Optimization of fresh agricultural products distribution considering the constraint of spoilage

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Abstract: In view of the spoilage and distribution complexity of fresh agricultural products, a distribution path optimization mathematical model considering spoilage constraints was constructed. With the goal of minimizing the total cost of fresh agricultural products distribution, including transportation cost, fixed cost, spoilage cost and penalty cost, an improved hybrid genetic algorithm was designed to solve the model, and CPLEX was introduced for comparative calculation. This paper takes Yangcheng Lake hairy crab distribution as an example to verify the effectiveness of distribution optimization, in order to provide a reference for the cost reduction and efficiency increase of fresh food distribution business.

Key words: Fresh agricultural products; Restraint of spoilage; Distribution optimization

I. Introduction

China's output of meat, vegetables, fruits and aquatic products ranks first in the world, and the loss of fresh agricultural products also ranks first in the world due to long transportation routes and improper cold chain distribution management. In the face of increasingly complex economic and social environment such as traffic congestion and diversified customer demands, reasonable planning of cold chain distribution has become an important content of current cold chain optimization research. Gooley.T.B (2006) used a double-layer programming model to study how distribution meets numerous customer needs, and took fresh meat distribution as an example to optimize the distribution route by using a double-layer programming model, pointing out its advantages in solving the distribution route problem. In view of the perishability characteristics of fresh agricultural products, James J.Asher (2010) introduced the penalty cost of violating the time window into the cost, and used the simulated annealing algorithm to study the network planning problem of distribution system, so as to realize the combination of scale and personalized service. Considering the carbon emissions of cold chain transportation, SAIF A (2015) proposed the corresponding logistics network planning model, and solved the model by using Lagrange decomposition and simulation optimization method. Recognizing the advantages of heuristic algorithms in solving the problem of distribution path planning, Yi Ronggui et al. (2014) proposed a cold chain logistics system based on cloud computing, constructed a mixed integer linear programming model that minimized the total cost, and used genetic algorithm to solve and simulate the model. Considering the storage and transportation costs of frozen and refrigerated food and other factors, Yang Wei et al. (2016) designed a particle swarm optimization algorithm with variable domain search strategy to solve the cold chain logistics distribution optimization problem. Zhang Weize (2018) constructed the spoilage function of fresh agricultural products, combined genetic algorithm and ant colony algorithm, and took carbon emission cost as a calculation factor to solve the cold chain logistics distribution route.

Therefore, on the basis of existing research, taking Yangcheng Lake hairy crab as an example and considering the dynamic demand of a large number of scattered customers online and offline, as well as the decay rate of hairy crab and other factors, a mixed integer linear programming model for cold chain distribution route optimization was constructed based on Baumol-Wolfe model. With the total distribution cost as the objective function, decay constraints were added to the model. The improved hybrid genetic algorithm was designed to solve the model, and was simulated to optimize it. The CPLEX optimization calculation method was used to compare and verify the effectiveness of the algorithm.

II. Establishment and improvement of cost model

Hybrid genetic algorithm is a kind of heuristic algorithm, first proposed by Professor Holland (1975) of the University of Michigan. Its principle is to provide a computational model simulating the natural evolution process to search for the optimal solution according to the natural selection and the biological evolution process based on the genetic mechanism of Darwin's biological evolution. For the optimization of the distribution route of fresh agricultural products, Eichi (2014) proposed to adopt genetic algorithm, but the constraint conditions were only based on the 3T theory of frozen products, it is assumed that the rot loss rate of hairy crab is, so the mathematical model expression of the rot cost is as follows: $\mu = k\sqrt{t/t_{GP}}$

$$\min \mu = \tau \sqrt{\frac{1}{t_{GP}} \left(\sum_{0=1}^{0} \sum_{i=1}^{I} \frac{d_{0i}}{k_{0i}} + \frac{1}{v_c^2(0i)} \right)} \quad (1)$$

The constraints are:

$$ET_i \le \sum_{0=1}^{0} \sum_{i=1}^{I} \frac{d_{a,0i}}{k_{a,0i}} \le LT_i \quad (2)$$

