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# A Closed-loop Green Supply Chain Model in Imperfect Environment

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***Abstract— This study presents a closed-loop model which combine manufacture chain with reverse chain that includes the collection of used products as well as distribution of the new products, considering inspection cost and reworking cost. The objective of this research is to discuss maximizing the profit of the supply chain and minimizing the total cost and shortages of products. The result shows that subsidy can affect profit to increase, and the new model can reduce a little bit of the profit in the supply chain.***

*Index Terms*—**Closed-loop Supply Chain, Green Supply Chain Management, Imperfect Environment**

## I. Introduction

Recently, we concern about the issue of environmental pollution, because the pollution are more extremely awful over the past decade. As environmental degradation and global warming, the strategy of Green supply chain management (GSCM) play an important role in the whole world, because GSCM is a critical to let a firm sustainable [1] .The European Union and many governments have enacted legislations. For example, used products and manufacturing-induced wastes [2][3].When people have the concept of environmental protection, researcher started to focus on the Green supply chain ,owing to the successful implementation of the green supply chain managenent,whole enterprise can continuously development.

Hamed [4] used genetic algorithm to build their model in different situation. The goal is optimize total profit, and reduce lost working days due to occupational accidents. And the results demonstrate the feasibility of the proposed model and the applicability of the developed solution. Rui Zhao [5] propose a model which apply a big data, to improve the green supply chain management. In their paper, the purpose is to optimize the model of a green supply chain, and reduce the inherent risk occurred by hazardous materials, associated carbon emission and economic cost. Ashkan Memari [6] present the develop a novel multi-objective mathematical model which apply multi-objective and genetic algorithm, and considering costs of production, distribution, holding and shortage cost and environmental impact of logistic network. The result is compared the gained Pareto fronts from Moga and purpose attainment programing solver. Alice Tognetti [7]considered that green supply chain is most important in the company. According to their German automotive industry, they find optimize system can be reduced by 30% at almost zero variable cost increase in the supply chain. In this paper, we apply the closed loop to build a green-supply chain in imperfect environment. The Closed-loop supply chain refers to the completely supply chain of the enterprise from purchasing to final sale, including product which need to recovery and life cycle of reverse logistics. The good example is the Japanese Ministry of the Environment for the automotive industry. [8] Its purpose is to close the flow of materials, reduce environmental pollution, and residual waste, and while lower the cost to provide customers. Govindan and Darbari [9] proposed integrated CLSC network model, and research in Indian market. They find that use closed loop model can let the firm in gaining sustainably from the numerous electronic product reuse opportunities And the imperfect environment means the imperfect production process, the produce defective product.Chiu[10] [11] note that recovery the defective product or inspect the product cannot avoid in the imperfect environment, consequently effective to reduce the cost for reworking the defective product. And he thought the machine malfunction affect the size of economics lot, the defective product do not reworking, if not to deal with the scrap.

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We want to build the model, which material can continue to be use; no matter directly product or the used product can be recovery. According to the above situation, we can waste less resources and less cost. In all the research, our research is different from other papers. Because we combing the reverse chain and the manufacture chain to be one supply chain. Detail item like, manufacturers and secondary material to be a unit, and the wholesalers and the disassembly plants to be a unit; the last but the least is retailers and the collecting plants. We use the less recourses and the cost, to maximizing the profit.

This paper is organized as follows. Section II defined the notation and assumptions. Next, Section III develops the integrated inventory model which combine the manufacturing chain and the reverse chain. And then, we showed numerical examples and analysis in Section IV. Finally, having the conclusion and discussing future research opportunities.

## II. Notations and Assumptions

### A. Notations

In order to develop a closed-loop green supply chain model, we use the profit formula to solve this problem, and we consider the cost of each item in this research.
The following notations and assumptions below are used to build the model:

