Optimization of Logistics Distribution Route based on Genetic Algorithm

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Abstract

This paper studies the optimization of agricultural product logistics path based on genetic algorithm. Analyzing the cost management, distribution process, a logistics distribution route optimization model is builded. The genetic algorithm is used to solve this model to realize the optimization of the logistics distribution path of agricultural products enterprises. The experimental results show that the optimized logistics distribution path improves the loading rate and reduces the distribution cost, which fully proves that the genetic algorithm-based agricultural product logistics path optimization has good feasibility and practical application value.

Keywords

Genetic Algorithm; Distribution Cost; Logistics Distribution Route Optimization Model; Optimization Results.

1. INTRODUCTION

With the rapid development of the logistics industry, construction and maintenance costs have gradually increased. On the basis of effective management of transportation costs and realization of cold chain logistics distribution, optimizing the running path of distribution vehicles is an urgent problem that agricultural products companies need to solve [1][2]. Optimizing the driving route of logistics vehicles can effectively reduce unnecessary driving routes and reduce the driving distance. It can also increase the utilization rate of vehicles and effectively reduce the total cost. Therefore, it is particularly important to choose a reasonable logistics route to ensure the timely and efficient delivery of products to customers.

The purpose of optimizing vehicle routes is not only to improve logistics efficiency and reduce logistics costs, but also to improve customer service levels. Scientists at home and abroad have developed a variety of solutions for different models, including: precise algorithms and heuristic algorithms. Based on the random service time, Sivaram et al. [3] [4] studied the path problem of vehicles in time windows. Under stochastic constraints, bifurcation and precise algorithm constraints are used to establish and solve the vehicle routing problem model. Heuristic algorithms are mainly based on natural body algorithms, such as genetic algorithm [5][6], frog-leaping algorithm [7] and so on. Scholars [8] [9] such as Luo studied the routing problem based on genetic algorithm and got a more reasonable vehicle distribution plan.

This paper studies the optimization of cold chain logistics distribution route of agricultural companies. By analyzing the cost management and distribution process, a logistics distribution route optimization model with the lowest total cost is established. According to the constructed objective function model and constraint conditions, the genetic algorithm is used to solve the problem. A reasonable logistics distribution route is obtained, and the distribution cost is

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reduced, thereby providing certain technical support for strengthening the management of agricultural product logistics distribution.

2. LOGISTICS ROUTE OPTIMIZATION MODEL

This section mainly constructs the mathematical model of logistics route optimization, and mathematically describes the route optimization problem. Put forward model assumptions for vehicles, distribution centers, customers, etc., construct the objective function with the lowest total cost of vehicle fixed cost, time penalty cost, and distance cost.

2.1. Model Assumptions

In order to make the established model more suitable for the actual agricultural products enterprises and improve the efficiency of the solution, before establishing the model, we describe the vehicles, distribution centers and customers, and then put forward assumptions.

(1) Regardless of the degree of traffic congestion, the speed of the vehicle remains constant.

(2) The locations of the distribution center and customers are known, and the products of the distribution center can be delivered to all customers.

(3) All delivery vehicles are of the same model, with the same maximum load.

(4) The vehicle starts working from the distribution center and finally returns to the distribution center.

(5) Different customers are optimized based on the straight-line distance, and the best distance is selected for calculation.

(6) Each customer can only be served by one vehicle.

Based on the discussion of the above problems and assumptions, the parameters used to construct the optimization model are shown in Table 1.

Table 1. Model parameters

parameter	Physical meaning	parameter	Physical meaning
q	Number of vehicles	n	Number of customers
h	Vehicle number, h=1,2,…,q	i	Customer number, i=0,1,2,3,.....,n
H	Vehicle collection, $h \in H$	j	Customer number, j=0,1,2,3,.....,n
q_t	Maximum load of the vehicle	R_i	Demand for custom i
f	Vehicle fixed cost	D_{ij}	Distance between customer i and custom j
c	Transport cost per unit distance	$[E_i, L_i]$	Best time window to reach customers
X_{ijh}	$\begin{cases} 1, \text{vehicle } h \text{ is driving between } i \text{ and } j \\ 0, \text{else} \end{cases}$	t_i	Time when the vehicle arrives at customer i
Y_{0jh}	$\begin{cases} 1, \text{custom } j \text{ is served by vehicle } h \\ 0, \text{else} \end{cases}$	ε_1	Increased operating costs when vehicle arrived ahead of schedule
N	A set of route numbers including the distribution center	ε_2	Penalty costs when vehicle arrived late of schedule
N'	A set of route numbers excluding the distribution center	V	Speed of the vehicle

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2.2. Objective Function

This paper considers vehicle fixed cost, distance cost and time penalty cost, and constructs the objective function with the lowest total cost.