Where t , is the transport time of the goods; t_{GP} The shelf life of hairy crab; d_{oi} For the distance between the Yangcheng Lake distribution center and the customer distribution point; k_{oi} For the time sensitive factor of fresh agricultural products spoilage; $v_c(oi)$ Is the processing cost of distribution center; τ Is the coefficient of quality loss rate. Therefore, the minimum cost objective function is improved to:

$$minz = c\sum_{k\in M}\sum_{i\in N}\sum d_{ij}x_{ijk} + c_0\sum_{k\in M}\sum_{j\in N}x_{0jk} + \sum_{k\in M}P_{L(k)} + \sum_{i\in I}P_{T(i)} + min\mu \quad (3)$$

III. Empirical analysis and application

1. Data sources

As one of the three kinds of fresh aquatic products, hairy crab has the basic characteristics of short life cycle, difficult storage and perishable. This paper takes the dynamic distribution of 20 direct points of hairy crabs in Yangcheng Lake as the research object, “0” represents the distribution center. According to GIS, the geographical location and parameters of 20 direct distribution points are displayed. Assume that the speed of refrigerated distribution vehicles is 60 km/h, the transportation cost is 11 yuan/km, the loading and unloading efficiency is 0.2 tons/hour, the fixed cost of each refrigerated distribution vehicle is =200 yuan, and the distribution rate c =1.5 yuan/km. The unit cost of Yangcheng Lake hairy crabs is 9 yuan/ton, the unit time decay ratio is 0.01 at a specific temperature during the transportation process, the unit time decay ratio is 0.02 when the door is opened, and the penalty cost generated by the early arrival or late delivery of the distribution vehicle is 100 yuan/hour.

Assume that the vehicle starts from the distribution center and must return to the distribution center after completing the delivery task. The starting point has the distribution task of 12 delivery points, as shown in Table 1. Assume that 10 new demands appear at time T (immediacy), including the secondary delivery demand generated by the direct store 3 and the direct store 11, and the situation of queuing for delivery is shown in Table 2:

The delivery points in the plan in Table 1 are specific to the features of instant new delivery points in Table 2

Delivery Points	Coordinates (km)	Quantity demanded (tons)	Time window	Delivery point	Coordinates (km)	Quantity demanded (tons)	Time window
1	(69.1, 99.4)	1	[2,5]	11	(54.8, 118.7)	0.8	[9,12]
3	(57.1, 276.5)	0.7	[9,10]	11	(54.8, 118.7)	0.8	[15,17]
3	(60.4, 58.9)	0.5	[7,11]	13	(58.1, 110.4)	1.1	[5,8]
4	(69.8, 147.5)	0.5	[8,11]	15	(64.5, 102.2)	0.3	[4,7]
5	(60.4, 58.9)	0.4	[14,6]	12	(68.5, 14.5)	1.0	[12,14]
6	(60.4, 139.3)	0.7	[13,5]	17	(56.9, 194.0)	0.4	[3,5]
7	(58.4, 43.4)	0.6	[9,12]	14	(57.8, 6.3)	0.5	[17,21]
8	(59.7, 31.0)	0.3	[4,6]	18	(63.5, 89.8)	0.2	[10,13]
9	(67.0, 235.1)	0.5	[10,4]	16	(56.2, 285.7)	0.2	[18,20]
10	(58.1, 222.8)	0.2	[20, 2]	20	(62.8, 42.8)	0.7	[11,16]
11	(61.8, 92.1)	0.1	[11,3]	19	(64.0, 241.0)	0.2	[16,20]

2. Definition of damage constraints

The timeliness and decay rate of delivery directly affect the tasting quality and market sales of crabs. Increasing the decay rate is the constraint condition, and the shorter the delivery lead time, the better. Suppose there is product loss in the distribution process, the residual quality rate, that is, the residual quality rate of hairy crab loss generated in the distribution process from 0 in the distribution center to the customer’s distribution point, is the quality constraint of distribution. The life cycle of crab starts from the freshness of fishing landing to the freshness of finishing the car, and ends with the freshness of crab decay to 0. $\mu \in (0,1)$ i $\mu_{0i} \in (0,1)$ μ

