ISSN: 2664-9640

Optimization of Reverse Logistics Order Allocation Considering Time Constraint

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Abstract

In the process of reverse logistics order allocation, the collection point will take into account its own inventory capacity, and will restrict the time for recycling companies to collect. Therefore, under the constraints of time for recycling companies, this paper considers transportation costs, recycling costs and time penalty costs, and establishes a mixed integer programming model in which recycling companies recover from multiple recycling points and minimize the total cost, which is a reverse logistics The uncertain recycling path and scattered recycling points of middle recycling companies provide optimization methods. Through the analysis of the above mathematical model, aiming at the shortcomings of the artificial bee colony algorithm, the neighborhood search method in the bee-harvesting stage is improved, and an improved artificial bee colony algorithm is designed according to the model, and a numerical example is simulated. The simulation results of the calculation example show that the designed model and algorithm can effectively reduce the total cost of recycling enterprises. The experimental results show that although the transportation cost of reverse logistics order distribution with time constraints has increased slightly, it can greatly reduce the time penalty cost and improve satisfaction, indicating the reliability and effectiveness of the algorithm to solve the model.

Keywords

Service hours; reverse logistics; recycling order delivery; artificial bee colony algorithm.

1. Introduction

In recent years, with the scarcity of resources and the deterioration of the environment, people's awareness of environmental protection has become stronger. More and more companies are paying attention to reverse logistics, hoping to optimize reverse logistics to reduce costs and save resources. And because of the convenience brought by the rapid development of transportation, people's requirements for time are becoming more and more demanding. How to reasonably plan the allocation of recycling orders, that is, how to achieve efficient recycling within limited resources and time is very important. significance.

The current research on order allocation is mostly combined with the problem of supplier selection. Kim et al. [1] proposed a multi-agent negotiation mechanism to solve the problem of multiple manufacturers assigning orders to multiple suppliers. Song Fashuai et al. [2] aimed at the order problem of multiple manufacturers outside the industrial cluster and multiple suppliers in the industrial cluster, rationally using the remaining production capacity of suppliers, and establishing the balance of production load rate among multiple suppliers as an order allocation decision. Order allocation model. Liu Liang et al. [3] studied the supply combination decision problem of a manufacturer and multiple suppliers under the risk of supply chain failure. Wang Jian et al. [4] studied the issue of interdependent order allocation in many-to-many supply chains, and adopted an automatic negotiation method to resolve conflicts caused by manufacturers' reliance on orders and suppliers' simultaneous orders.

The existing order allocation problems of reverse logistics mostly focus on supplier selection. For example, Moghaddam et al. [5] established a fuzzy multi-objective mathematical model of supplier selection and order allocation when studying reverse logistics, and considered customer demand, supply The ability of the supplier, the percentage of return and other factors. There are also studies on closed-loop supply chains in a fuzzy environment. Gauguin et al. [6] established a multi-objective mathematical programming model for parts from suppliers and recycling and remanufacturing in a fuzzy environment to solve market demand, supplier supply capabilities, and recycling. Conflict of product quantity and other issues. More scholars Ji Shuzhen et al. [7] regarded reverse logistics orders and vehicles as workpieces and machines, respectively, and solved the problem of order allocation and sequencing optimization when a reverse logistics center serves multiple demand points and the demand point recovery volume is different. Regarding reverse logistics, scholars have studied the issue of order allocation from different aspects, but the time constraints on the recycling process in the reverse logistics process have not been considered.

Issues with time constraints must additionally consider the service time and time window. For example, Zu-Jun Ma et al. [8] established a fresh product distribution route optimization model with time windows. Shi Jianli et al. [9] abstracted the distribution route problem of railway logistics center as the optimization of a batch distribution vehicle route problem with random travel time and service time. Guo Fang et al. [10] calculated logistics operation costs based on the optimization of traditional vehicle distribution routes, considering differentiated service time, vehicle diversity, charging strategies, and matching of people and vehicles. Li Zhenping et al. [11] considered the problem of fixed order of service time when the same customer has multiple needs. Li Guoming et al. [12] considered the vehicle problem with random demand and random service time with soft time windows, and proposed a combination of the nearest neighbor algorithm and the tabu search algorithm to solve the problem.

