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Research on Optimization of Closed Loop Supply Chain Integrated Model Based on Low Carbon

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With the development of the global economy, the emission of carbon dioxide and other greenhouse gases are getting larger and larger, which brings more and more serious environmental problems to nature that already has great pressure. The traditional enterprise development usually takes the cost minimization and the profit maximization as the enterprise management goal, at the expense of the environment. It is necessary to establish an optimized low carbon logistics closed loop supply chain integration model, which is characterized by the small amount of carbon emissions, the closed loop supply chain and the integration. This paper has discussed in detail of all sectors of the closed loop supply chain logistics cost structure, giving a closed loop supply chain logistics integrated optimization model, and through the example analysis, getting the result that the integrated management of the closed loop supply chain logistics can be implemented to reduce carbon emissions and add supply chain value and improve corporate profits which is an effective method to enhance the competitiveness of enterprises.

1. Introduction

More and more scholars began to put forward the theory of low carbon logistics, the logistics of closed-loop supply chain management, logistics integration and so on. Existing research has the following shortcomings: evaluation index rarely take the transformation of low carbon development for logistics service provider selection into account, under the background of low carbon economy, corporate carbon emissions and the enterprise economic efficiency are closely related. Dai Ding in the logistics and low-carbon economy has put forward, the logistics for the development of low-carbon economy is of great significance, on the one hand, because the logistics itself is one of the major energy consumption, carbon emissions is relatively large. Professor Yang Zhiyong studied how to improve the integrated supply chain management with the help of the theory of logistics level, and through the closed-loop supply chain management to promote the development of low carbon logistics (Yang et al., 2014; Liu, 2011). Liu Yijie investigated and analyzed the domestic and foreign research present situation and existing problems, introduced the concept and characteristics of green supply chain on the basis of green supply and cost recovery concept. Previous studies have indicated that long-term strategic cooperation needs to be based on the efficiency of the sustainable development of the ability to ensure (Schultmann, 2005). C.W.Dong and so on have studied how to integrate the issue of the green supply chain in the logistics operation (Dong, 2005; Liu, 2014). This paper studies the supply chain integration optimization model of low carbon logistics system, which is based on the integrated operational environment, the cost and profit as the variable, and discusses the optimization model of profit maximization of logistics system.

2. Integrated modelling of closed loop logistics system

2.1 The inventory constraints conditions of closed loop integrated logistics system

The relationship among input and output logistics and the corresponding storage capacity is defined by the inventory constraint.

Suppliers, wholesalers and retailers inventory constraints

$$0 \le Q_{i_m}^{InvRaw}(t) = Q_{i_m}^{IRaw}(t-1) + Q_{i_m}^{Raw}(t) - \sum_{\forall i_m^2} Q_{i_m^1, i_m^2}^{Raw}(t) \le a_{i_m}^{IRaw} \quad \forall (i_m, t) \tag{1}$$

Raw material supplier inventory changes over time, at a certain time t the amount of its raw materials is equal to the amount of the inventory in the t-1 time plus the new entry amount of raw materials in the t time minus the output amount of raw materials in the t time, the constraint condition is that the inventory should be less than the supplier's inventory capacity a.

Producers and reproduction businessman inventory constraints

$$0 \le Q_{i_m}^{M}(t) = \sum_{i=1}^{2} Q_{i_m}^{M}(t-1) + \sum_{i=1}^{2} Q_{i_r, i_m}(t) - y_{i_m} \times Q_{i_m}(t) \le a_{i_m}^{M} \quad \forall (i_m, t) \tag{2}$$

Similarly to the raw material suppliers, the manufacturer's inventory is also a function of time, including the inventory of raw materials, recovered products and recycled products; In addition, the logistics of dynamic intermediate change when the raw materials change into the product should also be considered, its coefficient is y_t, the constraint condition is that the inventory should be less than the manufacturer's inventory capacity a.