(1) Vehicle fixed cost

Fixed cost refers to the fixed cost of transportation and distribution of vehicles equipped with cold chain, which does not change due to transportation time, distance traveled, number of customers delivered and the number of goods delivered. This is mainly the depreciation cost of the vehicle and the driver's salary. The fixed cost formula is:

$$C_1 = qf \tag{1}$$

(2) Distance cost

Distance cost is the cost that continuously increases with the increase of transportation distance during a transportation process. It mainly refers to the cost of fuel consumption. The cost is related to the transportation distance, the weight of the transported goods, and the transportation speed. The expression of distance cost is

$$C_2 = \sum_{h=1}^{q} \sum_{i=1}^{n} \sum_{j=1}^{n} c\, D_{ij} X_{ijh} \tag{2}$$

(3) Time penalty cost

Customers have specific requirements for the delivery time of the goods. Failure to deliver the goods within the specified time will result in penalty costs [10]. If the vehicle is delivered earlier than the prescribed time, it will increase vehicle operating costs. If the vehicle is delivered later than the prescribed time, a penalty will be incurred. The total penalty cost is described as:

$$C_3 = \varepsilon_1 \sum_{i=1}^{n} max(E_i - t_i, 0) + \varepsilon_2 \sum_{i=1}^{n} max(t_i - L_i, 0) \tag{3}$$

This article aims to construct the optimal path with the lowest total cost, so the objective function is:

$$C = qf + \sum_{h=1}^{q} \sum_{i=1}^{n} \sum_{j=1}^{n} c\, D_{ij} X_{ijh} + \varepsilon_1 \sum_{i=1}^{n} max(E_i - t_i, 0) + \varepsilon_2 \sum_{i=1}^{n} max(t_i - L_i, 0) \tag{4}$$

2.3. Restrictions

When establishing the logistics path optimization model of cold chain distribution, in order to make the model more realistic and maximize customer satisfaction, the constraints of the logistics path model in this paper mainly include:

(1) $\sum_{i \in N} X_{ij} = 1, \forall_j \in N', \sum_{j \in N} X_{ij} = 1, \forall_i \in N'$. These two constraints ensure that each custom node can be accessed once.

(2) $\sum_{(0,j) \in N} Y_{0jh} \leq 1, \forall_h \in H$. It means that a vehicle leaves the distribution center at most once, and the vehicle will not depart after returning to the distribution center.

(3) $\sum_{j=1}^{n} X_{0jh} = 1, \sum_{i=1}^{n} X_{i0h} = 1$. It indicates that the vehicle departs from the distribution center and eventually returns to the distribution center.

(4) $\sum_{h=1}^{q} \sum_{i=1}^{n} \sum_{j=1}^{n} X_{ijh} = 1$. It means that in one delivery, each customer can only be delivered once.

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(5) $\sum_{h=1}^{q} q_t \geq \sum_{i=1}^{n} R_i$. It indicates that the sum of the maximum loads of all vehicles in a delivery is greater than the sum of all customer demand.

3. LOGISTICS ROUTE OPTIMIZATION BASED ON GENETIC ALGORITHM

In this section, genetic algorithm is used to solve the optimization model, combined with the actual meaning of the logistics path, the mathematical description of the genetic algorithm to the logistics path model is given, and the realization process of the optimization solution using genetic algorithm is presented.

3.1. Mathematical Description

(1) Coding

The coding operation is the first step to solve the distribution route problem using genetic algorithm. In actual research, the method to solve the distribution route problem is to combine different distribution points in order. When it is solved by computer, it needs to be converted into binary code, natural number code or floating point code, etc. In the specific problem addressed in this article, assume that there are 20 customer points. In order to improve the convergence of the algorithm, this paper chooses the natural number code, namely: 0 means distribution center, 1-20 means 20 customer points. The vehicle departs from the distribution center and returns to the distribution center after passing some customer points, forming a distribution path.

