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The Optimization Model and Algorithm of Remanufacturing Supply Chain Logistics Network with Option Contracts

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Abstract

By the point of view of remanufacturing enterprise, the studies of supply chain logistics network optimization problem focused on network optimization and logistics distribution between manufacturing enterprise and customer area. The present business environment is full of uncertainties. To compete effectively in such an environment, remanufacturing enterprises need to develop the capability of responding flexibly to changing market conditions and optimize effectively logistics networks. The mechanism of option contracts has effectively coordinated the relationship of remanufacturing enterprise and retailer and hedged against the risks of over- and under-production. There is few papers considers the mechanism of option contracts although there are lots of studies on supply chain logistics networks optimization problem. Therefore, the mechanism of option contracts is led into the study of remanufacturing supply chain logistics networks optimization problem. Considering environmental pollution influence factors in the remanufacturing process, a multi-objective optimization model of supply chain is developed. Dual-layer genetic algorithm mechanism was brought up. The first layer is responsible for supply chain logistics network structure with genetic algorithm. The second layer answers for specific supply chain logistics distribution with adaptive immune genetic algorithm. Finally, numerical examples demonstrate the validity of the model and algorithm for the optimization problem.

Keywords: *Option contracts, multi-objective, remanufacturing supply chain, adaptive immune genetic algorithm*

1. Introduction

Remanufacturing becomes the new manufacturing model for comprehensive consideration of environmental and resource efficiency. The new manufacturing model provides the key support for sustainable economy and has been highly valued by government and enterprises. The successful implementation of remanufacturing model not only needs foundation engineering technology, but also needs the efficient supply chain model to support logistics network.

According to the characteristics of the remanufacturing model, the researchers extended the forward logistics studies to the reverse logistics studies at the basis of previous studies on logistics networks optimization problem. PISHVAEE, *et. al.,* [1], considered closed-loop supply chain logistics network optimization problem in the environment of uncertain market demand and developed single objective mixed integer linear programming model. CRUZ-RIVERA, *et. al.,* [2], considered stochastic reverse logistics network optimization problem for the collection of end-of-life vehicles and

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developed single objective non-capacitated facility location model. MA, *et. al.,* [3], considered closed-loop supply chain logistics net-work for single objective remanufacturing optimization problem and developed mixed integer programming model. LIU, *et. al.,* [4], put different quality levels of recycled products as a random decision parameters, and considered capacitated constraints of logistic facilities. She developed stochastic programming model of integrated remanufacturing supply chain logistics network based on chance constrained programming. DI, *et. al.,* [5], considered the demand of renewable products and new products, the quantity of waste product returns, operational costs of production and transportation, logistics facilities capacity extension. He developed multi-period remanufacturing supply chain logistics network optimization model. WU, *et. al.,* [6], assumed different sales areas and sales price variance for renewable products and new products. He developed multi-period single objective deterministic remanufacturing supply chain logistics network optimization model.

By the point of view of remanufacturing enterprise, the above papers focus on optimization design of supply chain logistics network. Remanufacturing enterprise is subject of decision making. According to the market demand forecasts, remanufacturing enterprises focus on the determination for the number and location of facilities and logistics distribution between the various facilities. Retailer is in a subordinate position for the optimization problems of remanufacturing supply chain logistics network and does not affect the product supply for remanufacturing supply chain. The present business environment is full of uncertainties, including the uncertainties of market demand and waste product return. To compete effectively in such an environment, remanufacturing enterprises need to develop the capability of responding flexibly to changing market demand conditions. This is particularly true for remanufacturing enterprises dealing with perishable products with comparatively long production lead-times and short selling seasons, and adapt to high uncertainty of market demand. Hence, the decision-making of the supply chain system is from the manufacturing enterprise into the cooperation of the manufacturers and retailers.

