

Fresh Agricultural Products Distribution Optimization Considering Decaying Factors

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Abstract. The vehicles distribution of fresh agricultural products is a key between agricultural products retailers and customers. Therefore, optimization of distribution vehicles routing is a very important problem. Aiming at the goal of the lowest transportation cost of fresh agricultural products and the minimum decay variance of agricultural product, this paper constructs a multi-objective model considering the influence of decaying factors to optimize the distribution of fresh agricultural products, and then ant colony algorithm for solving the model is proposed. The results show that the established model and the designed algorithm are effective, which can provide theoretical basis and practical guidance for the routing optimization of fresh agricultural vehicles.

1. Introduction

In recent years, the output and circulation of fresh agricultural products in China have increased year by year, which raises higher management control requirements for all links between the delivery of fresh agricultural products from the origin to the consumers.

There are relatively many research results in logistics research so far. Zhang et al. [1] optimized the algorithm for solving the routing problem of cold chain product distribution, and adopted the tabu search algorithm to improve the accuracy and efficiency of the model. Verbic [2] started from the prediction parameters of cold chain product decaying, analyzed the decaying process of perishable products in the process of cold chain distribution, functioned the decaying degree with time and considered it in the vehicle routing model. Montanari [3] used two classical algorithms in mathematics to solve the cold chain logistics delivery sequence planning problem and improved the scientificity of the model. Jessup and Herrington [4] minimized the distribution cost as an optimization target when studying the impact of insufficient seasonal vehicles on fresh food distribution. Lim et al. [5] integrated two methods for solving the cold chain logistics distribution vehicle routing model: genetic algorithm and tabu search algorithm, which proved that the two algorithms have advantages in local optimization and overall optimization. The authors successfully combined the two algorithms to make the algorithm more capable of searching for a better solution. Amorim and Almada-Lobo [6] discussed the factors affecting the perishability of agricultural products in the process of agricultural product distribution, and constructed an optimization model that minimizes the freshness of distribution products to maximize the freshness of products. Svald and Stirn [7] established a fresh vegetable distribution model under the constraints of time, and solved the model by tabu search algorithm. Brito et al. [8] studied the problem of frozen food distribution based on uncertain time and solved the problem using fuzzy optimization method. Kassem and Chen [9] took into account the customer's time requirements and explored the problem of vehicle routing for both picking and delivery. Govindan et



al. [10] discussed the problem of cold chain logistics, optimized the economic and environmental benefits of fresh products in distribution, and constructed a routing optimization model with time windows.

In the article on the perishability of fresh agricultural products transportation, Osvald and Stirn [11] formulated the VRPTW with the change of travel time for the distribution of fresh vegetables. The objective function was the minimum of the transport distance, the time, the delay cost of delaying customer service, and the cost associated with perishability. In this model, the cost of decaying was calculated by multiplying the load transported in each arc by the required time. Hsu et al. [12] considered the randomness of the perishable food delivery process and proposed a random VRPTW model to obtain optimal delivery routes, loads, fleet dispatching and departure times for delivering perishable food from a distribution center, and the problem was solved by a heuristic algorithm.

At present, there are several characteristics of the research on vehicle routing optimization of fresh agricultural products. For one thing, most literatures design vehicle routing optimization problems from the perspective of models, considering transportation cost, cooling cost, and transportation type of vehicles during fresh transportation. For another thing, existing research uses intelligent algorithms or corresponding improved algorithms to solve the designed model, while the research on the value decay of fresh agricultural products is less. The contribution of this paper is that from the perspective of suppliers, one is to consider cost control, establish a vehicle routing optimization model with minimum cost, and the second is to establish a model of the minimum variance of corrupt agricultural products from the decaying factor of fresh agricultural products. The model replaces the traditional satisfaction model, which is measured by the mean value, making the model more convincing.

2. Problem description and model construction

2.1 Problem description

In this paper, the problem of distribution of fresh agricultural products affected by decaying factors is described as follows: A fresh agricultural product distribution center needs to complete the distribution task for a specific customer group, and the road network status of the distribution is more complicated. The distribution center has a limited number of delivery vehicles, and the delivery time required by the customers is indicated by a soft time window. The vehicle on each line has a corresponding penalty cost when its arrival time earlier or later than the delivery time window requested by the customer. It is required to arrange a suitable economic route for the delivery vehicles according to the actual road network condition. The objective is to minimize the total distribution cost and the decay variance of rotted agricultural product.

