcase on echelon 1 (supplier-manufacturer) and echelon 2 (manufacturer-distributor). Table 1 shows the scheme of four case scenarios used in this study. Respectively there are two sub-cases in the first echelon and second echelon. Subcase one at Echelon 1, described the supplier provide a delay in the payment period for time to complete the payment without interest costs. Manufacturer made payments right at the end of the delay in the payment period provided by the supplier. In this sub-case, the manufacturer not offered compensation for suppliers because making payments does not exceed the limit of the delay in the cash.

While in the second sub-echelon 1, it showed delays in the payment of the manufacturer. However, the manufacturer made the payment and not causes delay the period or before receiving the next shipment. In this sub-case, the manufacturer must compensate the supplier for making payments during the delay period provided by the supplier. There were two subcases on the echelon. It same as two subcases on the echelon 1. The difference was that it applied to the relationship between manufacturer and distributor. From this conceptual model, development is carried out in the previous model and explained in the next section.

Tabel 1 Case scenario

Echelon 1	Echelon 2	Case Name
$0 \le t_s = \tau_m \le \dfrac{n_2 Q}{Pn_1}$	$0 \le t_m = \tau_d \le \dfrac{Q}{D}$	1.1
	$0 \le t_m < \tau_d \le \dfrac{Q}{D}$	1.2
$0 \le t_s < \tau_m \le \dfrac{n_2 Q}{Pn_1}$	$0 \le t_m = \tau_d \le \dfrac{Q}{D}$	2.1
	$0 \le t_m < \tau_d \le \dfrac{Q}{D}$	2.2

2.4 Mathematical Model

In this study, a mathematical model was developed to coordinate players in an integrated supply chain system by reducing carbon emissions. Mathematical models are formulated by considering general cycle length $T = \frac{n_2 Q}{D}$.

Model for Case 1.1: $0 \le t_s = \tau_m \le \frac{n_2 Q}{Pn_1}$; $0 \le t_m = \tau_d \le \frac{Q}{D}$

For case 1.1, supplier costs, Manufacturer Costs (Raw Materials), Manufacturer Costs (Finish Goods), and Distributor Cost are presented in equation (1), (2), (3), and (4).

$$\psi_s^{1.1} = A_{s,f} + C_{s,f}\alpha n_2 Q + \frac{n_1(n_1 - 1)}{2}\left(h_{s,f} + S_{s,f}\right)\left(\frac{\alpha n_2{}^2 Q^2}{Pn_1{}^2}\right) + h_{s,f}\tau_m \alpha n_2 Q$$
$$+ \left(C_{m,w} - C_{s,f}\right)\alpha n_2 Q e^{k_s t_s} + E_m D T_{ci}$$

(1)

$$\psi_{m,w}^{1.1} = n_1 A_{m,w} + C_{m,w}\alpha n_2 Q + h_{m,w}\frac{\alpha^2 n_2{}^2 Q^2}{2\alpha Pn_1} - h_{m,w}\alpha n_2 Q t_s + h_{m,w}\frac{n_1 \alpha P t_s{}^2}{2} + S_{m,w}\frac{\alpha n_2{}^2 Q^2}{2Pn_1}$$
$$- C_{m,w}\alpha n_2 Q e^{k_m \tau_m}$$

(2)

$$\psi_{m,f}^{1.1} = A_{m,f} + C_{m,f} n_2 Q + \left(h_{m,f} + S_{m,f}\right)\left(\frac{n_2 Q^2(2D + (P - D)n_2 - P)}{2DP}\right) + h_{m,f}\tau_d n_2 Q$$
$$+ \left(C_{d,f} - C_{m,f}\right)n_2 Q e^{k_m t_m} + E_m D T_{ci}$$

(3)

$$\psi_{d,f}^{1.1} = n_2 A_{d,f} + C_{d,f} n_2 Q + n_2 h_{d,f}\frac{(Q - Dt_m)^2}{2D} + \frac{S_{d,f} n_2 Q^2}{2D} - n_2 Q C_{d,f}\left(1 - e^{k_d t_m}\right) + n_t \frac{DA_0}{Q}$$
$$+ n_t \frac{DT_e}{Q}$$

(4)

The total cost of every cycle the system is obtained by totalizing equation (1), (2), (3), and (4). For The total annual cost is produced by The total cost of every period divide the length of the general cycle. Formula The total annual cost Case 1.1 is shown in equation (5).