It is validation that option contracts mechanism coordinates the supply chain relationship between manufacturers and retailers in the effective method. According to the actual market demand, retailers purchase the products from manufacturing enterprises and manufacturing enterprises produce the products for retailers' order. It hedges against the loss associated with over- and under-ordering. BARNES-SCHUSTER, *et. al.,* [7], studied how options provide managerial flexibility in response to uncertain market changes and how to achieve channel coordination by options and developed a two-stage model to explore the roles of the option contracts. HAZRA and MAHADEVAN [8] considered a buyer reserves capacity in advance from one or multiple suppliers with demand uncertainty. They developed a capacity reservation model to explore the issues of how much capacity the buyer should reserve and how many suppliers it should select. ZHAO, *et al.* [9], took a cooperative game approach to consider the coordination issue in a manufacturer-retailer supply chain using option contracts. This avoided incurring inventory costs and was able to respond flexibly to market changes. CHEN and PARLAR [10] developed a newsvendor model in which the newsvendor can purchase the put options to hedge against losses associated with low demand. YANG and QI [11] developed a general three-step method to find a coordinating contract for supply chain. They showed that several well-known contract types can be viewed as applications of their method. HU, *et. al.,* [12], presented comprehensive comparisons between the single directional option and the bidirectional option in a supplier-retailer supply chain. ZHAO, *et. al.,* [13], develop a supply contract for a two-echelon manufacturer-retailer supply chain with a bidirectional option, which may be exercised as either a call option or a put option. Under the bidirectional option contract, they derived closed-form expressions for the retailer’s optimal order strategies.

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This paper includes three main innovations for the optimization for remanufacturing supply chain logistics network: Firstly, we take the mechanism of option contracts into the optimization for remanufacturing supply chain logistics network. The mechanism of option contracts coordinates the relationship between remanufacturing enterprise production planning and the actual market demand in supply chain. The decision-making of the supply chain system is the cooperation of the manufacturers and retailers. Secondly, we consider influence factors of the process of recycling waste products and pollution of the environment in reverse logistics network of remanufacturing supply chain. Finally, improved dual-layer genetic algorithm mechanism was brought up [14-16]. We organize the rest of this paper as follows: In Section 2, the model of description and assumptions are presented. Then in Section 3, we develop the mathematical model formulas for remanufacturing supply chain logistics network optimization problem and solve the problem. Consequently, numerical examples demonstrate the validity of the model and algorithm for the optimization problem in Section 4, followed by discussions and conclusions in Section 5.

2. Preliminaries

In recent years, the great changes have taken place between manufacturers and retailers. In the past, manufacturers were subject of decision making in supply chain. According to market demand forecasts, the manufacturers made the production planning, determined the reasonable structure of logistics network and implemented effective product logistics distribution. Actually, the business environment for remanufacturing supply chain is full of the uncertainties of market demand and recycled waste products. To compete effectively in such an environment, manufacturers need to develop the capability of responding flexibly to changing market conditions. By the point of view of manufacturers, the studies disposed the uncertainties of market demand and recycled waste products with random function. With the way, this does not hedge against the loss associated with over- and under-ordering. It is a widely accepted fact that the supply chain partnership is established to hedge against the crisis. Hence, option contracts mechanism is an effective way to coordinate the supply chain.

2.1. Option Contracts Mechanism

Option contracts mechanism have attracted substantial attention not only in the domain of financial market, but also in the domain of supply chain management (SCM). Option contracts mechanism is brought up to accommodate fluctuating market demand, so as to implement an efficient supply chain system. There are two parameters in the option contracts mechanism, namely the option price o and the exercise price e. The option price is an allowance paid by the retailer to the manufacturer for reserving one unit of the production capacity. The exercise price is to be paid by the retailer to the manufacturer for one unit of the product purchased by exercising the option. In the paper, we bring up option contracts mechanism on the study of the optimization problem of remanufacturing supply chain logistics network. Let p be the retailer’s retail price. Let c be the marginal production cost of the manufacturer. Let v be the salvage value per unit of unsold product for both the manufacturer and the retailer. We focus on the reasonable and non-trivial case where $p>c>v$, $0 \le o<c-v$,and $e>v$. Let Q^n_{or} denote the market demand forecast of customer zone n by the retailer. Let Q^n_{om} denote the market demand forecast of customer zone n by the manufacturer. Let X^n denote the actual market demand of customer zone n.