Based on the above, this article studies recycling companies to recycle from multiple recycling points. It is necessary to consider the deadline for service time from recycling points and the earliest start of recycling service time. Under this restriction, in addition to considering the spatial path, time scheduling must also be considered. It can be seen that this article aims at minimizing the total cost of transportation cost, recovery cost, and time penalty cost. A mixed integer programming model. Moreover, due to the complexity of the order allocation problem, the artificial bee colony algorithm is used to solve the problem. Aiming at the shortcomings of the artificial bee colony algorithm's weak local search ability, the artificial bee colony algorithm's neighborhood search mechanism in the honeybee stage is improved to improve the algorithm's performance. Search ability and solving efficiency.

2. Problem description and symbol explanation

2.1. Problem Description

Suppose there is a recycling center with k vehicles of the same type. Starting from the recycling company, several recycling points are collected. There are j recycling points. The recycling point j sends a large number of recycling orders to the recycling company i, requiring [a_j,b_j] Complete the recycling within the time period. After the recycling company i receives the recycling order, the order will be allocated and the path planning will be carried out. Considering the restrictions on the vehicle capacity and the daily working time limit of each vehicle, transport the products to be recycled to the recycling company , To achieve the minimum total cost of recycling enterprises, that is, to optimize the problem of making full use

ISSN: 2664-9640

of limited resources for efficient recycling, so as to realize the entire recycling process, as shown in Figure 1.

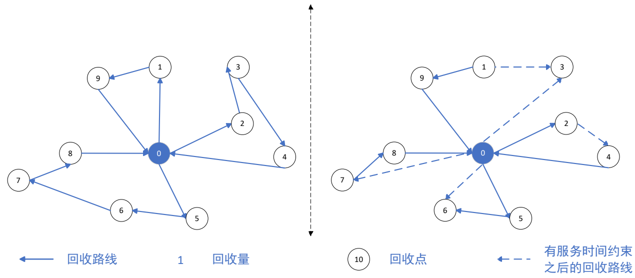

Figure 1: Schematic diagram of recycling companies recycling products from various recycling points considering time constraints

2.2. Basic assumption

Based on the above problem description, the following assumptions are made:

1) The locations of recycling companies and recycling points are known;

2) Recycling companies occupies a dominant position, and the stocks of recycling companies are large enough;

3) Vehicles travel at a constant speed at different speeds in congested and non-congested situations;

4) The vehicles of the recycling companies are of the same model and sufficient number, with load restrictions;

5) Each vehicle has a daily working time limit;

6) Each recycling point can only issue one order, and recycling companies can accept multiple orders within their capabilities;

7) The recycling route does not take into account special circumstances such as traffic jams and weather effects;

8) The vehicle must depart from the recycling company and eventually return to the recycling company;

9) The time window required by each collection point is known.

2.3. Symbol Description

i: Recycling company serial number,$i \in I$;

j: Recycling point number, $j \in J$;

k: Number of vehicles, $k \in K$;

p: Recycling product recycling price;

t: Time required for unloading of recovered goods;

$[ET_j, LT_j]$: The best time window of recycling service provided by recycling point j to recycling enterprises

$[E_j, L_j]$: Recycling point j can accept recycling service time window;

T: Maximum operating time per vehicle per day;

v_k: Travel speed of vehicle k;

Q_k: Maximum vehicle load of vehicle k;

Q_j: Recycling point j needs to be recycled;

q_{ki}: Current load capacity of vehicle k at collection point j

d_{ij}: The distance between each collection point j and the distance between each collection point j and the recycling company i;

C_k: Unit cost when the k model vehicle is empty;

ISSN: 2664-9640

C_m: Unit cost of k model vehicle when fully loaded;
C_1: Fixed usage cost of type k vehicles;
C_2: Unit cost of old product unit processing;
x_{ijk}: 0-1 variable, vehicle k passes through recycling point j from recycling company i.