| Notation Definition |
|---|
| SP-Supply chain of profit |

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STR-total revenue of supply chain
STC-total cost
Cp-procurement cost of physical flow i
Cin-inspection cost of production process
Cre-reworking cost of defective products
Cir-inventory cost for storing raw materials
Ci-inventory cost for storing products
Cit-Inventory cost for storing used product that has been treated by a reverse logistics chin member
Cint-Inventory cost for storing used product that has not been treated by a reverse logistics chin member
Ct-transportation cost
Cb-sales return cost
$\alpha$ - Defective ratio
$\beta$ -Return ratio
S -Unit Subsidy
F-recycling fees charged by the corresponding EPA for manufacturing products
θ-predetermined products sale return ratio
δ-predetermined production defective ratio
Cl-hourly labor cost
Cf-unit cost final disposal
Ctr-transitional treatment cost
Cc-collecting cost of used product returned from end-customer
Qi- Quantity of Inventory---decision variable
Qir- Quantity of raw materials inventory
Qit- Quantity of inventory of used product that has been treated
Qint- Quantity of inventory of used product that has not been treated invent
Qf- Quantity of final disposal---decision variable
Ql- Quantity of labor
Qm- Manufacturing quantity---decision variable
Qr- Raw materials quantity---decision variable
Qtr- Transitional treatment quantity---decision variable
$Q_{i,j}$- The generalized form of a decision variable referring to the physical flow quantity transported from layer i in manufacturing/reverse chain to layer j in manufacturing/reverse chain
Qre-Quantity of used-product that has been returned by end customers
Si- Facility capacity for inventory
Sir- Facility capacity for raw-material inventory
Sint- Facility capacity for inventory that has not been treated
Sit- Facility capacity for inventory that has already been treated

B. Assumptions

(1) Only the single-product condition is considered in the proposed model.
(2)Shortages are not allowed.
(3) The time-varying quantity of product demands from end-customers in any given time interval
is given.
(4) There is a given return ratio, referring to the proportion of the quantity of used products returned from end-customers, and through the reverse logistics chain.
(5) Facility capacities associated with chain members of the proposed integrated logistics system are known.
(6) The lead-time associated with each chain member either in the general supply chain or in the reverse supply chain is given.

## III. MODEL FORMULATION

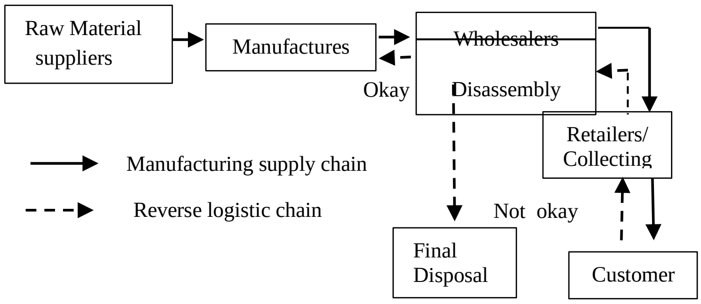


Figure I the concept of the green supply chain model

A. Objective formula

In the figure, there are six unit in this model, and the solid represents manufacturing supply chain, the dotted line represents the reverse logistic chain. If the used-material can be recycle, it will go to the manufactures step, but if not, it will go to the final disposal.

Max SP=STR-STC

Max=(MTR+RR+RS)-(SPC+SMC+SIC+STRC+SBC+SCC +SRC+SLC+SFC+STTC+STCC)

According to our assumption, we integrated the supply chain and the reverse chain to optimize the model, and the objective of our model is maximum net profit in the supply chain. And the SP is measure by subtracting the corresponding aggregate costs from the respective aggregate revenues and costs. The profit mines the cost that we are consider: Procurement, Manufacturing, Inventory, Transportation, Recycling fees, Collection, Transition treatment, Final disposal.

1 .STR- total revenue from the profit of the supply chain +the subsidies which are oriented from the supply flows of the returned used product transported to the layer of disassembly plants for government subsidies.

$$\sum_{\forall t}\{[\sum_{i=1}^{4}\sum_{j=i+1}^{5} Rsi,sj\,(t)*Qsi,sj(t)] + [\sum_{\forall S2}\sum_{\forall S4} R24(t)*Q24(t)] + [\sum_{\forall s2}\sum_{\forall s5} R25(t)*Q25(t)] + [\sum_{\forall s3}\sum_{\forall s5} R35(t)*Q35(t)] + [\sum_{i=3}^{5}\sum_{j=i-1}^{4} Rsi,sj(t)*Qsi,sj(t)] + [\sum_{\forall s5}\sum_{\forall s3} R53(t)*Q53(t)] + [\sum_{\forall s4}\sum_{\forall s3} S*Q43]\} \quad (1)$$

2. SPC –total raw-material procurement cost, the first formula is initialized cost of raw material, and the second one is from raw material suppliers and the used material.

