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Research on Optimization of Cold Chain Logistics Distribution Path Based on P Company

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ABSTRACT. *With the development of cold chain technology and the improvement of people's living standards, the demand for cold chain logistics is becoming more and more prosperous. In view of the fact that most cold chain logistics companies still have many problems such as high distribution costs and untimely distribution. Considering the high cost of cold chain transportation, the total cost of the five costs of fixed cost, fuel consumption cost, refrigeration cost, cargo damage cost, and penalty cost is the minimum optimization goal, a cold chain logistics distribution route optimization model is constructed, and genetic algorithm and hybrid are designed. Particle swarm optimization solves the problem, and the optimized path effectively reduces the company's cold chain distribution time and cost, and improves the efficiency of cold chain transportation.*

KEYWORDS: *Cold chain logistics, Distribution path optimization, Genetic algorithm, Hybrid particle swarm optimization*

1. Introduction

At present, China's cold chain logistics is developing rapidly, but it still cannot meet the growing demand of the people. Most cold chain logistics distribution products are perishable and perishable, and require high freshness. At present, there are still some problems in domestic cold chain logistics distribution, such as incomplete distribution, lack of strategic guidance on the distribution path planning, and distribution vehicles. Problems such as low loading rate and unreasonable delivery time control. The existence of these distribution problems greatly affects the distribution efficiency and customer satisfaction, therefore, cold chain logistics research becomes increasingly important [1]. Mo Haixi et al. built a cold chain

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distribution model based on the factors of distribution center location through analytic hierarchy process and goal planning method[2]; Guo Fu et al.[3] combined the improved VRP problem with cold chain transportation. Li Shuqin et al.[4] established a multi-model vehicle route optimization model with soft time window constraints to study the impact of different environmental performance vehicles. Ronald et al.[5] established a mathematical model for solving complex facility location based on inventory capacity and distribution route through genetic algorithm; Wu Lihong et al.[6] considered the main influencing factors of fresh food distribution through goal planning method and ant colony algorithm to establish The cost models of the two main modes of self-operation and outsourcing were solved by intelligent algorithms; Chaug et al.[7] used integer programming algorithm to consider the time window needs of different customers to provide food in different temperature ranges, and analyzed the best multi-temperature joint distribution model. Distribution cycle; Liu Xiu et al.[8] used genetic algorithms to convert carbon emissions into carbon costs, and constructed a cold chain distribution path optimization model in a low-carbon environment; Sinaide et al.[9] applied the variable domain search algorithm to generalized variable The domain algorithm solves the vehicle routing problem with a randomly varying domain. By collating the literature of domestic and foreign scholars on cold chain logistics distribution, it was found that the scholars mainly optimized the distribution path optimization, distribution center location, mode selection, etc., and established a mathematical model for optimization analysis, which lacked the quantification of specific cases. the study. In view of the shortcomings of the existing research, this study intends to take the company P's cold chain logistics distribution as the research object, through the analysis of the current distribution status of the research object, using genetic algorithm and hybrid particle swarm algorithm to solve the optimization.

2. Research Content

2.1 Model Establishment

According to the actual situation of P company's distribution path, this paper takes the minimum total cost of fixed cost, variable cost, refrigeration cost, cargo damage cost and penalty cost as the optimization goal. In order to make the model more realistic and simplify the calculation, this study makes assumptions about relevant factors and sets constraints. Combined with the situation of Company P, we will use one distribution center to deliver multiple customers as the basis, take Company P's distribution center and customers as the research object, and take the minimum total cost of fixed cost, fuel consumption cost, refrigeration cost, and cargo damage cost as the optimization goal. Construct an optimized model of P company's cold chain logistics distribution path.

2.2 Model Establishment

2.2.1 Basic Assumptions

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(1) Assuming that the temperature in the cold chain distribution vehicle is constant and suitable;

(2) It is assumed that the cargo damage rate of the delivered product is only related to time, and other influencing factors are ignored;

(3) Assuming that all the delivery vehicles have the same model, the maximum load and the longest driving distance of the vehicle are the same, a certain amount of overload is allowed, but it needs to be calculated at a penalty cost;

(4) Assuming that the location of the distribution center and customers are known, the goods in the distribution center can be delivered to all customers.