3. Model building

3.1. Analysis of each cost of reverse logistics

The problem studied in this paper can be described as recycling companies from multiple recycling points with a variety of vehicle models, taking into account the various costs in the recycling process, including transportation costs, recycling costs, and carbon emissions costs.

$$\min Z = Z_1 + Z_2 + Z_3 \tag{1}$$

The detailed steps of each part of the cost are as follows:

(1) Transportation cost

The transportation cost includes the fixed delivery cost and the transportation variable cost. The transportation variable cost is determined by the type of the vehicle, and is usually related to the mileage and the vehicle load. Therefore, Z_1 can be expressed as the fixed cost and the transportation variable cost. And as shown below:

$$Z_1 = C_1 \sum_i \sum_j \sum_k x_{ijk} + \sum_i \sum_j \sum_k (C_k + \frac{C_m - C_k}{Q_k} \cdot q_{ki}) \cdot x_{ijk} \cdot d_{ij} \tag{2}$$

(2) Recovery processing cost

Recovery processing costs include recovery costs and processing costs. The quality of recycled products is uncertain, which is the biggest difference between reverse logistics and ordinary logistics. Recycled products have different degrees of wear due to their characteristics, and recycling companies need to dispose of the products after they recycle such products. Therefore, the sum of the recycling cost and the processing cost Z_2 of the recycled product is:

$$Z_2 = C_2 \cdot \sum_i \sum_j \sum_k q_{ki} \cdot x_{ijk} + p \cdot \sum_i \sum_j \sum_k q_{ki} \cdot x_{ijk} \tag{3}$$

(3) Time penalty cost

Consider that in the case of recycling orders, the recycling point has a requirement for recycling time. Delivery beyond this time period will affect the subsequent work of the recycling point. Among them, $[ET_j, LT_j]$ is the best time window of recycling service provided by the recycling point to recycling companies, $[E_j, L_j]$ is its acceptable time window, recycling companies must provide recycling services to recycling point j It is carried out within this time window, otherwise the recycling company will pay a certain penalty cost. The penalty cost function is as follows:

$$Z_3 = \begin{cases} c_1(E_j - s_j) & s_j < E_j \\ 0 & E_j < s_j < LT_j \\ c_2(s_j - L_j) & s_j < T_j \end{cases} \tag{4}$$

Among them, s_j represents the time when the vehicle arrives at the collection point, c_1 represents the opportunity cost of the vehicle's arrival in advance, and c_2 represents the penalty cost per unit time of vehicle delay.

Therefore, the time penalty cost Z_3 of the recycling company is:

$$Z_3 = c_1 \max((E_j - s_j), 0) + c_2 \max((s_j - L_j), 0) \tag{5}$$

ISSN: 2664-9640

3.2. Reverse logistics model establishment

In summary, the optimization model of reverse logistics recycling order allocation considering traffic congestion is:

$$\begin{aligned}\min Z &= Z_1 + Z_2 + Z_3 \\ &= C_1 \sum_i \sum_j \sum_k x_{ijk} + \sum_i \sum_j \sum_k (C_k + \frac{C_m - C_k}{Q_k} \cdot q_{ki}) \cdot x_{ijk} \cdot d_{ij} \\ &+ C_2 \cdot \sum_i \sum_j \sum_k q_{ki} \cdot x_{ijk} + p \cdot \sum_i \sum_j \sum_k q_{ki} \cdot x_{ijk} \\ &+ c_1 \max((E_j - s_j), 0) + c_2 \max((s_j - L_j), 0)\end{aligned} \tag{6}$$

s.t.