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$$\sum_{\forall t}\{[\sum_{\forall S1} Cr(t)*Q\,r(t)] + \sum_{\forall t}[\sum_{i=1}^{3}\sum_{j=i+1}^{4} Cpsi,sj(t)*Qsi,sj(t)] + [\sum_{\forall s2}\sum_{\forall s4} Cp24*Q24]\} \quad (2)$$

3. SMC-total manufacturing cost, including manufacturing cost, inspection cost and reworking cost.

$$\sum_{\forall t}\{\left[\sum_{\forall s2} Cs(t)*Qs(t)\right]+\left[\sum_{\forall s2} Cin(t)*Qs(t)\right] + \left[\sum_{\forall s2} Cre(t)*Q(t)*\alpha\right]\} \quad (3)$$

4. SIC-inventory cost

$$\sum_{\forall t}\{[\sum_{i=1}^{2}\sum_{\forall si} Cir(t)*Qir(t)] + [\sum_{i=2}^{4}\sum_{\forall si} Ci(t)*Qi(t)] + [\sum_{i=2,i\neq 3,i\neq 5}^{6}\sum_{\forall si} Cint(t)*Qint(t)] + [\sum_{i=2,i\neq 3}^{4}\sum_{\forall si} Cit(t)*Qit(t)]\} + \sum_{s3}[Ci34(t)*Qi34(t)+Ci36(t)*Q\,i36(t)]\} \quad (4)$$

5. STRC-total transportation cost in any chain member of the supply chain

$$\sum_{\forall t}\{[\sum_{\forall s3}\sum_{j=5}^{6} Ct\,s3,sj*Qs3,sj] + [\sum_{i=1}^{4}\sum_{j=i+1}^{5}\sum_{\forall si}\sum_{\forall sj} Ct\,si,sj(t)*Qsi,sj(t)] + [\sum_{i=3}^{4}\sum_{j=i-1}^{3}\sum_{\forall si}\sum_{\forall sj} Ct\,si,sj(t)*Qsi,sj(t)] + [\sum_{\forall s2}\sum_{j=4}^{5} Cts2,sj(t)*Qs2,sj(t)] \quad (5)$$

6. SCC-total sales return cost

$$\sum_{\forall t}\left\{\left[\sum_{\forall s2} Cre(t)*Q(t)*\delta\right] + [\sum_{i=2}^{4}\sum_{j=i+1}^{5}\sum_{\forall si}\sum_{\forall sj} Ctsi,sj(t)*Qsi,sj(t)*\delta] + [\sum_{\forall s2}\sum_{\forall s5} Ct25(t)*Q25(t)*\delta\right] + \left[\sum_{\forall s3}\sum_{\forall s5} Ct35(t)*Q35(t)*\delta\right] + [\sum_{\forall s2}\sum_{\forall s5} Ct24(t)*Q25(t)*\delta]\right\} \quad (6)$$

7. SLC-labor cost

$$\sum_{\forall t}\left\{\sum_{i=1}^{5}\sum_{\forall si} Cl1i*Ql1i(t) + \sum_{i=2,i\neq 5}^{6}\sum_{\forall si} Cl2i*Ql2i(t)\right\} \quad (7)$$

8. SFC-the final dispose fee

$$\sum_{\forall t}\left\{\sum_{\forall s3} Cf(t)*Qf(t)\right\} \quad (8)$$

9. STTC-the transitional treatment procedures executed potentially in all the supply chain, expect the final disposal

$$\sum_{\forall t}\{\sum_{j=2}^{4}\sum_{\forall sj} Ctr(t)*Qtr(t)\} \quad (9)$$

10. STCC-the amount of returned used product collected from the end-customer layer to the members of supply chain.

$$\sum_{\forall t}\left\{\sum_{j=3}^{4}\sum_{\forall S5}\sum_{\forall Sj} Ccs5,sj(t)*Qs5,sj(t)\right\} \quad (10)$$

B. Constraint

Demand constraints-

$$D(t) \geq \sum_{i=2}^{4}\sum_{\forall si}\sum_{\forall s5} Qsi,s5(t) \geq 0, \forall t \quad (11)$$