(2) Initial population

The correct selection of the initial population can improve the efficiency of subsequent evolutionary iterations, thereby obtaining an accurate optimal solution. The population size is usually 30-200. If the population is too large, the search range will be expanded and the efficiency of searching for the optimal solution will decrease. If the population is too small, the solution of the algorithm can easily fall into a local optimum. Therefore, we set the population size to 100. Assuming a total of 20 customers, the random function randperm is used to generate a set of random chromosome sequences, and one chromosome corresponds to a distribution route plan.

(3) Fitness function

When using genetic algorithm to solve, the fitness function is used to evaluate the quality of chromosomes. The larger the fitness value of the chromosome, the easier it is to be retained. The purpose of this research is to minimize the total cost, so the inverse of the objective function is chosen as the fitness function:

$$F = \frac{1}{C} \tag{5}$$

(4) Operator design

1) Select operation

This article chooses the roulette method for selection, that is, the probability of selecting each individual depends on the ratio of its fitness value to the overall fitness value of the group. First calculate the fitness value of each chromosome, then calculate the sum of the fitness values of all chromosomes, and finally calculate the probability of each chromosome being selected:

$$P_{sm} = \frac{F_m}{\sum_{m=1}^{M} F_m}, m = 1,2,\ldots,M \tag{6}$$

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Where, F_m represents the fitness value of the individual, M represents the population size, and $\sum_{m=1}^{M} F_m$ represents the sum of the population fitness values.

2) Crossover operation

The crossover operation is equivalent to gene recombination in the process of natural selection, the exchange of gene fragments between the parent chromosomes to produce new offspring. The crossover process is the random selection of chromosome pairs and the selection of a specific position in the chromosome gene as the crossover point. In this paper, we choose part of the crossover method. First, select the two parent chromosomes A and B, select the appropriate gene fragments to exchange, generate A'and B', and then exchange according to the one-to-one correspondence principle.

3) Mutation operation

The mutation operation is to replace some genes of the chromosome with new genes. Selection and crossover operations realize the optimality of the global search, and mutation guarantees the local search ability. The combination of the three can ensure that the genetic algorithm search solution is more effective. This article chooses the reverse transformation method.

(5) Termination condition

Genetic algorithm can not provide accurate optimal solution, but the optimal solution can be obtained after repeated search. There are generally two final value conditions: one is to stop the search after reaching the maximum number of iterations, and the other is to stop when the value of the fitness function does not change much. The termination condition chosen in this article is the maximum number of iterations, that is, the search stops automatically after a certain number of searches.

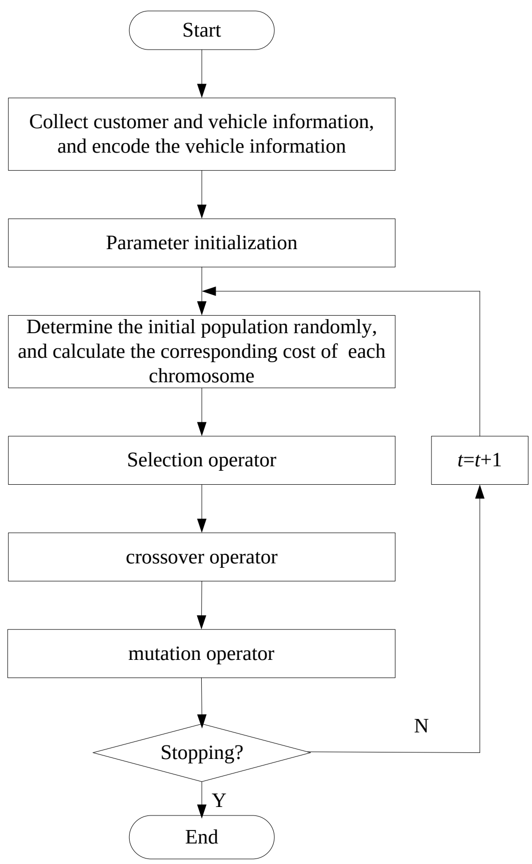

Figure 1. Algorithm implementation flowchart

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3.2. Algorithm Implementation

The flow chart of solving the optimization of distribution route based on genetic algorithm is shown in Figure 1. The implementation process is summarized as follows.