3. Validation of algorithm effectiveness

The above hybrid genetic algorithm was used for redesign, assuming population size: N=50; Chromosome length: L=21; Maximum number of iterations: =500; L_s Crossover probability: =0.3; P_c Variation probability =0.1, mainly from the total cost in the distribution process by using the improved genetic algorithm VRP solution, according to the distribution center and 20 direct stores geographical location, acceptable delivery time window, demand and other basic information, the introduction of decay cost (2) formula, on the basis of (3) to consider the actual probability of variation, the minimum total cost of distribution objective function is: P_m

$$minz = c\sum_{k\in M}\sum_{i\in N}\sum d_{ij}x_{ijk} + c_0\sum_{k\in M}\sum_{j\in N}x_{0jk} + \sum_{k\in M}P_{L(k)} + \sum_{i\in I}P_{T(i)} + \sum_{s\in I}P_{m(s)} + min\mu \quad (4)$$

Bring the determined value obtained from the above solution into the original problem to solve, and if the new solution is less than the previous solution, it will be set as the new optimal solution. Determine whether the iteration meets the stop condition or convergence condition. If the maximum number of iterations has reached 500, the iteration is stopped, the optimal solution (i.e. the minimum value) is selected, and the corresponding delivery point ordering is the optimal distribution scheme. Based on 10 new delivery points in real time, taking vehicles as a unit group, the calculation time of each group is about 30s, and the iteration results in a minimum total cost of 1611, which can obtain a lower total cost value and the corresponding path planning in a short time. CPLEX is used to calculate the total cost value for comparison, and the effectiveness of this algorithm is measured. Due to the too long time for solving CPLEX of 4 groups, the calculation time of each group is set to 4800s, and the minimum value is not obtained within this time, so 5 groups are reset, and the target value is 1829, which is 13.5% higher than the target value of this study. MATLAB software is used to make the spatial route planning diagram under the mixed genetic algorithm. Due to the secondary demand generated by the direct store 3 and the direct store 11, the CPLEX calculation speed is slow, and the planning diagram of 5 lines is calculated. Compared with the road map made by the two methods, the optimization of the distribution route can be clearly seen after adding 10 delivery points in real time. Through the improved hybrid genetic algorithm, under the constraint condition of the maximum iteration number of 500, combined with the decay coefficient, the optimal solution of the distribution cost corresponding to the new distribution route is 1611, which is 13.5% lower than the 1829 obtained by CPLEX algorithm.

To sum up, considering the rot loss constraint, using the improved hybrid genetic algorithm to compute the path optimization is a complex system optimization problem. The sensitivities of various constraints on the total cost are as follows: Transportation cost of refrigerated truck based on driving distance, driving time, fuel cost, fixed cost of delivery, damage cost determined by cargo value and transportation time, additional cost beyond the maximum driving distance, and penalty cost beyond the time window limit, etc. The above improved hybrid genetic algorithm overcomes the problem of prematurity and convergence of a single heuristic algorithm. The above results can be obtained in a relatively short time.

IV. Conclusions and Suggestions

The above cost optimization scheme considering the fresh and fresh decay rate of hybrid genetic algorithm is based on certain constraints and environmental assumptions, in the actual situation under the uncertain conditions of the study of the problem needs to be further discussed. From the results of 20 distribution terminals, it can be seen that the study population size is small when the initial state is determined due to the multi-state parallel, so the new state is generated by the method of full permutation random extraction. In the process of real-time distribution, considering the rot rate for the real-time appearance of various dynamic delivery points, the optimization of dynamic distribution routes is essentially realized through cost accounting. Therefore, this paper constructs a cold chain logistics distribution cost optimization model that comprehensively considers the cost, time window constraint, decay rate and other factors, which has certain practical application value.

In addition, taking cost driver as the medium, the distribution activity is dynamically tracked, and the sensitivity of each parameter to affect the total cost can be obtained through the calculation of the improved algorithm. In addition to the distribution point distribution, distribution quantity and other parameters are determined by the customer, the sensitivity of the remaining optimal solution is as follows: transportation cost, fixed cost, decay cost, additional cost, penalty cost, etc. Additional costs due to improper distribution management, such as cargo warehousing, repeated delivery, staff errors and other reasons, as well as the impact of traffic and weather and other irresistible factors on distribution costs, are not within the scope of this paper, but their impact will lead to changes in the above parameters, by changing the number of iterations can obtain a more stable cost optimization scheme.

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