2.2.2 Parameter Description

Based on the above problem descriptions and assumptions, the parameters and their meanings used in the construction of the model in this study are as follows:

q: number of vehicles;

C_1: fixed costs;

C_2: fuel consumption cost per unit distance;

D_{ij}: Distance between stores;

$$X_{ijh} = \begin{cases} \dfrac{1 \;\; \text{Vehicle h driving on i, j}}{0 \;\; \text{otherwise}} \end{cases};$$

$$y_{jh} = \begin{cases} \dfrac{1 \;\; \text{Vehicle h meets the needs of customer j}}{0 \;\; \text{otherwise}} \end{cases};$$

C_f: unit cooling energy cost;

e: average power of refrigeration equipment;

t_j: unloading time at customer j;

p: unit price of the commodity;

R_i: the demand at customer i (calculated by weight);

b_1: Damage rate of goods during transportation;

b_2: Damage rate of goods during unloading;

Q_{in}: the quantity of goods remaining in the car after unloading at customer i;

i,j: store node number, $i=0,1,2,3......,n$ (0 represents the distribution center, n represents the number of all stores);

N: a group of node numbers including the distribution center;

$N`$: exclude other node numbers after the distribution center;

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h: vehicle number, h=1,2,...,q (q is the total number of vehicles distributed);

H: vehicle assembly,;

q_t: the maximum load of vehicle h;

a: vehicle loading and unloading efficiency;

f_{ijh}: the load of vehicle h in the interval (i, j);

L_h: the maximum distance traveled by vehicle h;

v: the speed of the vehicle.

2.2.3 Cost Analysis

(1) Fixed cost

The fixed cost is the cost of the cold chain vehicle fixed consumption during the transportation and distribution process. It does not change with the transportation time, transportation distance, the number of customers distributed, the number of goods distributed, mainly including the depreciation costs of vehicles and equipment, drivers Salary, etc. The expression of fixed cost is shown in (1):

$$F_1 = q * C_1 \qquad (1)$$

(2) Fuel consumption cost

This cost is related to the transportation distance, the weight of the transported goods, and the transportation speed. In the above assumption, the transportation speed has been assumed to be constant, and its influence on variable costs has been ignored. Finally, based on past data, an average transportation variable cost is calculated. The expression of fuel consumption cost is shown in (2):

$$F_2 = \sum_{h=1}^{q} \sum_{i=1}^{n} C_2 D_{ij} X_{ijh} \qquad (2)$$

(3) Cost of cargo damage

The products transported by the cold chain are mostly perishable and spoiled products, and the transportation vehicles will cause the loss of the cold chain products when unloading. When the specific expression of the cost of cargo damage is shown in equation (3):

$$F_3 = \sum_{h=1}^{q} \sum_{i=1}^{n} \left(X_{ijh} * p * R_i * b_1 * \frac{D_{ij}}{v} * X_{ijh} * p * Q_{in} * b_2 * t_j \right) \qquad (3)$$

(4) Cooling cost

The cooling energy consumption of the vehicle during transportation is equal to the average power of the refrigeration equipment multiplied by the transportation

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time. The transportation time is measured by the transportation distance divided by the transportation speed. The expression of refrigeration cost is shown in (4):

$$F_4 = \sum_{h=1}^{q}\sum_{i=1}^{n}\frac{e*f}{v}*D_{ij}*X_{ijh} \qquad (4)$$

2.2.4 Objective Function

Through the analysis of the above four costs, the final optimization goal of this article is:

$$F = F_1 + F_2 + F_3 + F_4 = q*C_1 + \sum_{h=1}^{q}\sum_{i=1}^{n}C_2 D_{ij} X_{ijh} + \sum_{h=1}^{q}\sum_{i=1}^{n}\left(X_{ijh}*p*R_i*b_1*\frac{D_{ij}}{v}*X_{ijh}*p*Q_{in}*b_2*t_j\right) + \sum_{h=1}^{q}\sum_{i=1}^{n}\frac{e*f}{v}*D_{ij}*X_{ijh} \qquad (5)$$

The constraints are:

$$X_{ijh} = \sum_{h\in H} y_{jh} \qquad (6)$$

$$\sum_{i\in N} X_{ij} = 1, \forall j \in N', \sum_{j\in N} X_{ij} = 1, \forall i \in N' \qquad (7)$$

$$\sum_{(0,\ j)\in A} y_{0jh} \le 1, \forall h \in H \qquad (8)$$

$$\sum_{h=1}^{q}\sum_{i=0}^{n}\sum_{j=1}^{n+1} D_{ij}*X_{ijh} \le L_h \qquad (9)$$

$$f_{ijh} \le qt*y_{ijh} \qquad (10)$$

$$\sum_{j=1}^{n} X_{0jh} = 1, \sum_{i=1}^{n} X_{i0h} = 1 \qquad (11)$$

$$\sum_{i=1}^{n}\sum_{i=0}^{n}\sum_{j=1}^{n} X_{ijh} = 1 \qquad (12)$$

$$\sum_{h=1}^{q} qt \ge \sum_{i=1}^{n} R_i \qquad (13)$$

Among them, the two constraints of formula (7) are the basic constraints of the VRP problem; formula (8) indicates that each distribution vehicle leaves the distribution center at most once, and the vehicle is prevented from being used again after returning to the distribution center; formula (9) indicates In a distribution process, the maximum distance traveled by each distribution vehicle does not exceed