$$\psi_{SC}^{1.1} = \frac{A_{s,f}D}{n_2Q} + C_{s,f}\alpha D + \frac{n_1(n_1-1)}{2}(h_{s,f}+S_{s,f})\frac{\alpha n_2 QD}{Pn_1^2} + h_{s,f}\tau_m\alpha D + (C_{m,w}-C_{s,f})e^{k_s t_s}\alpha D$$
$$+ \frac{E_m DT_{ci}D}{n_2Q} + \frac{n_1 A_{m,w}D}{n_2Q} + \frac{C_{m,w}\alpha n_2 QD}{n_2Q} + \frac{h_{m,w}\alpha^2 n_2^2 Q^2 D}{2\alpha Pn_1 n_2 Q} - \frac{h_{m,w}\alpha n_2 Q t_s D}{n_2Q}$$
$$+ \frac{h_{m,w}n_1\alpha Pt_s^2 D}{2n_2Q} + \frac{S_{m,w}\alpha n_2^2 Q^2 D}{2Pn_1 n_2 Q} - \frac{C_{m,w}\alpha n_2 Q e^{k_m\tau_m}D}{n_2Q} + \frac{A_{m,f}D}{n_2Q} + C_{m,f}D$$
$$+ (h_{m,f}+S_{m,f})\left(\frac{Q(2D+(P-D)n_2-P)}{2P}\right) + h_{m,f}\tau_d D + (C_{d,f}-C_{m,f})e^{k_m t_m}D$$
$$+ \frac{E_m DT_{ci}D}{n_2Q} + \frac{A_{d,f}D}{Q} + C_{d,f}D + \frac{h_{d,f}(Q-Dt_m)^2}{2Q} + \frac{S_{d,f}Q}{2} - C_{d,f}D(1-e^{k_d t_m})$$
$$+ n_t A_0 n_2 + n_t T_e n_2$$

$$(5)$$

Model for Case 1.2: $0 \le t_s = \tau_m \le \frac{n_2 Q}{Pn_1} \, dan \, 0 \le t_m < \tau_d \le \frac{Q}{D}$

For the model case 1.2, Supplier Costs 1.1 is $\psi_s^{1.2} = \psi_s^{1.1}$, Manufacturer Costs (Raw Materials) 1.1 $\psi_{m,w}^{1.2} = \psi_{m,w}^{1.1}$. Formula The total annual cost case 1.2 is shown in equation (6).

$$\psi_{SC}^{1.2} = \frac{A_{s,f}D}{n_2Q} + C_{s,f}\alpha D + \frac{n_1(n_1-1)}{2}(h_{s,f}+S_{s,f})\frac{\alpha n_2 QD}{Pn_1^2} + h_{s,f}\tau_m\alpha D + (C_{m,w}-C_{s,f})e^{k_s t_s}\alpha D$$
$$+ \frac{E_m DT_{ci}D}{n_2Q} + \frac{n_1 A_{m,w}D}{n_2Q} + \frac{C_{m,w}\alpha n_2 QD}{n_2Q} + \frac{h_{m,w}\alpha^2 n_2^2 Q^2 D}{2\alpha Pn_1 n_2 Q} - \frac{h_{m,w}\alpha n_2 Q t_s D}{n_2Q}$$
$$+ \frac{h_{m,w}n_1\alpha Pt_s^2 D}{2n_2Q} + \frac{S_{m,w}\alpha n_2^2 Q^2 D}{2Pn_1 n_2 Q} - \frac{C_{m,w}\alpha n_2 Q e^{k_m\tau_m}D}{n_2Q} + \frac{A_{m,f}D}{n_2Q} + C_{m,f}D$$
$$+ (h_{m,f}+S_{m,f})\left(\frac{Q(2D+(P-D)n_2-P)}{2P}\right) + h_{m,f}\tau_d D + (C_{d,f}-C_{m,f})e^{k_m t_m}D$$
$$- C_{d,f}e^{k_m(\tau_d-t_m)}D + \frac{E_m DT_{ci}D}{n_2Q} + \frac{A_{d,f}D}{Q} + C_{d,f}D + \frac{h_{d,f}(Q-Dt_m)^2}{2Q} + \frac{S_{d,f}Q}{2}$$
$$+ C_{d,f}e^{k_m(\tau_d-t_m)}D - C_{d,f}D(1-e^{k_d t_m}) + n_t A_0 n_2 + n_t T_e n_2$$

$$(6)$$

Model for Case 2.1: $0 \le t_s < \tau_m \le \frac{n_2 Q}{Pn_1} \, dan \, 0 \le t_m = \tau_d \le \frac{Q}{D}$

