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Distribution Channel Analysis in Closed-Loop Logistics Network

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Abstract. In this paper, we analyze the performance of closed-loop Logistics (CLL) network with various distribution channels. For CLL network, forward and reverse logistics with various facilities such as suppler, manufacturer, distribution center, retailer, collection center, recovery center, etc. are taken into consideration. Three types of distribution channels (normal delivery, direct delivery, and direct shipment) are used for constructing the CLL network. For comparison, two types of the CLL network are considered; First type of the CLL network is to consider normal delivery alone, whereas in second type, normal delivery, direct delivery and direct shipment are taken into consideration. Each type of the CLL network is implemented in numerical experiment using genetic algorithm approach and their performances are compared with each other under various measures of performance. Finally, it can be observed that second type outperforms the first one.

Keywords; Distribution channel analysis; Closed-loop logistics network; Forward and reverse logistics; Normal delivery; Direct delivery and shipment

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1. Introduction

With the rapid development of industry and the increased concerns on environmental problems, many companies have focused on constructing their closed-loop logistics (CLL) networks. In general, the CLL network is consisted of forward logistics (FL) and reverse logistics (RL). For the FL, supplier, manufacturer, distribution center (DC), retailer and customers are considered and they are all used for making and distributing a product. For the RL, collection center, recovery center, secondary market and waste disposal center are taken into consideration and they are all used for reuse, recycling and waste disposal of the returned product from customer in FL. Since the CLL network should be constructed using various facilities at each stage of the FL and RL, how to construct right distribution channel is particularly important for improving the performance of the CLL network. For constructing distribution channel, normal delivery, direct delivery and direct shipment can be usually considered. For example, the distribution channel using suppler, manufacturer, DC, retailer and customer can be referred to normal delivery, whereas the distribution channel from DC to customer except for retailer can be considered as direct delivery, and the distribution channel from manufacturer to customer except for DC and retailer can be taken into consideration as direct shipment.

Each distribution channel has been considered in my conventional literatures [1-8]. Unfortunately, however, they only considered one or two distribution channels in the FL and RL, respectively. That is, they do not considered each distribution channel in CLL network. A few papers treated them in CLL network [9-11]. Min et al. [9] firstly introduced the concept of direct shipment in the CLL network. Soleimani and Kannan [10] and Cardoso et al. [11] used direct delivery and direct shipment including normal delivery in the CLL network. Although some papers mentioned above have been considered various distribution channel in the CLL network, they do not compare the performance between them. Therefore, in this paper, we will compare the performances under simultaneously considering normal delivery, direct delivery and direct shipment in the CLL network. In section 2, the CLL network with normal delivery, direct delivery and direct shipment is constructed. A mathematical formulation and a genetic algorithm (GA) approach for representing and implementing it are suggested in section 3. In section 4, an numerical experiment using two scales of the CLL network is done and the performance of the CLL network with normal delivery alone and that of the CLL network with normal delivery, direct delivery, and direct shipment are compared with each other using various measures of performance. Finally, some conclusions and future study direction are presented in section 5.

2. CLL Network

Fig. 1 shows a conceptual structure of the CLL network. For product production, supplier sends materials (or parts) to manufacturer. Manufacturer produces product using materials and then sends it to retailer through DC. Finally, the product is sold to customer. In this FL, manufacturer can also send product to retailer or customer without DC or retailer directly, each of which can be called as direct delivery and direct shipment. For collection, recovery and waste disposal, collection center collects the returned product from customer and then divided it into two types (recoverable or unrecoverable returned products). The recoverable returned product is sent to recovery center and the unrecoverable returned product is sent to waste disposal center to be landfilled. Recovery center recovers the quality of some recoverable retuned products and then sends it to secondary market for reuse, but, the other recoverable returned products are disassembled into recoverable materials and then sends them to supplier for recycling. In this RL, collection center can also send some returned product to secondary market directly without recovery center, which can be called as direct delivery.

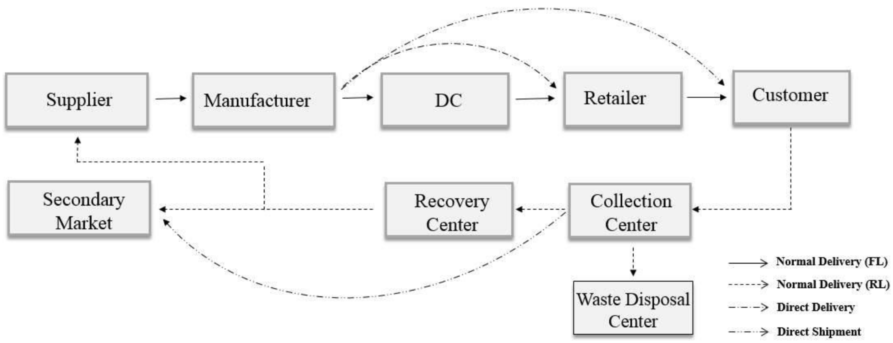

Fig. 1 CLL network with various distribution channels

3. Mathematical Formulation and GA Approach

To present the CLL network of Fig. 1, a mathematical formulation is suggested in this section. Since the CLL network usually aims to minimizing cost or maximizing profit (or revenue) which results from its operation, we also consider the minimization of total cost (TC) as the objective function of the CLL network. The TC is consisted of total transportation cost (TTC), total handling cost (THC) and total fixed cost (TFC). The TTC, THC and TFC are the sum of the costs between the facilities to be opened at each stage. The TC should be obtained under satisfying various constraints. For the constraints, i) only one facility at each stage should be opened, ii) the incoming flow to a facility should be the same or greater than the outgoing one from it, iii) decision variable for the facilities to be opened at each stage should take value 0 or 1, and iv) all variables should take non-negativity.