The profit formula for customer zone n by the retailer:

$$\Pi^n_{or} = (p-e)\min\{Q^n_{or}, X^n\} - oQ^n_{or} \tag{1}$$

The profit formula for customer zone n by the manufacturer:

$$\Pi^{n}_{om} = oQ^{n}_{om} + e\min\{Q^{n}_{om}, X^{n}\} - cQ^{n}_{om} + v\max\{Q^{n}_{om} - X^{n}, 0\} \quad (2)$$

Q^{n}_{s} denotes the market demand forecast of customer zone for supply chain. The variable is determined by stochastic variable function of market demand. With some algebra, we have:

$$\Pi^{n}_{s} = p\min\{Q^{n}_{s}, X^{n}\} + v\max\{Q^{n}_{s} - X^{n}, 0\} - cQ^{n}_{s} \quad (3)$$

2.2. Description

The complete closed-loop remanufacturing supply chain system is consisted of five parts: remanufacturing enterprises, retailers, collection/inspection centers, customer zones and disposal centers. Logistics network structure of closed-loop remanufacturing supply chain presented in this study is shown in Figure 1.

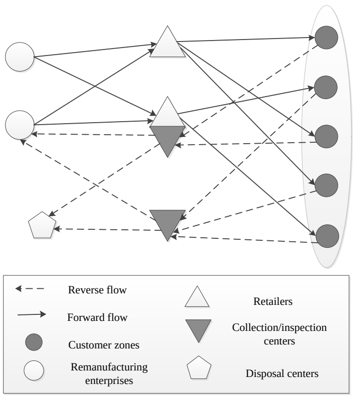

Figure 1. Logistics Network Structure of Closed-Loop Remanufacturing Supply Chain

The processing of waste products is characterized by two parameters, namely remanufacturing and scrap processing. Remanufacturing closed-loop supply chain system structure presented in this study is shown in Figure 2.

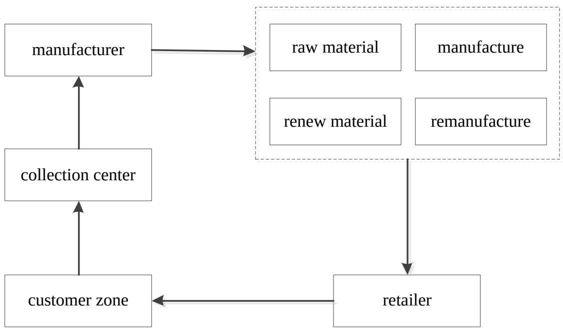

Figure 2. The Structure of Remanufacturing Closed-Loop Supply Chain System

2.3. Notation and Variables

The following notation is used:

I the set of alternative retailers, where $i \in I$;

J the set of alternative collection/inspection centers, where $j \in J$;

M the set of alternative remanufacturing enterprises, where $m \in M$;

N the set of customer zones, where $n \in N$;

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ff_i , fh_j and f_m the construction of fixed costs of retailer, collection/inspection center, and remanufacturing enterprise;

β the retrench rate to the construction of integrated center;

β_1 and β_2 the reuse rate of collection/inspection center and remanufacturing enterprise;

p , p_r , p_e , v_1 and v_2 denote the sale price per unit, the recovery price per unit, disposing the environmental impact per unit, and salvage value;

c_f and c_r denote the transportation cost of forward logistics and reverse logistics per unit;

h_1 and h_2 the environment impact of the transportation per unit;

d_{mi} , d_{in} , d^r_{nj} and d^r_{jm} the distance between all kinds of facilities;

X^n denote the actual market demand of customer zone n;

X^n_r denote the actual stochastic waste product returns of customer zone n;

A_m and A_i denote the capacity of remanufacturing enterprises and retailers;

R_m and R_j the recovery capacity of collection/inspection center and remanufacturing enterprise;

k and k' the specified number of retailers and collection/inspection centers;

$P(\sigma, q_j)$ denote the actual environment influence function for collection/inspection center i;

The following variables are used:

YF_i the decision variable for the opening of retailers;

YH_j the decision variable for the opening of collection/inspection centers;

y_{in} the decision variable for logistics distribution of customer zones;

y_{nj} the decision variable for waste product returns of customer zones;

$x_{mi,t}$ and $x_{in,t}$ the product distribution for remanufacturing enterprises and retailers;

$x^r_{nj,t}$ and $x^r_{jm,t}$ the product returns for collection/inspection centers and remanufacturing enterprises.

2.4. Assumptions

The optimization models presented in this study have the following assumptions:

(1) We assume information is complete symmetry between three kinds of facilities, which are remanufacturing enterprises, retailers, and collection/inspection centers.