$$\sum_{i \in I} \sum_{k \in K} x_{ijk} = 1, j \in J \tag{7}$$

$$\sum_{i \in I} \sum_{k \in K} x_{ijk} \geq 1, j \in J \tag{8}$$

$$\sum_{i \in I} x_{ilk} \geq \sum_{i \in I} x_{ljk}, l \in I, j \in J, k \in K, i \neq j \tag{9}$$

$$\sum_{i \in I} \sum_{j \in J} x_{ijk} \leq 1, k \in K \tag{10}$$

$$\sum_{i \in I} \sum_{j \in J} x_{ijk} d_{ij} \leq Z_r, k \in K \tag{11}$$

$$\sum_{i \in I} \sum_{j \in J} x_{ij} q_{ki} \leq Q_k, k \in K \tag{12}$$

$$\sum_{j \in J} Q_j \cdot t + \sum_{i \in I} \sum_{j \in J} \frac{d_{ij}}{V_{ij}} \leq T, i \in I \tag{13}$$

$$x_{ijk} = 0 or 1, i \in I, j \in J, k \in K \tag{14}$$

Equation (7) expresses that it is used to restrict each recycling point can only be passed by the recycling vehicle once; Equation (8) is used to restrict the recycling center to exist in multiple distribution routes; Equation (9) is used to restrict entry to a certain recycling point It is the same vehicle as the vehicle leaving the collection point; formula (10) is used to restrict the number of times each vehicle can be collected to any collection point not more than once; formula (11) represents the mileage of any vehicle in a single delivery Must not exceed the specified value; formula (12) the total recovery volume of all recovery points in each route meets the vehicle capacity limit; formula (13) the running time of each vehicle cannot exceed the maximum running time; formula (14) is the decision variable constraint .

4. Algorithm Design

Artificial Bee Colony Algorithm (ABC) has the advantages of fewer control parameters, higher search accuracy, and better robustness. Compared with classic optimization methods, ABC algorithm does not have strict requirements on objective functions and constraints. Less external information is used in the search process, and only the fitness function is used as the basis for evolution. Karaboga [13] pointed out that compared with genetic algorithm, differential evolution algorithm and particle swarm algorithm, the solution quality of ABC algorithm is relatively better. In recent years, the ABC algorithm has received extensive attention from the academic community and has been successfully applied in many fields such as artificial neural network training, combinatorial optimization, power system optimization, system and engineering design.

There are three main types of bees in the bee colony: picking bees, following bees and detecting bees. The main task of picking bees is to explore and develop food sources, and pass the collected nectar source information to other bees; follow bees are a group of bees waiting for information in the hive, according to the information provided by the picking bees, they choose to follow the bees with a certain probability Collecting nectar; while the reconnaissance bee is the bee that chooses not to follow the bee, and randomly goes out to collect the nectar. When the original nectar-collecting bee gives up the original nectar source, it will also become a reconnaissance bee. The number of reconnaissance bees is generally 5 of the number of bees in the colony. %-10%.

4.1. Solution encoding

This article uses natural number coding to encode such problems. Arranging the N recycling points means the order in which the recycling points are passed by the service vehicles. It is necessary to insert multiple points representing the recycling companies to divide them into multiple ends to represent multiple lines on which multiple vehicles travel [14]. First, the number of the collection point is represented by a natural number j, which represents the jth collection point, and 0 represents a recycling company. First generate an ordered sequence with reclaim points, and then insert n-1 0s in the sequence to divide the sequence into n segments, each segment represents a service line corresponding to a vehicle, where n represents the number of vehicles. The recycling enterprise can be represented by vehicle k, then the original feasible solution Food={0,1,2,3,0,4,5,0,6,7}, then the path it represents is:

Vehicle 1: 0-1-2-3-0;

Vehicle 2: 0-4-5-0;