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procedure: GA approach
input : problem data, parameters
output: best solution
begin
   t = 0;
   generate population P(t) randomly by encoding routine;
   evaluate P(t) by fitness routine;
   store initial best solution I_best from P(t);
   while (not termination condition) do
      create offspring N(t) by applying 2X to P(t);
      create N(t) by applying random mutation to P(t);
      evaluate N(t) by fitness routine;
      select P(t+1) from P(t) & N(t) by elitist selection routine;
      store current best solution C_best from P(t+1);
      if I_best < C_best then
         I_best = C_best
      end if
      t = t + 1
   end
output best solution (I_best)
end
```

Fig. 2 Pseudo code for GA approach

Since the CLL network is an NP-hard problem [2] and conventional approaches such as hill climbing and Tabu search are difficult to solve it, GA approach has been successfully applied to optimize it [2, 8, 12-13]. Therefore, in this paper, we also apply GA approach to solve the mathematical formulation for the CLL network. For the GA approach, firstly initial population is randomly generated by encoding routine and it is then suffered from three GA operators (two-point crossover: 2X, random mutation and elitist selection in enlarged sampling space). The detailed implementation scheme is shown in Fig. 2

4. Numerical Experiment

Two scales for the CLL network are considered in numerical experiment. Each scale has various sizes of facilities at each stage as shown in Table 1. For comparing the performance of the CLL network (CLL1) with various distribution channels as shown in Fig. 1, that of another CLL network (CLL2) with normal delivery only is also considered. Especially, the changes of the rates of normal delivery, direct delivery and direct shipment can be considered in the CLL1. The changes are shown in Table 2. For example, the case 1 means that the rate of normal delivery from manufacturer to DC is 0.8(α_1), that of direct delivery from manufacturer to retailer 0.1(α_2), that of direct shipment from manufacturer to customer 0.1(α_3), that of normal delivery from collection center to recovery center 0.8(β_1), and that of direct delivery from collection center to secondary market 0.2(β_2). The parameters for the GA approach is that population size is 20, crossover rate 0.5, mutation rate 0.2 and total number of generations 1,000. Total 20 iterations were ran for removing the randomness of the GA approach. The computation environment is as following: Matlab R2015 under IBM compatible PC 3.40GHZ processor (Inter Core i7-3770 CPU), 8GB and Window 7.

Table 1. Two scales of CLL network

Scale	Supplier	Manufacturer	DC	Retailer
1	2	2	4	5
2	4	4	8	10

Customer	Collection Center	Recove-ry Center	Secondary Market	Waste Disposal Center
10	5	4	4	2
20	10	8	8	4

Table 2.Various cases

	Case 1	Case 2	Case 3	Case 4
α_1	0.8	0.6	0.4	0.2
α_2	0.1	0.2	0.3	0.4
α_3	0.1	0.2	0.3	0.4
β_1	0.8	0.6	0.4	0.2
β_2	0.2	0.4	0.6	0.8

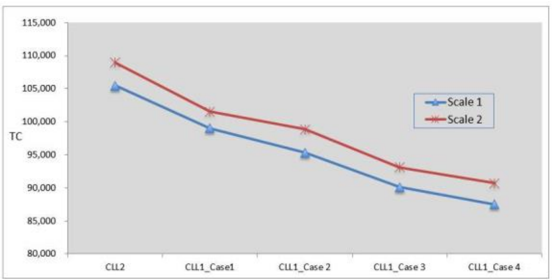

Fig. 3 Performance of CLL1 and CLL2

Fig. 3 shows the performance (TC) of the CLL1 and CLL2. The comparison between the performances of the CLL2 and that of the CLL1 in case 1 shows that the TC of the former is greater than that of the latter, which implies that the latter is more efficient than the former in terms of the TC. Similar situations are also shown in the comparison between the performances of the CLL2 and those of the CLL1 in cases 2, 3, and 4. With Fig. 3, we can reach a conclusion that the CLL network with normal delivery, direct delivery, and direct shipment outperforms the CLL network with normal delivery alone

Conclusion

In this paper, we have suggested a CLL network with normal delivery, direct delivery, and direct shipment. For constructing the CLL network, supplier, manufacturer, DC, retailer and customer in the FL and collection center, recovery center, waste disposal center and secondary market in the RL have been used. For presenting the CLL network, a mathematical formulation with the objective of minimizing TC under satisfying various constraints has been suggested and it has been implemented using the GA approach. In numerical experiments, two scales of the CLL network has been presented to compare the performance between the CLL network with normal delivery, direct delivery, and direct shipment and another CLL network with normal delivery alone. Experimental results have shown that the former outperforms the latter. For future study, more various scales of the CLL network will be presented and more various approaches such as hybrid GAs and particle swarm optimization (PSO) will be used for comparing the CLL network.

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