Step1: Collect customer and vehicle information, and encode the vehicle information.

Step2: Initialization, including setting the population size, maximum number of iterations, crossover probability and mutation probability.

Step3: Determine the initial population randomly, and use the fitness function to calculate the corresponding cost of the chromosome.

Step4: Perform selection, crossover and mutation operations to obtain better offspring chromosomes.

Step5: Determine whether the termination condition is met, if the maximum number of iterations is reached, stop the iteration, otherwise execute Step4.

4. EXPERIMENTAL RESULTS AND ANALYSIS

This section introduces the basic customer and vehicle information, utilizes Matlab software to optimize the simulation, gives the experimental results and analyzes.

4.1. Data Collection

(1) Customer informaition

The coordinates of the distribution center are (50, 50), and there are 20 customers in total. The coordinates, demand, and delivery time window of each customer are shown in Table 2. The vehicles depart from the distribution center uniformly and return to the distribution center after the distribution is completed.

Table 2. Customer informtion

Customer number	Customer coordinates	Demand /kg	Delivery time window
1	(57,65)	55	(9:00, 9:30)
2	(70,60)	38	(7:00, 7:30)
3	(70,36)	70	(14:00, 15:00)
4	(30,45)	43	(14:00, 15:00)
5	(40,50)	50	(9:30, 9:50)
6	(65,35)	39	(15:30, 15:50)
7	(26,58)	40	(8:00, 8:30)
8	(70,75)	30	(15:30, 15:50)
9	(35,80)	45	(16:00, 16:30)
10	(20,47)	55	(10:00, 10:30)
11	(50,33)	45	(10:00, 10:30)
12	(30,75)	60	(16:00, 16:30)
13	(60,80)	55	(7:00, 7:30)
14	(90,44)	40	(7:00, 8:00)
15	(54,39)	36	(17:00, 17:30)
16	(19,23)	63	(17:20, 18:00)
17	(40,75)	45	(10:00, 10:30)
18	(66,58)	30	(16:00, 16:30)
19	(80,86)	60	(15:30, 16:00)
20	(30,15)	50	(10:00, 10:30)

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(2) Vehicle information

Suppose there are 6 refrigerated trucks participating in the distribution, and the vehicle load is 200kg. This article assumes that the average vehicle speed is 30 km/h. The fixed cost of each vehicle is 309 yuan, and the variable cost of transportation per unit distance is 2.5 yuan/km. Other specific parameters are shown in Table 3.

Table 3. Vehicle information

Parameter	Physical meaning	Parameter value
f	Vehicle fixed cost	309 yuan/vehicle
c	Transport cost per unit distance	2.5 yuan/km
ε_1	Increased costs when vehicle arrived ahead of schedule	100 yuan/h
ε_2	Penalty costs when vehicle arrived late of schedule	150 yuan/h
q_t	Maximum load of the vehicle	200 kg
V	Speed of the vehicle	30 km/h

4.2. Optimization Result Analysis

The parameters of the genetic algorithm are set as follows: the population size is 100, the mutation probability is 0.2, the crossover probability is 0.8, and the maximum number of iterations is 400.

The random initial distribution path data is shown in Table 4. Taking the lowest total cost as the optimization goal, after 400 optimizations by genetic algorithm, the optimal distribution path is shown in Table 5. The load capacity, full load rate, driving distance, driving time, as well as the required vehicle fixed cost, time penalty cost, distance cost and total cost are compared in Table 6.

From the comparison results in Table 6, it can be seen that after optimization, the agricultural product company can arrange 5 vehicles for distribution. After optimization, the average loading rate of 5 vehicles is 94.9%, indicating that the optimization process can increase the loading rate of vehicles. At the same time, compared with the 6 vehicles before optimization, it can reduce fixed costs and greatly reduce distance costs, that is, fuel consumption costs are reduced, making distribution more reasonable and lower total costs. The experimental results fully prove that the logistics route optimization model constructed is very reasonable, and the genetic algorithm can be used to obtain a better delivery route.