Vehicle 3: 0-6-7-0;

That is, the sequence from one vehicle number to the next vehicle number is the sequence of collection points that this numbered vehicle passes through

4.2. Population initialization

In the artificial bee colony algorithm, each food source corresponds to a feasible solution, and at the same time, the number of bees collected is equal to the number of food sources. During the order distribution of the food supply chain, SN initial solutions are randomly generated, each solution is a D-dimensional vector, and D is the number of optimized parameters. According to the coding method in Section 3.1, D in this article is 36, and each initial The solution is randomly generated as shown in the following formula:

$$X_{ij} = X_{\min} + rand(0,1)(X_{\max} - X_{\min}) \tag{15}$$

Among them, $i \in \{1,2,\dots,SN\}, j \in \{1,2,\dots,D\}$,rand is a random number between 0 and 1, and X_{max} and X_{min} are the upper and lower bounds.

According to the constraints, the article is improved to:

$$X_{ij} = rand(0,1) \times C \tag{16}$$

C is the amount of recycling required for each recycling point to meet this constraint.

4.3. Improve the search process during the bee harvesting stage

The bee-harvesting stage of ABC is based on the initial solution to search for its neighborhood. Generate a candidate location from the location of the original honey source, the search formula is:

$$V_{ij} = X_{ij} + \phi_{ij}(X_{ij} - X_{kj}) \tag{17}$$

Where k is a nectar source different from i, j is a randomly selected subscript, and $\emptyset_{ij}$ is a random number between [0,1], which controls the generation of nectar sources in the

ISSN: 2664-9640

neighborhood of X_{ij}. The candidate position represents the comparison between the original nectar source position X_{ij} and a random nectar source X_{kj} in the neighborhood.

Based on the search strategy inspiration of literature [12-13], the search strategy is improved to search for more high-quality solutions nearby, and the local search ability of the algorithm is improved. In order to achieve different search ranges for individuals with different fitness values, this paper introduces the concept of similarity ϕ [12], which is defined as follows:

$$\Phi = \frac{fit_i}{fit_{best}} \tag{18}$$

Where fit_i represents the fitness value of individual i, and fit_{best} represents the fitness value of the best individual in the population.

According to the individual similarity ϕ and the grouping ratio, the population is divided into the better advanced group and the poorer backward group in the current group, and the two subgroups are searched in different ranges.

4.3.1. Crossover operation for the backward bee colony

The crossover operation can exchange information between the two initial solutions, which can prevent individuals from falling into the local optimum to a certain extent. Since every retailer has constraints, it is not possible to directly exchange two gene fragments, and a new crossover strategy is adopted:

1) Randomly determine the number of orders that need to be fixed. The positions of the number of orders that need to be fixed in Figure 3 are 2, 6, 9;

2) Remove the number of orders at positions 2, 6, 8, 9;

3) Fill the number of orders with position numbers other than 3, 6, 8, 9 in the global optimal individual into the current individual in turn. Through this crossover method

Two new solutions can be generated. Compare the better solution with the current solution. If the new solution is better than the current solution, replace it。

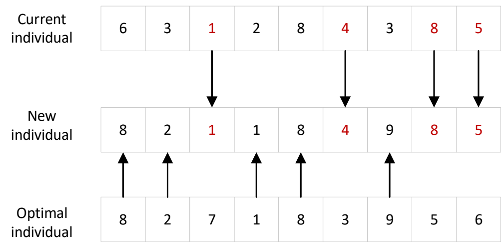

Figure 2: Cross operation

4.3.2. Crossover operation for the backward bee colony

Mutation is an effective way to break through local optimization, and a method based on substitution mutation is adopted. First, randomly select a gene position on the initial solution, and the number corresponding to the gene is C; then randomly generate a non-negative integer that meets the required recovery amount of the recovery point, and set it as F; and determine whether the constraint conditions are met, if so, Let F replace C to become the new gene at this position, as shown in Figure 4.