2.2 model construction

$G = (V, E)$	the undirected complete graph of the networks
$V = \{0, \dots, n, \}$	the node set, including the distribution center
$V' = V \setminus \{0\}$	the node set of customers, without the distribution center
K	the total number of vehicles
d_i	the demand of customer i
C	the cost of each unit distance
S_{ij}	distance from customer i to customer j
θ	decaying rate of fresh agricultural products
Q	the vehicle capacity
y_0^k	the departure time from the distribution center of vehicle k
y_i^k	the arrival time of vehicle k at customer i
p	unit loss price of fresh agricultural products
t_{ij}	time from customer i to customer j
u_i	service time of customer i

$[r_i, s_i]$	the time window of customer i
c_1	penalty coefficient earlier than the time window
c_2	penalty coefficient later than the time window
M	infinite coefficient
$x_{ij}^k = \begin{cases} 1, \text{arc}(i,j) \text{ is crossed by vehicle } k \\ 0, \text{otherwise} \end{cases}$	
$z_i^k = \begin{cases} 1, \text{customer } i \text{ is serviced by } k \\ 0, \text{otherwise} \end{cases}$	

According to the description of the problem and symbol, the multi-objective optimization model of fresh agricultural products vehicle routing problem can be formulated as the following:

$$\min z1 = \sum_{i \in V} \sum_{j \in V} \sum_{k \in K} C S_{ij} x_{ij}^k + p \sum_{i \in V'} \sum_{k \in K} z_i^k * Q * \theta * (y_i^k + u_i - y_0^k) \quad (1)$$

$$+ c_1 \sum_{i \in V'} \max[(r_i - y_i^k), 0] + c_2 \sum_{i \in V'} \max[(y_i^k - s_i), 0]$$

$$\min z2 = \frac{1}{n} \sum_{i \in V'} [\theta * d_i * (y_i^k + u_i - y_0^k) - \frac{\sum_{i \in V'} \sum_{k \in K} \theta * d_i * (y_i^k + u_i - y_0^k)}{\sum_{k \in K} Q}]^2 \quad (2)$$

Subject to:

$$\sum_{k \in K} z_0^k = m \quad (3)$$

$$\sum_{k \in K} z_i^k = 1 \quad \forall i \in V' \quad (4)$$

$$\sum_{i \in V'} x_{ij}^k = z_j^k \quad \forall j \in V, k \in K \quad (5)$$

$$\sum_{j \in V'} x_{ij}^k = z_i^k \quad \forall i \in V, k \in K \quad (6)$$

$$\sum_{i \in V} \sum_{k \in K} x_{ij}^k = 1 \quad \forall j \in V' \quad (7)$$

$$\sum_{i \in V'} d_i * z_i^k \leq Q \quad \forall k \in K \quad (8)$$

$$y_i^k \geq y_0^k + t_{0i} - (1 - x_{0i}^k)M \quad \forall i \in V', k \in K \quad (9)$$

$$y_{i+1}^k \geq y_i^k + t_{i(i+1)} + u_i - (1 - x_{i(i+1)}^k)M \quad \forall i, i+1 \in V', k \in K \quad (10)$$

$$y_i^k \geq 0 \quad i \in V', k \in K \quad (11)$$

The objective function (1) minimizes the total cost, including the transportation cost, the rotten cost caused by transportation, and the penalty cost. The objective function (2) minimizes the decaying variance of the transported agricultural products. Constraint (3) means that m vehicles depart from the distribution center. Constraint (4) indicates that each customer can only be served by one vehicle. Constraint (5) - (6) means that vehicles must depart after serving one customer. Constraint (7) ensures that each customer is served once by exactly one vehicle. Constraint (8) is the capacity constraints which state the total goods carried by vehicle k must not exceed its capacity. Constraint (9) - (10) represent the time constraint to each customer. Constraint (12) specifies that y_i^k is a decision variable.

3. Algorithm

The multi-objective optimization model of the vehicle routing problem of fresh agricultural products considering the influence of decaying factors belongs to the NP-hard problem. For this problem, the ant colony algorithm(ACO) is used to solve it.