(2) Logistics facilities are established on alternative locations, and operation costs are known. There is only one logistics facility established on the same alternative location, but one retailer and one collection/inspection center are established on the same alternative location.

(3) The performances of remanufacturing enterprises and collection/inspection centers are known, including quantity, location and operation capacity.

(4) In this study, we consider single type product and environment influence appeared in the product remanufacturing process. Renewable products and new products can be replaced each other in the same customer zone.

(5) In this study, we consider influence factors of the process of recycling waste products and pollution of the environment in reverse logistics network of remanufacturing supply chain.

(6) Customer zones are known. Each customer zone is waste product collection zone and product market zone. According to market demand, we coordinate between vendors and remanufacturing enterprises with options contracts mechanism.

(7) In each customer zone there is only one retailer to respond to customer demand, and there is only one collection/inspection center to recover waste products. Transportation cost is proportional to the transportation distance.

3. Multi-Objective Remanufacturing Supply Chain Optimization Model

3.1. Mathematical Models

According to description and assumptions, the following mathematical models of multi-objective remanufacturing supply chain optimization problem are designed:

$$\begin{aligned} MaxC = &\left(\sum_{n\in N} \Pi_s^n + \sum_{n\in N}\sum_{j\in J} x_{nj}^r \cdot v_2(1-\beta_2) + \sum_{j\in J}\sum_{m\in M} x_{jm}^r \cdot v_1(1-\beta_1) - \sum_{n\in N}(X_n^r \cdot p_r) \right) \\ &- \left(\sum_{i\in I} YF_i \cdot ff_i + \sum_{j\in J} YH_j \cdot fh_j + \sum_{m\in M} f_m - \sum_{i=j\in I} \beta(YF_i \cdot YH_j)(ff_i + fh_j) \right) \\ &- \left[c_f \cdot \left(\sum_{m\in M}\sum_{i\in I}(x_{mi,t} \cdot d_{mi}) + \sum_{i\in I}\sum_{n\in N}(x_{in,t} \cdot d_{in}) \right) \right. \\ &\left. + c_r \left(\sum_{n\in N}\sum_{j\in J}(x_{nj}^r \cdot d_{nj}^r) + c_r \sum_{j\in J}\sum_{m\in M}(x_{jm}^r \cdot d_{jm}^r) \right) \right] \end{aligned} \tag{4}$$

$$MinH = p_e \cdot \left(\sigma \cdot \sum_{n\in N}\sum_{j\in J} \frac{x_{nj}^r}{d_{nj}} + h_1 \sum_{n\in N}\sum_{j\in J} x_{nj}^r + h_2 \sum_{j\in J}\sum_{m\in M} x_{jm}^r \right) \tag{5}$$

s.t.

$$\sum_{i\in I} YF_i = k \tag{6}$$

$$\sum_{j\in J} YH_j = k' \tag{7}$$

$$y_{in} \le YF_i \tag{8}$$

$$\sum_{i\in I} y_{in} = 1 \tag{9}$$

$$y_{nj} \le YH_j \tag{10}$$

$$\sum_{j\in J} y_{nj} = 1 \tag{11}$$

$$x_{in} \ge y_{in} \cdot \min\{Q_s^n, X^n\} \tag{12}$$

$$x_{nj}^r \ge X_r^n \cdot y_{nj} \tag{13}$$

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$$\sum_{m \in M} x_{mi} = \sum_{n \in N} x_{in} \tag{14}$$

$$\sum_{m \in M} x^{r}_{jm} = (1-\beta_2)\sum_{n \in N} x^{r}_{nj} \tag{15}$$

$$\sum_{i \in I} x_{mi} \le A_m \tag{16}$$

$$\sum_{n \in N} x_{in} \le A_i \tag{17}$$

$$\sum_{n \in N} x^{r}_{nj,t} \le R_j \tag{18}$$

$$\sum_{j \in J} x^{r}_{jm} \le R_m \tag{19}$$

$$YF_i, YH_j, y_{in}, y_{nj} \in \{0,1\} \tag{20}$$

$$x_{mi}, x_{in}, x^{r}_{nj}, x^{r}_{jm} \ge 0 \tag{21}$$

The objective function(4) shows maximum profits of remanufacturing supply chain system. The objective function(5) shows minimum operation costs of influential environment. Constraint(6)~(7) show the quantities of retailers and collection/inspection centers. Constraints(8)~(9) are determined that only one retailer responds to customer demand in each customer zone. Constraints(10)~(11) are determined that only one collection/inspection center recovers waste products in each customer zone. Constraints(12)~(15) show corresponding relations for the quantity of various types of products. Constraints(16)~(19) show the operation capacity of the various facilities. Constraints(20)~(21) show the operation capacity of the various facilities.