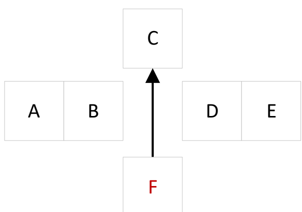

Figure 3: Mutation operation

ISSN: 2664-9640

4.4. Follow the bee stage

Follower bees are bees waiting to receive nectar source information in the hive, and make food source choices based on the food source information provided by the harvesting bees. Under normal circumstances, following the bee will be achieved by observing the swing dance of the picking bee.

According to the information transmitted by the bee, the initial solution is selected according to a certain probability, and the selected initial solution is developed in the following way. The probability formula is as follows:

$$P_i = \frac{f_i}{\sum_{i=1}^{SN} f_i} \tag{19}$$

Among them, f_i is the fitness of the food source X_i The greater the fitness, the greater the probability of being selected.

4.5. Detect bee stage

In the artificial bee colony algorithm, if the solution is not improved for consecutive limit generations in the algorithm, then this food source will be abandoned by the harvesting bee, and the leading bee corresponding to the food source will become a detection bee and will immediately find a new food source . The scout bee uses formula (14) to randomly generate new solutions.

5. Example simulation and analysis

5.1. Simulation

In order to verify the effectiveness of the algorithm, 19 recovery points are selected, the rated load Q of the vehicle is 8t, the fuel type is diesel, and the parameter values in the model are shown in Table 1.

There is a recycling company in a certain area, and the recycling company collects from 19 different collection points. See Table 1-2 for other parameters of recycling companies and recycling points. The calculation example is run under the environment of Windows10 64-bit operating system and MATLAB 2018a.

Table 1: Relevant parameters of recycling companies and recycling points

Parameter	Parameter value	Parameter	Parameter value
p(RMB)	20	C_k (L/km)	0.08
t(h)	0.1	C_m (L/km)	0.236
T(h)	6	C_1 (RMB)	80
v_f (km/h)	60	C_2 (RMB/h)	60

Table 2: Recycling companies and recycling points need to be recycled and demand

CustomerNumber	RecyclingAmount/t	Coordinate	Time Window
0	0	(0，0)	[0,0,180,180]
1	2.27	(3，2)	[0,10,80,100
2	2.03	(1，5)	[10,35,75,112]
3	4.44	(5，4)	[5,25,68,95]
4	1.20	(4，7)	[0,5,55,75]

ISSN: 2664-9640

5	3.24	(0，8)	[15,30,75,120]
6	2.74	(3，11)	[35,75,112,137]
7	1.30	(7，9)	[40,75,105,150]
8	1.25	(9，6)	[25,45,75,105]
9	3.37	(10，2)	[5,25,65,95]
10	0.64	(14，0)	[65,85,120,150]
11	2.69	(2，16)	[35,50,80,100]
12	1.14	(6，18)	[20,35,75,100]
13	3.49	(11，17)	[48,75,115,145]
14	1.52	(15，12)	[10,30,75,96]
15	1.59	(19，9)	[70,90,130,155]
16	2.18	(22，5)	[0,20,56,73]
17	1.40	(21，0)	[55,74,112,140]
18	1.89	(27，9)	[0,20,65,94]
19	2.52	(15，19)	[60,85,115,150]

5.2. Analysis of the distribution result of the recovery order

According to the algorithm design and solving steps in Chapter 3, the improved artificial bee colony algorithm is used to solve the problem. Improved ABC solution parameters: the colony size is 1000, the number of solutions is 500, the dimension D is 19, limit=10, the mutation rate is 0.01, and the number of iterations is 500. The program was run 20 times in total, and the running time was 61.1196 seconds, and the minimum objective function was 6.4795×10^4. The recycling company's return order path is shown in Table 3 and Figure 4.