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its specified maximum travel distance; formula (10) limits the maximum load of the vehicle; formula (11) indicates that the vehicle departs from the distribution center and eventually returns Distribution center; formula (12) means that in a single delivery, each customer can only be delivered once and can be delivered; formula (13) means that the sum of the maximum load of all vehicles in a delivery is greater than the demand of all customers with.

3. Algorithm Analysis

3.1 Model Genetic Algorithm

3.1.1 Genetic Algorithm Design[10]

(1) Coding operation

In this study, the natural number coding method was selected, with 0 representing the distribution center and 1-30 for the 30 distribution points. The path between two zeros represents a sub-path, indicating that the delivery vehicle departs from the delivery center and returns to the delivery center after completing the task [11].

(2) Generate initial population

This study set the population size to 200. There are a total of 30 customers in this study, so the random function randperm disrupts 1 to 30 to generate a random sequence, that is, one chromosome corresponds to one distribution path scheme.

(3) Evaluation of individual fitness

When using the genetic algorithm to solve the problem, the fitness function is used to evaluate the quality of the chromosome. The larger the fitness value of the chromosome, the easier it is to be retained. The fitness value of the chromosome reflects whether it is the best feasible solution.

(4) Genetic operator design

1)Select operation

Choose a rule similar to the survival of the fittest in nature, which is more able to adapt to the environment and retain it, and those who cannot adapt to the environment are eliminated.

2) Cross operation

In this process, it is mainly to retain the fine genes of the father, to form a better individual offspring. In the study, the crossover probability was set to 0.6 during the solving process, and the crossover position was taken from the INT(n/3) to INT(2n/3) positions of the coding gene from left to right. In this study, a partial matching crossover method was selected.

3) Mutation operation

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The mutation operation is to replace the gene at a certain gene position on the chromosome with a new gene. In this study, Pm was selected as 0.03, and the mutation method was selected as reverse transformation.

(5) Termination conditions

The termination condition selected in this study is the number of iterations. When the iteration reaches 200 times, the program stops searching by itself.

3.1.2 Genetic Algorithm Solution Process

According to the design of the above genetic algorithm, the solving process of the genetic algorithm mainly includes the following steps.

Step1: transform the actual problem into a problem that the computer can identify and solve, determine the parameter set of the actual problem, and encode the parameter set;

Step 2: Screen coding groups, randomly determine the initial population, and set the initial number of iterations;

The third step: select, cross and mutate the chromosome of the parent to obtain a new chromosome of the offspring;

Step 4: After the genetic operations of selection, crossover and mutation, the chromosome is decoded for fitness evaluation, and the chromosome with high fitness value is retained, and the next iteration is continued. The iteration population changes from p(t) to p(t +1), and return to the third step;

Step 5: Determine whether the termination condition is met, compare the number of iterations with the maximum number of iterations, when it is less than the maximum number of iterations, return to the fourth step, and execute step 6 when it is greater than or equal to the maximum number of iterations;

Step 6: The termination condition is satisfied, the search ends, and the optimal solution for this iteration is output.

3.2 Hybrid Particle Swarm Optimization Algorithm

3.2.1 Design of Hybrid Particle Swarm Optimization

In this paper, when solving the problem of vehicle routing optimization, we consider adding the operation method of genetic algorithm (GA) to select crossover and mutation to discrete particle swarm optimization (DPSO). In the iterative search process, the site sequences obtained by coding the logistics transportation and distribution sites are selected and crossed with the current optimal site sequence and the group optimal site sequence, which speeds up the convergence rate; the mutation operation is performed after

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the selection cross operation is completed , Randomly generate two positions in each distribution site sequence to mutate, which improves the algorithm's global search ability [12] The main crossover and mutation rules are:

(1) Selection and crossover strategy

In the iterative process of the hybrid particle swarm optimization algorithm, the position vector is equivalent to the sequence of stations formed by coding the distribution stations in logistics transportation. Two different numbers are randomly generated by the method of randomly generating numbers, which represent two positions, respectively, forming a position sequence , And use the position sequence to intercept the current optimal site sequence in each site sequence in each iteration at a corresponding position, thereby obtaining a site sequence segment in a current optimal site sequence.