3.2. Model Solution

In this study, multi-objective optimization models are transformed into single objective optimization model with primary-object method and linear weight method. The process of transformation is as follows:

Firstly, the total benefits of the remanufacturing supply chain are the main objective with primary-object method. The objective function (4) and (5) are transformed into the objective function (22) with linear weight method. The objective function (22) is following definition:

$$MaxTC = C - \theta \cdot H \tag{22}$$

, where $\theta = \beta_0{}^2$.

Constraint(13) contains stochastic variables. We transform stochastic variable of constraint(13) into stochastic chance-constrained variable as follows:

$$P_r\left\{ X^{n}_{r} \cdot y_{nj} \le x^{r}_{nj} \right\} \ge \delta \tag{23}$$

, where P_r denotes stochastic probability.

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Let Y be stochastic variable with $Y = X_r^n \cdot y_{nj} - x_{nj}^r$, where E denotes expectation and V denotes variance. According to constraint (23), expectation of stochastic variable Y is $E(Y) = E(X_r^n) \cdot y_{nj} - x_{nj}^r$ and variance of stochastic variable Y is $V(Y) = E(X_r^n) \cdot y_{nj}^{\ 2}$.

Let η be stochastic variable of the standard normal distribution with $\eta = \frac{Y - E(Y)}{\sqrt{V(Y)}}$. $Y = X_r^n \cdot y_{nj} - x_{nj}^r$ is equivalent to $\eta = \frac{Y - E(Y)}{\sqrt{V(Y)}} \le \frac{-E(Y)}{\sqrt{V(Y)}}$. Therefore, constraint (23) is equivalent to $P_r\left\{\eta \le \frac{-E(Y)}{\sqrt{V(Y)}}\right\} \ge \delta$.

Finally, constraint(10) is equivalent to as follows:

$$x_{nj}^r \ge \Phi^{-1}(\delta)\sqrt{V(X_r^n) \cdot y_{nj}^{\ 2}} + E(X_r^n) \cdot y_{nj} \tag{24}$$

3.3. Improved Dual-Layer Genetic Algorithm Mechanism

Through above method, the optimization model is transformed into single objective mixed integer nonlinear programming model. The model is NP-hard problem. It is difficult to solve directly the model. In the study, we optimize the model solution with improved dual-layer genetic algorithm (IDGA). The design idea of the algorithm is as follows: We determine the rational layout and location of supply chain logistics network with the first layer genetic algorithm and make rough calculations. According to supply chain logistics network, the optimal scheme of logistics distribution is determinate with the second layer genetic algorithm, and we make precise calculations. Finally, we conclude that the optimal solution of optimization problem.

The first layer genetic algorithm deals with supply chain logistics network and makes rough calculations for the optimization model. The chromosome of the first layer genetic algorithm is composed of decision variables and . 0 denotes the close status of logistics facility. 1 denotes the open status of logistics facility. The algorithm of second layer deals with logistics distribution and makes precise calculations for optimization model. Adaptive immune genetic algorithm(AIGA) is taken into the second layer algorithm. The chromosome of the second layer algorithm is composed of decision variable and. 0 or 1 denotes the relationship between customer zones and logistics facilities.

With IDGA to solve the optimization model, the particular idea of IDGA is as follows:

step1: Initialization parameters for IDGA.

step2: The population POP1 initialize for general genetic algorithm in the first layer.

step3: According to the initialization chromosomes of population POP1, the structure of remanufacturing supply chain logistics network is determined.

step4: Calling adaptive immune genetic algorithm in the second layer, the optimal solution of supply chain system is obtained for every chromosome in the first layer.

step5: The selection operator for general genetic algorithm in the first layer. The selection operator uses the roulette selection method to choose the optimal chromosomes of the parents.

step6: The crossover operator and mutation operator for general genetic algorithm in the first layer. We obtain the optimal chromosomes of the children.

step7: Generating a new generation of population in the first layer.

step8: The confirmation of termination conditions. If termination conditions meet the maximum, the algorithm is finished and output the optimal solution for remanufacturing

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supply chain logistics network problem. If termination conditions doesn't meet the maximum, the algorithm continue to perform step5~step7.