3.1 Basic principle of ACO

The researchers found that ants mainly showed two characteristics when searching for food in an area: (1) ants will instinctively release a certain amount of information when they are researching for food; (2) ants are sensitive to the surrounding environment, they are instinctive to the distance from the source of food and the information released by the same ants. In most cases, the route with the highest concentration of pheromone is selected.

3.2 The process of ACO

First, randomly distributing each ant to each city node and initializing the pheromone quantity.

Second constructing taboo table. Initially, the taboo table stores the first city node number where the ant is located. Each ant selects the next node to be traversed according to the transfer rule. Each time a node is traversed, the node number is added to the taboo table to prevent the ant pair. The elements in the taboo table are traversed twice. When all the numbers of the city nodes are stored in the taboo table, it means that the ant has completed a traversal, and the program completes an iteration. At this time, the total length of the path taken is calculated, and the local pheromone is updated.

Third, updating global information. After the end of one iteration of the algorithm, the global pheromone update is performed on the path that has been traversed. Comparing the total length of all ant search paths and store the optimal solution for the current optimization. The taboo table is cleared, repeat the step two.

When the number of iterations reaches the set maximum number of iterations, it indicates that the stop condition has been met, the loop is exited. The current shortest route length and the corresponding shortest route to it are output.

4. Computational results

4.1 Initial data

A distribution center has 4 vehicles with a load capacity of 8t, which is responsible for distribution to 20 customers. The speed of the vehicle is 30km/h, the transportation cost of the vehicle is $C=2$ yuan/km, and the unit loss price of agricultural products is $p=15$ yuan, time window penalty factor $c_1 = 2$ yuan /min, $c_2 = 10$ yuan/min. It is required to arrange the routes reasonably so that after all the distribution tasks are completed, the total cost is the least, and the variance of the agricultural product decay is the smallest. The data of the distribution center and customer needs are shown in table 1.

Table 1. Data about distribution center and customer

Number of customer	X-axis(km)	Y-axis(km)	Demand(t)	Starting time(min)	Ending time(min)	Service time(min)
0	35	35	0	0	0	0
1	41	49	1	161	181	10
2	35	17	1.2	58	80	10
3	55	20	1.9	129	159	10
4	20	50	0.5	81	91	6
5	55	60	1.6	97	127	14
6	30	60	1.6	104	134	15
7	30	5	0.8	61	90	7
8	10	20	1.9	45	85	17
9	45	65	0.9	126	136	8
10	65	20	0.6	172	182	5
11	55	45	1.3	96	126	12
12	50	35	1.9	53	73	13
13	20	40	1.2	67	88	9

14	15	60	1.7	120	150	13
15	5	30	2	137	167	3
16	65	35	0.3	153	163	2
17	55	5	2.9	48	78	20
18	45	10	1.8	75	107	15
19	10	43	0.9	70	105	10
20	45	20	1.1	52	72	10

The number 0 is the distribution center, and the rest are the customers.

In the ACO, the number of ants is 30, the pheromone important factor is 1, the heuristic function important factor is 0.5, the pheromone volatilization factor is 0.1, and the number of iterations is 300. In this paper, we consider a double-objective problem in the study of the distribution path optimization of fresh agricultural products considering the influence of decaying factors. The linear weighting method is used to solve the double-objective problem. The weight of total cost is k_1 and the weight of the decay degree is k_2 . The rate of decaying of fresh agricultural products $\theta=0.2, 0.6$, and the corresponding results are obtained according to different weights.

4.2 Calculation result

When $\theta=0.2$, the optimal value of total cost is 2158004.40 yuan, and the optimal variance of decay degree is 12907.68. When k_1 and k_2 take different weights, the corresponding delivery situation is as shown in the following tables and the following figures.

Table 2. $\theta=0.2, k_1=0.1, k_2=0.9$

$\theta=0.2$	$k_1=0.1, k_2=0.9$
the route of first vehicle	0->12->11->16->3->20->2->0
the route of second vehicle	0->1->9->5->19->13->4->14->0
the route of third vehicle	0->6->17->10->18->7->0
the route of fourth vehicle	0->8->15->0