Table 3: Recycling company recycling path

Vehicle number	Recovery path
1	0-9-10-17-16-0
2	0-13-19-14-15-0
3	0-8-3-1-0
4	0-7-4-2-6-5-0
5	0-11-12-18-0

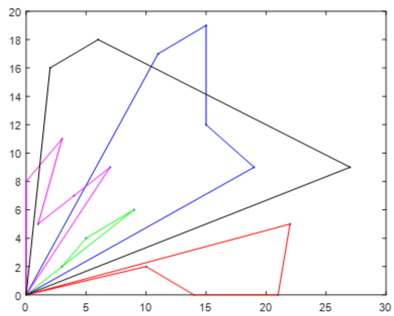

Figure 4: Recycling path diagram of recycling companies

It can be seen from Table 4 that the total cost of the distribution plan that takes into account the service time is smaller than that of the distribution plan that does not consider the service time. Regardless of the service time, the recovery cost does not change much, and only the transportation cost and the time penalty cost are more important. Big impact. Therefore, the plan considering the service time is more optimized, and the satisfaction of the recycling point is also higher.

Table 4: Whether to consider the comparison of service time scheduling plans

Operation result average value	Dispatch plan without considering service time	Scheduling plan considering service time
Total Cost	6.6365×10^4	6.4795×10^4
Transportation Cost	17259.00	19634.4
Cost Recovery	38827.6	37357.2
Time Penalty Cost	10278.4	7794.4

5.3. Algorithm comparison

Comparing ABC and the improved ABC algorithm for 300 iterations, it can be seen from Figure 5 that in the process of algorithm iteration, the gap between the objective function values obtained by IABC and ABC is increasing. The bee stage has been improved. During the iteration process, the minimum value of the IABC function has been significantly reduced, indicating that the improved strategy for the bee harvesting stage in this article is effective. At the same time, as the number of algorithm iterations increases, it can be seen from Figure 5. Obviously, when the number of iterations reaches about 80 times, ABC reaches the optimal value, and the objective function value solved by IABC still has a relatively obvious decrease, reaching the optimal after 200 times. This further shows that the search mechanism in this article can be expanded. The search range improves the optimization speed and accuracy of the solution, and the improved artificial bee colony algorithm has higher solution quality, which verifies the effectiveness of the algorithm in solving the model.

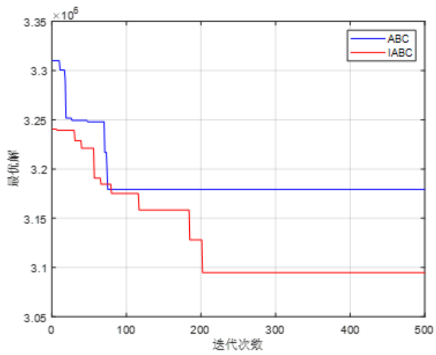

Figure 5: Comparison of 20 runs of IABC and ABC

6. Conclusion

This paper considers the optimization problem of reverse logistics recovery order allocation with service time constraints. The main conclusions are as follows:

1) According to the characteristics of recycled products and the requirements for cost reduction, taking into account the factors of service time, from the three aspects of transportation cost, recycling processing cost and time penalty cost, we have established recycling companies that aim to minimize the total cost of recycling. An order distribution model for recycling at a recycling point, and a conclusion that whether considering the service time has a greater impact on the total cost, transportation cost, and time penalty cost, the impact on the recycling cost is not significant;

2) Considering the shortcomings of artificial bee colony algorithm's weak local search ability and fast convergence in the later stage of evolution, crossover, mutation, and improved

ISSN: 2664-9640

neighborhood search are carried out at the stage of collecting bees. The improved IABC algorithm converges faster than the ABC algorithm, and the solution results better.

In the actual reverse logistics operation environment, the complexity is far greater than the ideal state in the article. In the subsequent research of the thesis, the problems of multiple vehicles can be combined.

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