With AIGA to solve the optimization model in in the second layer, the particular idea of AIGA is as follows:

step1: Antigen recognition.

step2: The population POP2 initialize for AIGA in the second layer. This encodes antibodies and randomly generates initial population POP2 for AIGA.

step3: Calculating the affinity degree of antibody and antigen. Affinity degree is defined as:

$$aff(X_i) = \frac{1}{1 + P(X_i)} \tag{25}$$

step4: Immune selection. Immune selection operator T_s determines the antibodies to enter the immune Clone operation based on antibody incentive degree $sim(X_i)$. Antibody incentive degree is defined as:

$$T_S(A_i) = \begin{cases} 1, sim(X_i) \geq Q_{ts} \\ 0, sim(X_i) < Q_{ts} \end{cases} \tag{26}$$

step5: Clone operator. Clone operator T_c reproduces selected antibody with immune selection operator. Clone operator T_c is defined as:

$$T_C = clone(X_i) \tag{27}$$

step6: Adaptive crossover operator and mutation operator. Crossover probability p_c and mutation probability p_m are defined as:

$$p_c = e^{2(A(N)-1)} \tag{28}$$

$$p_m = 0.1e^{2(A(N)-1)} \tag{29}$$

step7: Vaccine extraction and vaccination.

step8: Clone inhibition. After the above steps, clone inhibition operator select antibody population again. The operator inhibits low affinity degree of antibody and keeps high affinity degree of antibodies into the new population.

Step9: Generating a new generation of population in the second layer.

Step10: The confirmation of termination conditions. If termination conditions meet the maximum, the algorithm is finished and output the optimal solution for remanufacturing supply chain logistics network problem. If termination conditions doesn't meet the maximum, the algorithm continue to perform step3~step9.

4. Numerical Examples

We assume there are one remanufacturing enterprise and five customer zones in remanufacturing closed-loop supply chain system, and there are six alternative points. Three retailers and three collection/inspection centers are built on alternative points. The unit cost of forward logistics is 1 RMB /km and the unit cost of reverse logistics is 0.8 RMB /km.

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The fixed operation costs of the remanufacturing enterprise are 100 thousand RMB. Table 1, describes operation costs of retailer and operation costs of collection/inspection center on each alternative point. Table 2, describes the values of parameters for multi-objective optimization models. Table 3, describes the costs for multi-objective optimization models.

Table 1. Operation Costs of Facilities KRMB

Alternative point	1	2	3	4	5	6
retailer	50	60	70	52	49	61
Collection/inspection center	49	52	48	56	51	47

Table 2. Values of Parameters

Parameter	β	β_1	β_2	h_1	h_2	σ
Value	0.2	0.3	0.4	0.01	0.02	0.1

Table 3. Costs for Optimization Models RMB

Parameter	v_1	v_2	p	p_r	p_e
Value	100	120	1000	150	500

Let Q_s^n be the market demand forecasts of customer zones with $Q_s^n = \xi(Q - \alpha p)$, where $\xi \in [0,2]$ and α is 0.1. Table 4 describes market capacity of each customer zone.

Table 4. Market Capacity of Each Customer Zone

Market capacity	Customer zone				
	1	2	3	4	5
Q	400	450	350	430	390

Let X_r^n be the actual waste product returns of customer zones with $X_r^n = \varepsilon \cdot (a + b \cdot p_r)$, where $\varepsilon \in [0,2]$. Let b be customer sensitivity of recycled price, where $b = 0.5$. Let a be environmental awareness index in each customer zone, where table 5 describes environmental awareness index a in each customer zone.

Table 5. Environmental Awareness Index

Environmental awareness	Customer zone				
	1	2	3	4	5
a	50	45	55	47	53

Table 6, describes operation capacity of each alternative point, includes retailer and collection/inspection center.