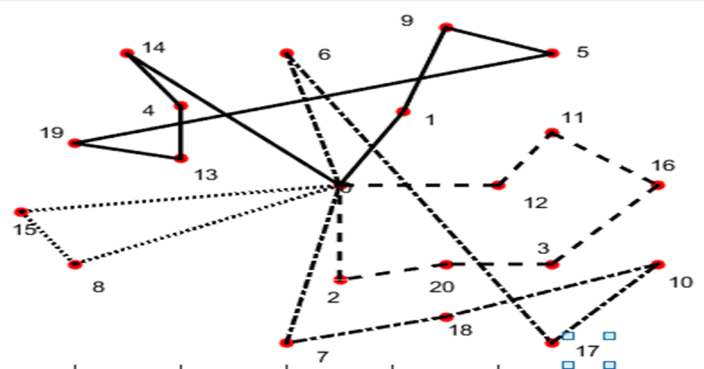
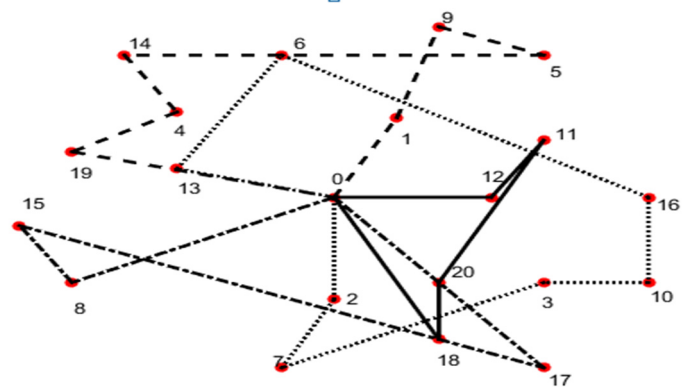


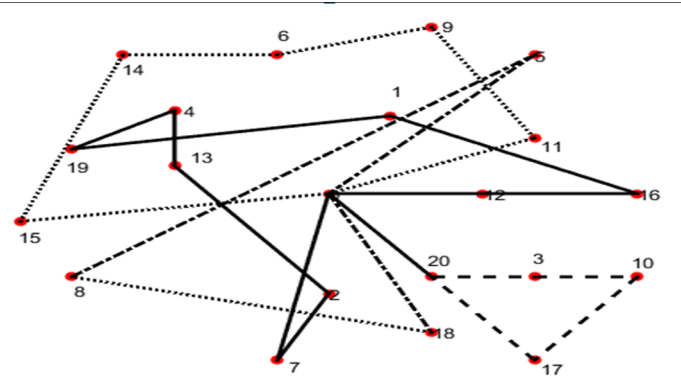
Figure 1. $\theta=0.2, k_1=0.1, k_2=0.9$

Table 3. $\theta=0.2, k_1=0.5, k_2=0.5$

$\theta=0.2$	$k_1=0.5, k_2=0.5$
the route of first vehicle	0->12->11->20->18->0
the route of second vehicle	0->1->9->5->14->4->19->0
the route of third vehicle	0->13->6->16->10->3->7->2->0
the route of fourth vehicle	0->8->15->17->0

Figure 2. $\theta=0.2$, $k_1=0.5$, $k_2=0.5$ Table 4. $\theta=0.2$, $k_1=0.9$, $k_2=0.1$

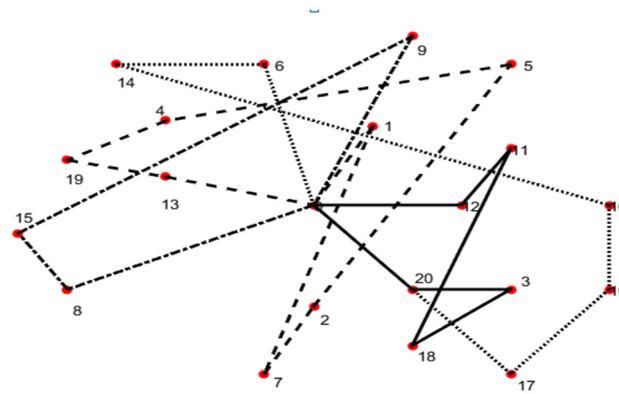
$\theta=0.2$	$k_1=0.9$ $k_2=0.1$
the route of first vehicle	0->12->16->1->19->4->13->2->7->0
the route of second vehicle	0->20->3->10->17->0
the route of third vehicle	0->11->9->6->14->15->0
the route of fourth vehicle	0->18->8->5->0