Inventory constraints-

1.For raw-material suppliers:

$$\mathrm{Ssir1} \leq \mathrm{Qir(t)} = \mathrm{Qir(t-1)} + \mathrm{Qr(t)} - \sum_{\forall s2} Qs1,s2(t) \leq Sirs1 \quad \forall(S1,t) \quad (12)$$

2.For product manufacturers:

- Material

$$Ssir_2 \leq Qir_2(\mathrm{t}) = Qir_2(\mathrm{t}-1) + \sum_{\forall s1} Q_{1,2}(t) - r_2^{\frac{2}{m}} * Q_s(t) \ \forall(2,t) \quad (13)$$

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- Product

$$Ssi_2 \le Qi_2(\mathrm{t}) = Qi_2(\mathrm{t}-1) + Q_s(\mathrm{t}) - \sum_{l=3}^{5}\sum_{\forall sj} Q_{2,j}(t) \le Si_2\ \forall(2,t) \quad (14)$$

$$Ssint_2 \le Qint_2(t) = Qint_2(t-1) + [\sum_{\forall 3} Q_{3,2}(t)] - Qtr_2\,(t) \le Sint_2\ \ \forall(2,t) \quad (15)$$

$$Ssit_2 \le Qit_2(t) = Qit_2(t-1) + \gamma_{t2}^{tre} * Qtr_2(t) \le Sint_2\ \ \forall(2,t) \quad (16)$$

3. For wholesalers and retailers:

$$Ssi_{sj} \le Qi_{sj}(\mathrm{t}) = Qi_{sj}(\mathrm{t}-1) + \left[\sum_{j=2}^{j-1}\sum_{\forall si} Q_{si,sj}\,(t)\right] - [\sum_{n=j+1}^{5}\sum_{\forall sn} Q_{sj,sn}(t)] \le Si_{si}\ \ \forall(\mathrm{sj},\mathrm{t})], \mathrm{j} = 3 \text{ or} 4 \quad (17)$$

$$Ssint_3 \le Qint_3(t) = Qint_3(t-1) + [\sum_{\forall 5} Q_{5,3}(t) + \sum_{\forall 4} Q4{,}3(t)] - Qtr_{s3}\,(t) \le Sint_{s3}\ \ \forall(3,t) \quad (18)$$

$$Ssi_{32} \le Qi_{32}(t) = Qi_{32}(t-1) + S32 * Qtr_3(t) - \sum_{\forall s2} Q_{32}(t) \le Si_{32}\ \forall(3,t) \quad (19)$$

$$Ssi_{36} \le Qi_{36}(t) = Qi_{36}(t-1) + S36 * Qtr_3(t) - \sum_{\forall s6} Q_{36}(t) \le Si_{36}\ \forall(3,t) \quad (20)$$

4. For Retailers/Collecting

$$Ssint_4 \le Qint_4(t) = Qint_4(t-1) + [\sum_{\forall 5} Q_{5,4}(t)] - Qtr_4\,(t) \le Sint_4\ \ \forall(4,t) \quad (21)$$

$$Ssit_4 \le Qit_4(t) = Qit_4(t-1) + Qtr_4(t) - \sum_{\forall 4}\sum_{\forall 3} Q_{4,3}(t) \le Sint_4\ \ \forall(4,t) \quad (22)$$

5. For final disposal

$$Ssint_6 \le Qint_6(t) = Qint_6(t-1) + [\sum_{\forall 3} Q_{3,6}(t)] - Qf_6\,(t) \le Sint_6\ \ \forall(6,t) \quad (23)$$

clearly state the units for each quantity in an equation.

## IV.NUMERICAL EXAMPLE

### *A. Parameter settings*

Our data is from Sheu et al (2005) [10].The case of a well-known Taiwan notebook manufacturer.