(2) Mutation strategy

After the site sequence completes the cross operation with the current optimal site sequence and the particle swarm current optimal site sequence, the mutation operation is performed on it. Randomly generate two numbers from the number of site sequences, which respectively correspond to the positions of the sites in the site sequence, and perform the operation of swapping the sites corresponding to the two locations, that is, the mutation operation.

4. Example Analysis

4.1 Basic Data Information

The distribution center distributes products to 30 stores or supermarkets in a city according to the needs of stores and supermarkets. The distribution center distributes goods for each gate store and supermarket every day. Vehicles start from the distribution center and return to the distribution center after the delivery is completed. The vehicles are sorted and cleaned for the next use. The demand is known, and the unloading time is calculated based on the demand and the driver's unloading efficiency. Specific customer information and the relative distance between company P customers are known

4.2 Results Analysis

4.2.1 Analysis of Genetic Algorithm Results

According to the design of genetic algorithm above, Matlab is used to solve the model. After 200 iterations, the model is solved to obtain an approximate optimal solution of 7845.97. The plan after the distribution

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route optimization is to be distributed by 4 vehicles, the running time is 13.417289 seconds, the distribution route optimization plan is shown in Table1:

Table 1 Distribution Route Optimization Plan

vehicle	Delivery route	Deadweight(KG)	Full load rate
1	0-8-15-17-22-7-21 -14 -13-0	1490	99.6%
2	0-25-23-16-24-4-5-28-20-0	1380	92.3%
3	0-3-1-2-30-27-29-26-0	1400	93.6%
4	0-10-12-18-9-6-19-0-11-0	1390	92.9%

The model constructed in this study takes the lowest total cost as the optimization goal. After 200 iterations, the approximate optimal solution of the model is found to be 7845.97. Among them, the lowest cost route obtained by genetic algorithm has a fixed cost of 1236.00; a fuel consumption cost of 886.00; a refrigeration cost of 3298.95; a cargo damage cost of 2384.70; and a penalty cost of 40.32. Through the data survey and calculation, it can be known that the original total cost of P company is 10581 yuan/day, and the genetic algorithm has been greatly optimized, and the cost savings are about 25.85%.

The optimization process of genetic algorithm and the optimal solution in the iterative process are shown in Figure 1. The line segment on the figure is a line segment composed of 200 points, and each point is the result of each iteration. In the actual operation process, the number of termination iterations has been tried in 200, 300, 500, 800, 1000, and the final results are all between 7,000 and 8,000, so the final cost of this article is the smallest optimal solution of 7845.97 as the approximate optimal solution .

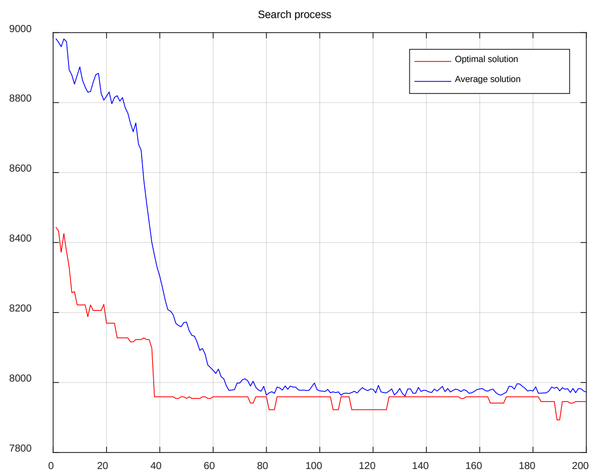

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Fig.1 Genetic Algorithm Result Diagram

4.2.2 Analysis of Results of Hybrid Particle Swarm Optimization

According to the above design of the hybrid particle swarm algorithm, Matlab is used to solve the model. After 500 iterations, the model is solved and the approximate optimal solution 7934.21. The plan after the distribution route optimization is to be distributed by 4 vehicles, the running time is 15.470161 seconds, and the plan for the distribution route optimization is:The first car: 0 -23-14-9-24-20-25-16-8-0;Second car: 0-26-3-5-12-11-4-6-21-0;The third car: 0-18-22-19-30-27-7-10-0;The fourth car: 0-15-2-28-29-1-17-13-0.