For the model case 2.1, Manufacturer Costs (Finish Goods) is $\psi_{m,f}^{2.1} = \psi_{m,f}^{1.1}$, Distributor Cost $\psi_{d,f}^{2.1} = \psi_{d,f}^{1.1}$. Formula The total annual cost case 2.1 is shown in equation (7).

$$\psi_{SC}^{2.1} = \frac{A_{s,f}D}{n_2Q} + C_{s,f}\alpha D + \frac{n_1(n_1-1)}{2}(h_{s,f}+S_{s,f})\frac{\alpha n_2 QD}{Pn_1^2} + h_{s,f}\tau_m\alpha D + (C_{m,w}-C_{s,f})e^{k_s t_s}\alpha D$$
$$- C_{m,w}e^{k_s(\tau_m-t_s)}\alpha D + \frac{E_m DT_{ci}D}{n_2Q} + \frac{n_1 A_{m,w}D}{n_2Q} + \frac{C_{m,w}\alpha n_2 QD}{n_2Q} + \frac{h_{m,w}\alpha^2 n_2^2 Q^2 D}{2\alpha Pn_1 n_2 Q}$$
$$- \frac{h_{m,w}\alpha n_2 Q t_s D}{n_2Q} + \frac{h_{m,w}n_1\alpha Pt_s^2 D}{2n_2Q} + \frac{S_{m,w}\alpha n_2^2 Q^2 D}{2Pn_1 n_2 Q} + \frac{C_{m,w}\alpha n_2 Q e^{k_s(\tau_m-t_s)}D}{n_2Q}$$
$$- \frac{C_{m,w}\alpha n_2 Q e^{k_m\tau_m}D}{n_2Q} + \frac{A_{m,f}D}{n_2Q} + C_{m,f}D$$
$$+ (h_{m,f}+S_{m,f})\left(\frac{Q(2D+(P-D)n_2-P)}{2P}\right) + h_{m,f}\tau_d D + (C_{d,f}-C_{m,f})e^{k_m t_m}D$$
$$+ \frac{E_m DT_{ci}D}{n_2Q} + \frac{A_{d,f}D}{Q} + C_{d,f}D + \frac{h_{d,f}(Q-Dt_m)^2}{2Q} + \frac{S_{d,f}Q}{2} - C_{d,f}D(1-e^{k_d t_m})$$
$$+ n_t A_0 n_2 + n_t T_e n_2$$

$$(7)$$

Model for Case 2.2: $0 \le t_s < \tau_m \le \frac{n_2 Q}{P n_1}$ **dan** $0 \le t_m < \tau_d \le \frac{Q}{D}$

For the model case 2.1, Supplier Costs is $\psi_s^{2.2} = \psi_s^{2.1}$, Manufacturer Costs (Raw Materials) $\psi_{m,w}^{2.2} = \psi_{m,w}^{2.1}$, Manufacturer Costs (Finish Goods) $\psi_{m,f}^{2.2} = \psi_{m,f}^{1.2}$, Distributor Cost $\psi_{d,f}^{2.2} = \psi_{d,f}^{1.2}$. Formula The total annual cost case 2.2 is shown in equation (8).

$$
\begin{aligned}
\psi_{SC}^{2.2} = {} & \frac{A_{s,f}D}{n_2 Q} + C_{s,f}\alpha D + \frac{n_1(n_1-1)}{2}\left(h_{s,f}+S_{s,f}\right)\frac{\alpha n_2 QD}{P n_1^2} + h_{s,f}\tau_m \alpha D + \left(C_{m,w}-C_{s,f}\right)e^{k_s t_s}\alpha D \\
& - C_{m,w}e^{k_s(\tau_m - t_s)}\alpha D + \frac{E_m D T_{ci} D}{n_2 Q} + \frac{n_1 A_{m,w} D}{n_2 Q} + \frac{C_{m,w}\alpha n_2 QD}{n_2 Q} + \frac{h_{m,w}\alpha^2 n_2^2 Q^2 D}{2\alpha P n_1 n_2 Q} \\
& - \frac{h_{m,w}\alpha n_2 Q t_s D}{n_2 Q} + \frac{h_{m,w}n_1 \alpha P t_s^2 D}{2n_2 Q} + \frac{S_{m,w}\alpha n_2^2 Q^2 D}{2P n_1 n_2 Q} + \frac{C_{m,w}\alpha n_2 Q e^{k_s(\tau_m - t_s)}D}{n_2 Q} \\
& - \frac{C_{m,w}\alpha n_2 Q e^{k_m \tau_m}D}{n_2 Q} + \frac{A_{m,f}D}{n_2 Q} + C_{m,f}D \\
& + \left(h_{m,f}+S_{m,f}\right)\left(\frac{Q(2D+(P-D)n_2-P)}{2P}\right) + h_{m,f}\tau_d D + \left(C_{d,f}-C_{m,f}\right)e^{k_m t_m}D \\
& - C_{d,f}e^{k_m(\tau_d - t_m)}D + \frac{E_m D T_{ci} D}{n_2 Q} + \frac{A_{d,f}D}{Q} + C_{d,f}D + \frac{h_{d,f}(Q-Dt_m)^2}{2Q} + \frac{S_{d,f}Q}{2} \\
& - C_{d,f}D\left(1-e^{k_d t_m}\right) + n_t A_0 n_2 + n_t T_e n_2
\end{aligned}
\tag{8}
$$