2.2 Integrated modelling of closed loop logistics system

Assuming Z is the multiple objective function of this integrated logistics system, indicating the total profit of logistics system, which contains two sub objectives, namely to maximize forward production logistics net profit (NPm), and to maximize reverse logistics net profit(NPr). Taking into account the actual efficiency of each of the two sub objectives, set the weight of two sub goals were Wm and Wr, as well as the loss during logistics transport process, which is set Loss. As a result, the closed loop integrated logistics model can be expressed as:

Objective Function $max\, Z = Wm \times NPm + Wr \times NPr - LOSS$ (3)

Satisfying the constraint conditions:

$$0 \le Q_i(t) \le a_i \quad \forall (i,t) \tag{4}$$

$$Dc(t) = \sum_{j=2}^{4} \sum_{\forall i_c^j} \sum_{\forall i_c^5} Q_{i_c^j, i_c^5}(t) \ge 0 \quad \forall t \tag{5}$$

$$R(t) = \sum_{j=1}^{3} \sum_{\forall i_m^5} \sum_{\forall i_r^l} Q_{i_m^5, i_r^l}(t) = \delta \times Dc(t) \ge 0 \quad \forall t \tag{6}$$

where

NPm=TotalPm-TotalCm=TotalPm-(RMCm + ManufCm + InvCm + TranCm + RecyCm) (7)

NPr=TotalPr-TotalCr= TotalPr- (CollCr+TreatCr+InvCr+TranCr+DispCr) (8)

That is, forward logistics and reverse logistics profits are equal to their respective total revenue (TotalP) minus their respective total cost (TotalC). And the total profit Z is equal to the forward logistics total profit adding reverse logistics total profit, and minus some necessary loss, such as wear items in the process of logistics transportation, the corresponding opportunity cost caused by time difference and so on.

In the constraint conditions, Q (t) is the inventory and it changes with time t changes, the constraint is that the inventory is greater than the inventory capacity. Demand constraint (Dc) is also a time function, which refers to the relationship between the demand of the final customer and the logistics which mainly refers to the logistics between the product and the customer. R (T) is the reverse logistics process constraints.

3. Profit and cost analysis of closed loop logistics integrated system

3.1 Logistics profit analysis of closed loop supply chain management (TotalPm analysis)

Integrated logistics gross profit is the sum total of the forward logistics and reverse logistics, set to TotalPm, the profit of the forward logistics is the sum of the profits generated by the flow of raw material logistics and product logistics.

$$TotalPm = \sum_{\forall t} \{ [\sum_{\forall i_m^1} \sum_{\forall i_m^2} p_{i_m^1, i_m^2}(t) \times Q_{i_m^1, i_m^2}(t)] + [\sum_{j=1}^{3} \sum_{l=2}^{5} \sum_{\forall i_m^i} \sum_{\forall i_m^l} p_{i_m^j, i_m^l}(t) \times Q_{i_m^j, i_m^l}(t)] \} +$$
$$\sum_{\forall t} \{ [\sum_{l=1}^{3} \sum_{\forall i_m^1} \sum_{\forall i_m^2} P_{i_m^5, i_m^l}(t) \times Q_{i_m^5, i_m^l}(t)] + [\sum_{l=2}^{3} \sum_{\forall i_r^1} \sum_{\forall i_r^l} p_{i_r^1, i_r^l}(t) \times Q_{i_r^1, i_r^l}(t)] \tag{9}$$
$$+ [\sum_{j=2}^{3} \sum_{\forall i_r^j} \sum_{\forall i_r^{j+1}} p_{i_r^j, i_r^{j+1}}(t) \times Q_{i_r^j, i_r^{j+1}}(t)] + \sum_{\forall i_r^4} \sum_{\forall i_m^2} p_{i_r^4, i_m^2}(t) \times Q_{i_r^4, i_m^2}(t) \}$$

3.2 Logistics cost analysis of closed loop supply chain management (TotalCm analysis)

Integrated logistics system cost can be divided into various aspects of logistics cost like logistics and transportation costs of each link, logistics management costs, and information management costs according to the function of logistics activities. Costs of each link include raw materials costs (RMCm), production costs (ManufCm), inventory costs (InvCm), transportation costs(TranCm), return costs (RecyCm), etc. Logistics management costs include labor costs, planning, coordination and management costs, etc. Information management costs include order processing costs, customer service costs, etc.