The model constructed in this study takes the lowest total cost as the optimization goal. After 500 iterations, the approximate optimal solution of the model 7934.21. Among them, the lowest cost route genetic algorithm obtained by the hybrid particle swarm optimization algorithm has a fixed cost of 1236.00; a variable cost of 940.00; a cooling cost of 3354.75; a cargo damage cost of 2378.93; and a penalty cost of 15.53. Through data investigation and calculation, it can be seen that the original total cost of P company is 10581 yuan/day, and the hybrid particle swarm algorithm can also achieve the purpose of optimization, saving costs about 25.01%. But compared with genetic algorithm, the optimization result is worse, and the cost saving is lower. The number of iterations is longer, and the stable solution can be obtained only after about 500 generations. The optimization process of the hybrid particle swarm optimization algorithm and the optimal solution in the iteration process are shown in Figure 2.

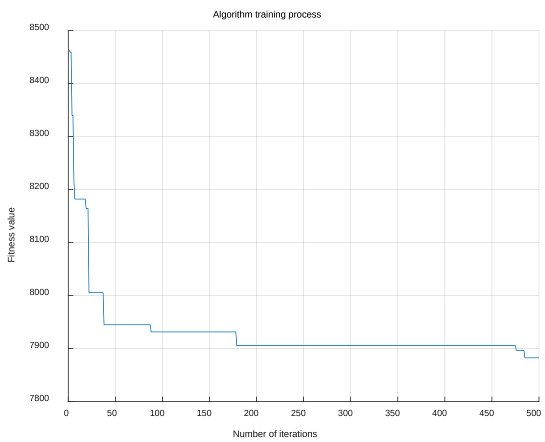

Fig.2 Results of the Hybrid Particle Swarm Optimization Algorithm

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5. Research Conclusion

This chapter takes the cold chain logistics distribution path of Company P as the research object, collects the relevant data of customers and vehicles, designs the solution process of genetic algorithm, and sets the relevant parameter values. According to the data obtained from the survey, the genetic algorithm and the hybrid particle swarm optimization algorithm were used to solve the model constructed in this study on Matlab. The performance of the two algorithms was compared and the optimization results were analyzed. It was found that the genetic algorithm had better optimization effects. Compared with the previous distribution plan, the optimized distribution path plan has a total cost reduction of 25.85% and only 4 vehicles are required. After analysis, it is found that the optimized plan effectively shortens the distribution mileage and improves the vehicle loading rate. Reduced distribution costs. The conclusion of this study will provide solutions for the optimization of the distribution path of related cold chain enterprises, reducing distribution costs and improving distribution efficiency.

References

[1] Wu Jiahuan. Research on the Optimization of Cold Chain Logistics Distribution Path of Shanghai Xinyi Company[D]. Donghua University, 2017.
[2] Mo Haixi, Gao Zhenhua, Chen Senfa. Location model of logistics distribution center based on AHP and target planning[J]. Highway Transportation Science and Technology, 2007, 24(5): 150-153.
[3] Guo Fu, Long Ying. Algorithm of vehicle routing problem with time window backhaul [J]. Journal of Northeastern University: Natural Science Edition (5): 575-578.
[4] Li Shuqin, Yang Bin, Zhao Lei, et al. Demand optimization of an environmentally-friendly multi-model combination distribution route with time windows[J]. Journal of Guangxi University (Natural Science Edition), 2013(02):154-160.
[5] Askin, Ronald G, Baffo, Ilaria, Xia, Mingjun. Multi-commodity warehouse location and distribution planning with inventory consideration[J]. International Journal of Production Research, 2014,52(7):1897-1910.
[6] Wu Lihong. Research on the retailer's online channel fresh product delivery method decision [D]. 2017.
[7] Chaug-Ing Hsu, Wei-Ting Chen, Wei-Jen Wu. Optimal delivery cycles for joint distribution of multi-temperature food [J]. Food Control, 2013, 34(01): 106-114.
[8] Liu Xiu. Research on Urban Agricultural Product Cold Chain Distribution Path Optimization from a Low Carbon Perspective [D]. Dalian Maritime University, 2018.
[9] Sinaide Nunes Bezerra, Sergio Ricardo de Souza, Marcone Jamilson Freitas Souza. A GVNS Algorithm for Solving the Multi-Depot Vehicle Routing Problem [J]. Electronic Notes in discrete Mathematics, 2018 (66): 167-174.

ISSN 2616-5902 Vol. 2, Issue 5: 102-113, DOI: 10.25236/AJBM.2020.020511

[10] (Japan) Xuan Guangnan, Cheng Runwei, Wang Dingwei, et al. Genetic algorithm and engineering design [M]. Beijing: Science Press, 2000.
[11] Li Minqiang. Basic theory and application of genetic algorithm [M]. Beijing: Science Press, 2002:35.
[12] Ye Runzhou. Optimization of last-mile express delivery based on improved hybrid particle swarm optimization algorithm [D]. Hefei University of Technology, 2019.