2.5 Numerical experiment procedure

In this section, numerical experiments conducted to compare the four scenarios that have been developed in Section 2. Besides, numerical examples represent the behavior of the model according to the four scenarios and examine the impact of late payments. Parameter values used in this example adapted from previous studies conducted by Aljazzar, et al. [14], where: $D = 1000$, $P = 3200$, $\alpha = 1$, $A_{s,f} = 441$, $A_{m,w} = 206$, $A_{m,f} = 175$, $A_{d,f} = 384$, $C_{s,f} = 20$, $C_{m,w} = 30$, $C_{m,f} = 50$, $C_{d,f} = 70$, $h_{s,j} = 3$, $h_{m,w} = 3$, $h_{m,f} = 12$, $h_{d,f} = 13.3$, $S_{s,f} = 3$, $S_{m,w} = 7.5$, $S_{m,f} = 9$, $S_{d,f} = 7.7$, $n_1 = 1$, $n_2 = 2$, $k_s = 0.01$, $k_m = 0.08$, $k_d = 0.04$, $e = 0.10$, $T_{ci} = 20$, $n_t = 7$, $A_0 = 10$, $T_e = 20$, $E_m = 0.632$, $T_{cap} = 80$.

We used the values of the input parameter already explain before to get the optimal solution. In this paper, Solver on Excel Software used to search the optimal solution of the model. The solver was chosen because simple and have relatively short computing time. Furthermore, Maple software used to validate the calculation.

3. Results and Discussion

3.1 Numerical experiment results

This section shows the result of a numerical example. The result is done to compare the four scenarios that have been explained in Section 2. Moreover, the numerical example also was arranged with another scenario that does not use delay in payment, and it presented in the scenario (0.0). Through a series of formulations and validations the result of optimum values Q, t_s, τ_m, t_m, and τ_d under four differences of scenarios are shown in Table 1.

Furthermore, sensitivity analysis is carried out for some important parameters. Distributor Return on Investment (ROI), emission tax rate when the delay in payment allowed, and not allowed. Very interesting to pay attention to the ROI of the distributor. Based on previous studies conducted by [14,16,21,25], Distributor ROI always discussed

because of its impact on the supply chain system. Therefore, in this experiment, the author experimented by varying the distributor ROI into several different percentages. Table 2 shows the results of sensitivity analysis by varying distributor ROI.

Table 1. Numerical experiment result

Scenario Name	0.0	1.1	1.2*	2.1	2.2
Q	542	491	800	599	800
t_s	0.00	0.01	0.01	0.01	0.01
τ_m	0.00	0.01	0.01	0.02	0.02
t_m	0.00	0.40	0.64	0.49	0.64
τ_d	0.00	0.40	0.65	0.49	0.65
SC	42,083	43,358	38,203	10,995	8,240
MC	90,452	93,223	24,900	125,410	54,947
DC	76,813	70,642	140,343	70,490	140,344
TSC	209,348	207,224	203,446	206,894	203,531
EC	23,738.39	26,190.41	16,175.03	21,523.9	16,175.01

Table 2. Effect of varying distributor ROI

k_d	Q	t_m	τ_d	EC
0.01	683	0.33	0.34	18,908.47
0.02	782	0.46	0.47	16,547.43
0.04	800	0.64	0.65	16,175.03
0.06	867	0.85	0.86	14,962.43
0.08	880	0.87	0.88	14,738.64
0.1	960	0.95	0.96	13,541.68

Emission tax rate considered as one of the critical parameters, variations are made on these parameters. Several previous studies that discussed the low carbon supply chain always examined emission tax rates or emission rates. According to Bai, et al. [30], policies such as cap-and-trade are effective methods for reducing carbon emissions. Surely, such policies consider tax rates or emission rates. Nevertheless, the role of the government as the policy provider is vital here; one of them is the cap-and-trade policy [5,30, 31]. Table 3 shows the results of sensitivity analysis by varying emission tax in two different conditions.