The raw material procurement costs (RMCm)

Raw materials used in the production process include two kinds, one is raw materials needed to be processed, one is no need to process or existing raw materials. Therefore, raw material procurement costs include three aspects, namely the cost of the raw material itself, costs paid by buying raw materials (one hand and second hand raw material ordering process) and the existing raw material cost. In view of the role of the logistics enterprise of each node has the diversity that is the manufacturers or sellers also can be suppliers, and vice versa, therefore, manufacturers, wholesalers and retailers are likely to have a certain amount of raw materials. The unit cost of each link of the raw material purchase cost is C, the purchase quantity is Q, For i manufacturers (demand businessman) and j suppliers (including one hand and second hand raw material suppliers), raw material procurement costs are:

$$RMCm = \sum_{\forall i_m} C_{i_m}^{raw} \times Q_{i_m}^{raw} + [\sum_{\forall i_m} \sum_{\forall j_m} C_{i_m j_m}^{M} \times Q_{i_m j_m} + \sum_{\forall i_r} \sum_{\forall j_m} C_{i_r j_m}^{SecM} \times Q_{i_r j_m}] + \sum_{i=1}^{2} \sum_{j=i+1}^{3} \sum_{\forall i_m} \sum_{\forall j_m} C_{i_m j_m}^{M} \times Q_{i_m j_m} \tag{10}$$

The production cost of product (ManufCm)

The production can be decomposed into the operation center, operating costs are distributed according to the amount of work consumed by the products and calculate the operating cost of the products, including direct material costs (including product materials and packaging materials), labor costs (production, packaging), and indirect costs of production (such as material handling, production preparation, equipment maintenance, etc.). Materials and labor costs can be directly included in the cost of product, the indirect costs can be separately to the work cost, then the cost of each job is assigned to the product cost according to the corresponding work reason. Finally, according to the direct material costs, direct labor costs and indirect costs of production, the unit cost C is calculated, so produce products of Q number, the production cost is:

$$\mathrm{ManufCm} = \sum_{\forall i_m} C_{i_m}^{manuf} \times Q_{i_m}^{manuf} \tag{11}$$

Inventory cost

Assuming the unit inventory cost is C, inventory Q is decision variable, the capital interest occupied by raw materials and inventory is B, then the cost of raw materials inventory is the sum of raw materials inventory costs of all suppliers and manufacturers, the cost of finished goods inventory is the sum of the inventory costs of all manufacturers, wholesalers and retailers, The interest occupied by the stock is the sum of the interest of all kinds of stock:

$$\mathrm{InvCm} = \sum_{i=1}^{2} \sum_{\forall j_m} C_{ij_m}^{InvR} \times Q_{ij_m}^{InvR} + \sum_{i=1}^{3} \sum_{\forall j_m} C_{ij_m}^{InvP} \times Q_{ij_m}^{InvP} + \sum_{i=1}^{5} \sum_{\forall j_m} B_{ij_m} \tag{12}$$

The transportation cost (TranCm)

The product transportation cost is the sum of the transportation costs from the manufacturer to the wholesale center or to the retailer, and the transportation cost from the wholesale center to the retailer. The owner of cargo cost is the costs of handling, loading and unloading. Assuming the unit transportation cost is C, the transportation quantity is Q, l is the transportation way, raw material suppliers, manufacturers, wholesalers and retailers of all nodes (i, j) are many-many relationships, the owner of cargo cost is H, the raw material suppliers, manufacturers, wholesalers and retailers of all nodes are related to the the owner of cargo cost, then the total transportation cost is:

$$\mathrm{TranCm} = [\sum_{\forall l_m} \sum_{\forall i_m} C_{l_m i_m}^{TranRaw} \times Q_{l_m i_m}] + [\sum_{i=1}^{3} \sum_{j=i+1}^{4} \sum_{\forall ij_m} \sum_{\forall l_m} C_{ijl}^{TranP} \times Q_{ijl}] + \sum_{i=1}^{4} \sum_{\forall j_m} H_{ij} \tag{13}$$

Return cost (RecyCm)

With the popularity of customer centric business strategy, the return rate in logistics sales activities is continuing to rise, the average return rate is about 6%, network sales can up to 35% the return rate. Therefore, the return of goods also makes a certain cost, the cost is the product of the unit cost of product quantity and return recovery operation:

$$RecyCm = \sum_{\forall i_m} C^{recy} \times Q_{i_m}^{manuf} \tag{14}$$

4. Optimizational closed loop integrated logistics system model

4.1 The constraint conditions of the optimization of closed loop integrated logistics system

The recycling station inventory constraints

There are two types of inventory, that is, the untreated and treated recyclables inventory, it is the inventory at t-1 plus the input inventory at t, and minus the amount of output from the untreated recyclables to the treated recyclables and the amount of output from the treated recyclables to the next link (such as the reproduction factories) at t, then the inventory constraint for the recycling station is:

$$0 \le Q_{i_r}^{InvC}(t) = \sum_{j=1}^{2} Q_{ji_r}^{InvC}(t-1) + \sum_{\forall i} Q_i(t) - \sum_{j=1}^{2}\sum_{\forall i_r} Q_{j,i}(t) \le a_{i_r}^{InvC} \quad \forall(i_r, t) \tag{15}$$