Table I Estimates of unit revenues

| Layer | Parameter | Unit Revenue |
|---|---|---|
| 1.Raw-material supplier | R12 | 42 |
| 2.Manufacturer | R23 | 485 |
| | R24 | 463.2 |
| | R25 | 913.95 |
| 3.Wholesaler | R32 | 10.85 |
| | R34 | 673 |
| | R35 | 850.3 |
| 4.Retalier | R43 | 21.15 |
| | R45 | 873 |
| 5.End-customer | R54 | 2.5 |
| | R53 | 2.5 |

Table II Estimates of supply chain unit cost

| Layer | Parameter | Unit cost (us$) |
|---|---|---|
| 1. .Raw-material supplier | Cre | 19.5 |
| | Cir | 1.75 |
| | Cl(m) | 5 |
| 2.Manufacturer | Cp12 | 24 |
| | Ci | 69.5 |
| | Cint | 1.05 |
| | Cir | 50 |
| | Ct32 | 0.216 |
| | Ci32 | 1.8 |
| | Ci36 | 0.23 |
| | Cr42 | 22.5 |
| | Ctr | 2.05 |
| | Ct12 | 0.205 |
| | Cit | 1.6 |
| | Cl(m) | 5 |
| | Cl(r) | 3.5 |
| 3.Wholesaler | Cp23 | 531.5 |
| | Ci | 86.5 |
| | Ct23 | 0.204 |
| | Cc53 | 2.15 |
| | Ctr | 1.75 |
| | Cint | 0.45 |
| | Ct43 | 0.313 |
| | Cl(m) | 5 |
| | Cl(r) | 3.5 |
| | Cf | 0.13 |
| 4.Retailer | Cp24 | 555.5 |
| | Cp34 | 621.5 |
| | Ci | 101.5 |
| | Cit | 0.9 |
| | Cc54 | 2.85 |
| | Ct24 | 0.204 |
| | Ctr | 9.35 |
| | Cint | 0.9 |
| | Cl6 | 3.5 |
| 5.Customer | Cl(m) | 5 |
| | Ct25 | 0.841 |
| | Ct45 | 0.433 |
| 6.Final disposal | Cint6 | 0.1 |
| | Ct36 | 0.102 |

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Table III Inventory capacity

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| $Sir_1$ | 7000 | $Ssir_1$ | 3500 | $Sint_4$ | 1500 | $Ssint_4$ | 750 |
| $Sir_2$ | 5000 | $Ssir_2$ | 2500 | $Sit_4$ | 1500 | $Sit_2$ | 800 |
| $Si_2$ | 5000 | $Ssi_2$ | 500 | $Sint_3$ | 2500 | $Sint_3$ | 1250 |
| $Si_3$ | 500 | $Ssi_3$ | 250 | $Si_{32}$ | 1500 | $Ssi_{32}$ | 750 |
| $Si_4$ | 100 | $Ssi_4$ | 50 | $Si_{36}$ | 500 | $Ssi_{36}$ | 250 |
| $Ssint_6$ | 250 | $Sint_6$ | 500 | $Sit_4$ | 750 | $Ssint_4$ | 400 |
| | | | | $Sint_2$ | 1000 | $Ssint_2$ | 500 |

Table IV Other parameters

| | |
|---|---|
| Return ratio(β) | 0.25 |
| Defective ratio(α) | 0.1 |
| Sales return ratio(δ) | 0.01 |
| Unit Recycle Fee(F) | 1.1 |
| Unit Subsidy(S) | 10 |
| Used-product Return | 1538 |

B .Analysis of numerical results

TableV Numerical results

| | MP | RP | TP |
|---|---|---|---|
| The value of original model | 5,396,333 | 300,762 | 5,698,095 |
| The value of combining model | | | 5,697,100 |

## IV. CONCLUSION

In recent years, we are concern about our issue of environmental pollution. Green supply chain has been becoming a trend of supply chain management. In this paper, we integrated manufacturing chain and reverse chain into our inventory model; there are some features in this paper, first, we considering the governmental regulations, second, this model in the imperfect environmental, which more closed to the reality. Third, we combine the manufactory chain and the reverse chain into the one formula.

The numerical results present that combining the supply chain can reduce recourse and cost, and it isn't waste more used-product. The value comes up, the maximum profit of manufacturing chain is $5396333 and the maximum profit of reverse chain is $300762. When we aggregate the two value, the maximum profit is $5698095, due to there will be some factors influence each other. And another value which we combine the model is $5697100.

In this paper, we use the subsidy into the investigation, when the subsidy increase, the profit of the reverse chain will be increase, this indicated subsidy can affect the reverse chain, and we found that combining the model can let some recourses to be recycle, and some cost can be merge. The combined value will be lower than the value without merge ring the supply chain.

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