Figure 3. $\theta=0.2$, $k_1=0.9$, $k_2=0.1$

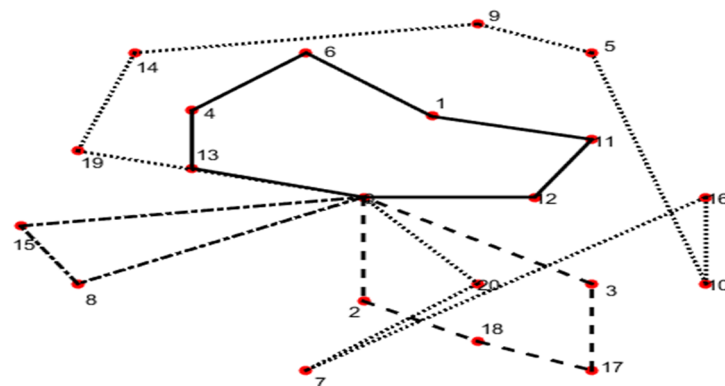
When $\theta=0.6$, the optimal value of total cost is 6350823.45 yuan, and the optimal variance of decay degree is 5937.21. When k_1 and k_2 take different weights, the corresponding delivery situation is as shown in the following tables and the following figures.

Table 5. $\theta=0.6$, $k_1=0.1$, $k_2=0.9$

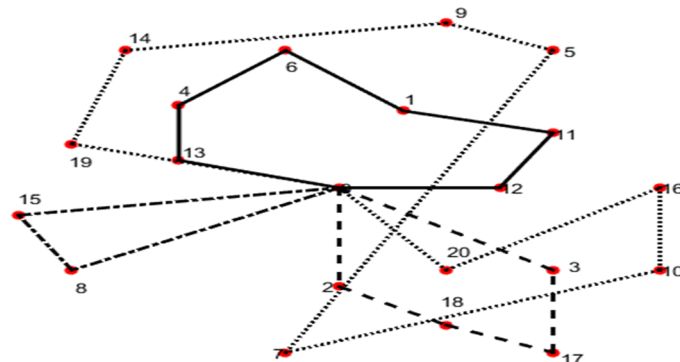
$\theta=0.6$	$k_1=0.1$ $k_2=0.9$
the route of first vehicle	0->12->11->18->3->20->0
the route of second vehicle	0->1->7->2->5->4->19->13->0
the route of third vehicle	0->6->14->16->10->17->0
the route of fourth vehicle	0->8->15->9->0

Figure 4. $\theta=0.6$, $k_1=0.1$, $k_2=0.9$ Table 6. $\theta=0.6$, $k_1=0.5$, $k_2=0.5$

$\theta=0.6$	$k_1=0.5$ $k_2=0.5$
the route of first vehicle	0->12->11->18->3->20->0
the route of second vehicle	0->2->18->17->3->0
the route of third vehicle	0->20->7->16->10->5->9->14->19->0
the route of fourth vehicle	0->8->15->0

Figure 5. $\theta=0.6$, $k_1=0.5$, $k_2=0.5$ Table 7. $\theta=0.6$, $k_1=0.9$, $k_2=0.1$

$\theta=0.6$	$k_1=0.9$ $k_2=0.1$
the route of first vehicle	0->12->11->1->6->4->13->0
the route of second vehicle	0->2->18->17->3->0
the route of third vehicle	0->20->16->10->7->5->9->14->19->0
the route of fourth vehicle	0->8->15->0

Figure 6. $\theta=0.6$, $k_1=0.9$, $k_2=0.1$

Through the comparison of the above charts, it can be found that the decay rate of fresh agricultural products has a great influence on the route of distribution. As the decay rate increases, suppliers are more inclined to make vehicles arrive near rather than long-distance transportation. At the same time, suppliers' preference for distribution cost and rotten variance also affects the routing choice of distribution.

5. Conclusion

Decaying is an important characteristic of fresh agricultural products. In this paper, the decay degree of agricultural products is assumed to be a certain value, and the decay degree variance is introduced to measure the customer satisfaction. On this basis, a multi-objective optimization model with the minimum distribution cost and the minimum variance of decay degree is established.

The results show that it is effective to consider the multi-objective optimization model of fresh agricultural products distribution routes and its solving algorithm considering the influence of decaying factors. It can provide theoretical basis and practical guidance for the decision-making optimization of fresh agricultural product distribution routes, the analysis results can be used as a basis for effective control of parameters in model applications.

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