Dismantling factories inventory constraint

In the waste dismantling factories, the treatment of recycling is divided into two categories, one kind is renewable and reusable recyclables, another kind is the final waste. Two items need to be stored separately, therefore, there are three types of inventory in the dismantling factories, that is, untreated recyclables inventory, the recyclables inventory which has been classified and can be reused, and the final waste inventory which has been disassembled and can't be reused. The state transition coefficient of these three types of recyclables is y, and the dismantling factories inventory constraint satisfies:

$$0 \le Q_{i_r}(t) = \sum_{j=1}^{2} Q_{ji_r}(t-1) + \sum_{\forall i} y_i \times Q_i(t) + \sum_{j=1}^{2}\sum_{\forall i_r} Q_i(t) - Q_{i_r}^{M}(t) \le a_{i_r} \quad \forall(i_r, t) \tag{16}$$

The final waste treatment factories inventory constraints

Along with the development of society, solid waste is increasing, many countries have enacted a series of relevant laws and regulations to deal with it. Different waste requires different final treatment to control destruction that waste brings to the environment. The inventory constraint for this type of waste is:

$$0 \le Q_{i_r}^{InvWast}(t) = Q_{i_r}^{InvWast}(t-1) + \sum_{\forall i_m} Q_{i_r}(t) - Q_{i_r}^{fina}(t) \le a_{i_r}^{InvWast} \quad \forall(i_r, t) \tag{17}$$

4.2 Optimization of closed loop logistics system model establishment and solution

In the established optimization model of logistics system, we can consider a system of closed-loop supply chain composed of a manufacturer and a retailer, manufacturer products through direct and indirect channel sales, and by the manufacturer for recycling, reclaiming retailers and third-party recovery one of the three channels for recycling of waste materials recycling and re-manufacturing.

In this optimizational integrated model, the manufacturer and retailer's game order is as follows: ①the manufacturer first decides wholesale price ω, sales price of direct sales channel Pd and the recovery price of waste products Pc; ②According to the established price of the manufacturer, the retailer will decide its own retail price Pr. According to the research hypothesis, the optimization problem of this model can be expressed as:

Also set up Z as a multi objective function of the integrated logistics system, representing the total profit of the optimized logistics system, which contains two sub objectives, that is to maximize net profit (NPm) of forward production logistics, and to maximize the net profit of reverse logistics (NPr). Taking into account the actual efficiency of each of the two sub objectives, set the weight of two sub goals were Wm and Wr, as well as the loss during the logistics transportation process, set to Loss. But the new logistics system considers the third party recovery, set the net profit of third party recovery is NPe, the weight is We, from this, the closed loop integrated logistics model can be expressed as:

Objective Function $max\,Z = Wm \times NPm + Wr \times NPr + We \times NPe - LOSS$ (18)

Satisfy the constraint conditions:

$$0 \le Q_i(t) \le a_i \quad \forall(i, t) \tag{19}$$

$$Dc(t) = \sum_{j=2}^{4} \sum_{\forall i_c^j} \sum_{\forall i_c^5} Q_{i_c^j, i_c^5}(t) \geq 0 \quad \forall t \tag{20}$$

$$R(t) = \sum_{j=1}^{3} \sum_{\forall i_m^5} \sum_{\forall i_r^l} Q_{i_m^5, i_r^l}(t) = \delta \times Dc(t) \geq 0 \quad \forall t \tag{21}$$

The optimized model satisfies the original constraint, and it also needs to satisfy the maximization profit of the recycle side, maximization model of the recycling side net profit NPe is as follows:

$$\begin{aligned} \max NPe &= (\varpi - Cm)Dr + (Pd - Cm)Dd \\ &+ (\Delta - Pc - C1)S(Pc) \end{aligned} \tag{22}$$

$$st.NPe \geq 0 \tag{23}$$

$$0 \leq Pc \leq Pd \tag{24}$$

$$Pc + C1 \leq \Delta \tag{25}$$

4.3 Total profit and total cost analysis of the optimizational closed loop integrated logistics system model

Enterprises in the logistics process, implement closed-loop integrated management on the forward logistics and reverse logistics which not only increase the sense of environmental protection, at the same time, enterprises also receive a real profit that is the goal of sustainable development of modern logistics.