Table 4. Distribution route before optimization

Vehicle	Route
1	0-17-19-8-14-0
2	0-13-12-15-6-0
3	0-11-1-3-0
4	0-5-2-10-9-0
5	0-7-4-16-18-0
6	0-20-0

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Table 5. Distribution route after optimization

Vehicle	Route
1	0-8-3-15-16-0
2	0-13-7-17-1-0
3	0-2-20-10-11-0
4	0-5-14-9-12-0
5	0-6-4-18-19-0

Table 6. Comparison results before and after optimization

Index	Before optimization	After optimization	Difference
loading rate	76.6%	94.9%	18.3%
Driving distance	852.48 km	850.75 km	1.73 km
Driving time	49.458 min	50.591 min	1.133 min
Vehicle fixed cost	1854 yuan	1545 yuan	309 yuan
Time penalty cost	2131 yuan	2127 yuan	4 yuan
Distance cost	5659 yuan	3075 yuan	2584 yuan
total cost	9644 yuan	6747 yuan	2897 yuan

5. CONCLUSIONS

This paper studies the agricultural product logistics route optimization based on genetic algorithm, and constructs the logistics route optimization model with the lowest total cost of vehicle fixed cost, time penalty cost, and distance cost. The genetic algorithm is used to describe the logistics path optimization problem mathematically, and the flow chart of the algorithm implementation is given. Combined with specific customer information and vehicle information, Matlab simulation is implemented, and the route optimization results are given. Experimental results show that the optimized delivery route can increase the loading rate of vehicles, reduce fixed costs, penalty costs, and distance costs, and fully prove the feasibility of model construction and optimization solutions. Adding more cost constraints and enhancing the applicability of the model will be further research directions.

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REFERENCES

[1] Yuan Xueguo, Zouping, Zhu Jun, et al. Development trend, problems and countermeasures of my country's cold chain logistics industry [J]. China Agricultural Science and Technology Review, 2015, 17(1): 7-14.

[2] Zhou Yong, Ji Yingfeng, Yang Hualong, et al. Simultaneous delivery and retrieval vehicle path optimization in cold chain logistics [J]. Mathematics in Practice and Understanding, 2016, 46(20): 18-26.

[3] Sivaram k V, Thansekhar M R, Saravanan R, et al. Multi-objective vehicle routing problem with time windows: Improving customer satisfaction by considering gap time [J]. Proceedings of the Institution of Mechanical Engineers Part B Journal of Engineering Manufacture, 2015, 13(3): 243-252.

ISSN: 2472-3703 DOI: 10.6911/WSRJ.202010_6(10).0049

[4] Ramachandiran R, Ramapraba R, Suresh J K. Multi Depot Vehicle Routing Problem using ODV EV Based Genetic Algorithm [C]. IEEE International Conference on System, Computation, Automation and Networking (ICSCAN), 2019, 1-6.

[5] Wang Youhong. Cluster optimization of fresh agricultural products logistics distribution path based on genetic algorithm [J]. Jiangsu Agricultural Sciences, 2018, 046(012): 358-362.

[6] Tang Peipei, Feng Xiaowei, Gong Yingli. Research on the optimization of intra-city distribution route for fresh food based on genetic algorithm [J]. Shanghai Management Science, 2018, 40(05): 94-100.

[7] Tang Tianbing, Zhang Mingming, Meng Zuqiang. Hybrid Leapfrog Genetic Algorithm for Solving Traveling Salesman Problem [J]. Journal of Guangxi University (Natural Science Edition), 2018, 43(5): 1811-1817.

[8] Luo Qing, Zhou Jun. Optimization of agricultural product logistics distribution path based on hybrid genetic algorithm [J]. Jiangsu Agricultural Sciences, 2017, 045(012): 174-177.

[9] Zhou Jianguo. Research on Optimization of Agricultural Product Distribution Route Based on Improved Genetic Algorithm [J]. Chinese Market, 2018, 000(001): 136-138.

[10] Zhang Lingrui. VRP research considering dynamic demand and customer satisfaction [D]. Kunming University of Science and Technology, 2016.