Table 6. Operation Capacity of Each Alternative Point

Alternative point	1	2	3	4	5	6
retailer	800	750	900	680	850	730
collection/inspection center	350	400	370	410	390	430

Table 7, describes the distance of remanufacturing enterprises and alternative points. Table 8 describes the distance of customer zones and alternative points.

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Table 7. The Distance of Production/Recovery Centers and Alternative Points km

Alternative point	1	2	3	4	5	6
Production/recovery centers	23	32	15	28	18	25

Table 8. The Distance of Customer Zones and Alternative Points km

Customer zone	Alternative point					
	1	2	3	4	5	6
1	4	3	2	5	1	3
2	2	1	3	3	4	2
3	1	2	5	2	3	2
4	5	3	2	1	3	4
5	2	3	1	2	4	2

Table 9, describes the actual market demand X^n of customer zones in selling season.

Table 9. The Actual Market Demand Xn of Customer Zones

Market capacity	Customer zone				
	1	2	3	4	5
X^n	345	400	295	370	315

We solved multi-objective optimization problem of remanufacturing supply chain with double genetic algorithm. In first layer IDGA, the population size is 30 and hereditary algebra is 120. In second layer AIGA, the population size is 30 and hereditary algebra is 120.

The results of remanufacturing supply chain optimization problem were obtained with IDGA. The retailers are built on alternative points as follows: 1, 3 and 4. The collection/inspection centers are built on alternative points as follows: 1, 5 and 6. Integrated facility is built on alternative point 1. Retailer 1 sells goods to customer zones 1 and 3. Retailer 3 sells goods to customer zones 2 and 5. Retailer 4 sells products to customer zones 4. The collection/inspection center 1 recycles waste products from customer zones 3 and 5. The collection/inspection center 5 recycles waste products from customer zones 1. The collection/inspection center 6 recycles waste products from customer zones 2 and 4.

AIGA is taken in the second layer of the typical dual-layer genetic algorithm(DGA). This can improve the accuracy of the optimal solution and search in the solution space fully. Figure 3, shows the compare of two kinds of algorithm, including IDGA and DGA.

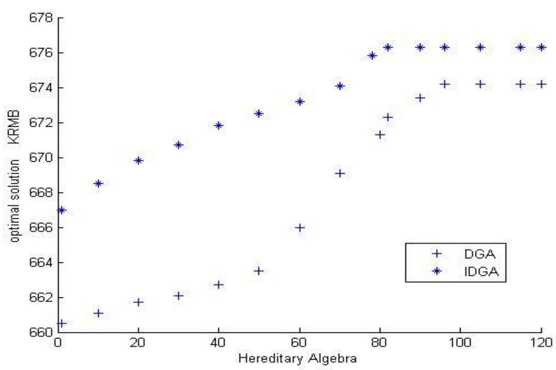

Figure 3. The Compare of Two Kinds of DGA

Based on the condition of the same data, we use the two kinds of DGA to solve the problem. We can get the following conclusion: Firstly, IDGA is higher accuracy than a typical DGA. Secondly, we get the optimal solution in the 82th generation with IDGA, but we get the optimal solution in the 96th generation with the typical DGA. The efficiency of IDGA is faster than the efficiency of a typical DGA. Searches scope of IDGA is more comprehensive in terms of solution space, and avoids the local "premature" situation.

5. Conclusions

In this paper, we take the mechanism of option contracts into the optimization for remanufacturing supply chain logistics network. The mechanism of option contracts coordinates the relationship between remanufacturing enterprise production planning and the actual market demand in supply chain. The decision-making of the supply chain system is the cooperation of the manufacturers and retailers.

To solve the proposed model, IDGA is designed to find the set of solutions. The performance of IDGA is compared to typical DGA in the same data conditions. The numerical results show that the proposed IDGA outperformed typical DGA in terms of solving problems model.

Future research could be aimed at fuzzy random models to accommodate the changing parameters of the business environment during the dynamic logistics network. In addition, it is a promising research avenue with significant practical relevance that we would take bidirectional options contracts mechanism to coordinate product demand for remanufacturing supply chain.

Acknowledgments

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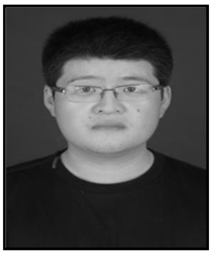

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