Accordingly, the closed-loop logistics cost after optimizing has also increased the recycling party cost, including waste collection costs (CollCr), recycled materials inventory cost(InvCr), dismantling, processing and processing costs (TreatCr) and final waste disposal costs (DispCr).

The waste collection costs (CollCr)

The collection costs mainly refer to the costs generated by collecting goods which will no longer have the value from users and placing them in recycling factories and other process of recycling activities, waste i collects from the user, including N collection process (user collection, recycling station collection, recycling disposal factory demolition, sorting or secondary market for repackaging, etc.), assuming the unit collection cost is C, the collection quantity is Q, then the cost of the waste collection process is:

$$\mathrm{CollCr} = \sum_{j=1}^{4} \sum_{\forall i} C_{ji_r}^{coll} \times Q_{ji_r} \tag{26}$$

Recyclables inventory costs

The recyclables inventory costs include untreated recyclables inventory cost, the cost of treated recyclables which has to be stored in the recycling factories (dismantling, sorting, etc.), the inventory cost of reproduction factory and a second-hand market and funds interest occupied by recyclables of all links of recycling. Assuming the unit inventory cost is C, the inventory is Q, the recyclables is i, the interest is B, then the recyclables cost is:

$$\mathrm{InvCr} = \sum_{j=1}^{4} \sum_{\forall i_r} C_{ji_r}^{InvR} \times Q_{ji_r}^{InvR} + \sum_{j=1}^{3} \sum_{\forall i_r} C_{ji_r}^{InvP} \times Q_{ji_r}^{InvP} + \sum_{j=1}^{4} \sum_{\forall i_r} B_{ji_r} \tag{27}$$

$$\mathrm{TranCr} = \sum_{l=1}^{n} \sum_{j=1}^{m} \sum_{x=1}^{a} \sum_{\forall i_r} C_{ljxi_r}^{Tran} \times Q_{ljxi_r}^{Tran} + \sum_{l=1}^{n} \sum_{j=1}^{m} \sum_{x=1}^{a} \sum_{\forall i_r} H_{ljxi_r} \tag{28}$$

The dismantling treating cost

The treatment cost is the cost produced in the process of dismantling, reproduction and reuse. The process includes the collection, dismantling, inventory, transportation and other links, each link relates to recyclables treatment. Assuming the unit processing cost is C, the treatment quantity is Q, the recyclables is i, then the cost of reverse logistics process is:

$$\mathrm{TreatCr} = \sum_{j=1}^{4} \sum_{\forall i_r} C_{ji_r}^{treat} \times Q_{ji_r}^{treat} \tag{29}$$

The final waste disposal costs (DispCr)

The cost of its disposal usually depends on the number and the difficulty of the disposal. The difficulty of disposal refers to the difficulty of methods and techniques for the use of waste disposal, different difficulty have different disposal cost. Assuming the waste is i, unit processing cost is C, the treatment quantity is Q, there is:

$$\mathrm{DispCr} = \sum_{\forall i_r} \mathrm{C}_{i_r}^{waste} \times Q_{i_r}^{waste} \quad (30)$$

4.4 Prediction of target value added in logistics industry after closed loop optimization

By looking at the China logistics and Purchasing Association published data and the calendar year logistics statistical yearbook data finishing 2004~2012 China's logistics value added, as shown in table 1.

Table 1: The added value of logistics industry in China in 2004-2012

year	Added value of logistics industry (100 million yuan)	Year-on-year growth (%)
2004	8459	——
2005	12271	30.0
2006	14120	15.1
2007	17925	22.5
2008	21528	20.1
2009	23100	7.3
2010	27739	16.7
2011	31895	13.9
2012	34797	9.1

GM (1,1) model was established by using Matlab software, and the grey prediction was carried out. The grey forecasting model is:

F(t+1)=85503.2958*exp(0.1434*t) -77044.2958 (31)

5. Conclusions

This paper makes a detailed analysis of the cost and profit of the forward logistics and reverse logistics in each link involved in the product life cycle, and gives the operation of the integrated optimization model on the basis of the original. Through the analysis of the profit and cost of optimized model system, we see, the integrated logistics management is an effective way to realize saving resources, environmental protection and improve enterprise efficiency; it is helpful for enterprises to gain competitive advantage.

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