Table 3. The Effect of varying emission tax rate when the delay in payment allowed and not allowed

Delay in Payment Allowed						Delay in Payment not Allowed					
T_{Ci}	Q	t_s	τ_m	t_m	τ_d	EC	T_{Ci}	Q	t_s	τ_m	t_m	τ_d	EC
5	448	0.01	0.01	0.37	0.38	7,464.31	5	404	0.00	0.00	0.00	0.01	8,275.77
10	560	0.01	0.01	0.46	0.47	11,660.72	10	542	0.00	0.00	0.00	0.01	12,063.16
15	717	0.01	0.01	0.58	0.59	13,588.19	15	651	0.00	0.00	0.00	0.01	14,988.19
20	800	0.01	0.01	0.64	0.65	16,175.01	20	744	0.00	0.00	0.00	0.01	17,396.06
25	880	0.01	0.01	0.70	0.71	18,329.57	25	827	0.00	0.00	0.00	0.01	19,511.08
30	960	0.01	0.01	0.76	0.77	20,125.00	30	902	0.00	0.00	0.00	0.01	21,419.24
Total Emission Cost						87,342.80	Total Emission Cost						93,653.50

3.2 Analysis & Discussion

Table 1 shows that all supplier scenarios always present short payment delays. The minimum of total supply chain costs occurs when using scenarios (1.2). The findings state that the short period delay in payment from suppliers occurs due to a small percentage of supplier ROI. Moreover, it becomes longer when the ROI increases. From this numerical experiment, ROI parameters hugely affect the player's income. It refers to a period of late payment from the producer that is longer than the supplier and the proportional to the higher ROI manufacturer.

On the other hand, the minimum emission cost also occurs in a scenario with a delay in payment. Decreasing emission costs arise due to an increase in quantity shipment. This decrease occurred due to shipping in large volumes, so vehicle travel more efficient.

Table 2 shows the effect of varying distributor ROI. According to sensitivity analysis, it concluded that the higher the distributor's ROI, the higher the payment period delay. Besides, the longer the manufacturer delays payment to the distributor, the distributor's order is higher. When the ROP of the distributor is 0.01, the time of the manufacturer's payment delay is 0.34 units, and the distributor's orders are 683 units. On the other hand, the manufacturer gives a longer delay in payment as big as 0.65 units of time when the distributor ROP 0.04. Hence, the order quantity increased to 800 units. The higher-order amount produces a smaller emission cost. These cost emissions occur due to various events, but in this research, the transportation cost represents emissions cost.

Table 3 presents the result of the numerical experiment when varying emission tax rate. The result shows a relation between the emission tax rate with a delay in the payment period and order quantity. When the emission tax rises, the delay in the manufacturer's payment period increases indirectly. Besides, the order quantity indirectly increases along with the rising delay in the manufacturer's payment period. Its automatically occurs and proves the model successfully integrates the supply chain system under study. Players in the supply chain system try to reduce emissions costs by coordinating through delays in payment when the emissions tax increase. Therefore, manufacturers provide a longer delay in the payment period, and distributors increase their order quantity for minimizing emissions costs.

According to numerical experiments, low emission costs occur when the delay of the payment is permitted. It can be concluded, a delay in payment becomes a coordination medium in an integrated supply chain system to reduce gas emissions. The success of delay in payment in reducing gas emissions because the period of delay in payment provided by the supplier makes the buyer buy in larger quantities. Besides, the order quantity is also strongly influenced by distributor ROI. In Table 2, the higher the distributor ROI produces, the higher the order quantity as well. Higher-order supplies can optimize shipping from suppliers to buyers, thereby reducing gas emissions. With this mechanism, both parties benefit from each other.

4. Conclusion

The model in this study successfully integrates the multi-echelon supply chain with late payments as media coordination. Coordination with delay in payment has succeeded in reducing the total supply chain costs, especially the cost of carbon emissions. Lower emission costs show successful coordination in the supply chain. The total cost of the supply chain system is lower when given a period of late payment. The period of late payment provided by the supplier makes customers purchase in larger quantities.

Moreover, the order quantity is strongly affected by distributor ROI. The higher of distributor ROI produce a higher order quantity as well. Higher-order supplies can optimize shipping from suppliers to buyers by reducing gas emissions. In this study, the cost of carbon emissions is obtained by considering transportation costs and distribution related to emissions. In further research can be developed by adding consideration to the expenses that occur during production and other business processes.

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