The Optimal Route Selection Model of Fresh Agricultural Products Transportation Based on Bee Colony Algorithm

Qingqing Ren
Hainan Vocational University
College of Economics and Management, Haikou, 570100, China

***Abstract*—In order to optimize the distribution route of fresh agricultural products and reduce the distribution cost, the optimal route selection model of fresh agricultural products transportation based on bee colony algorithm is constructed. After establishing the transportation road network model of fresh agricultural products and analyzing the transportation road information, the transportation road network zoning is realized by the dynamic zoning method of transportation road network based on spectral clustering algorithm, taking the unblocked area and congested area as the zoning purpose. Based on the traffic zoning information, the transportation route optimization model of fresh agricultural products with time window is constructed. Solved by bee colony algorithm to obtain the distribution route of fresh agricultural products with the lowest distribution cost and the highest customer satisfaction. The experimental results show that the model can choose the fresh agricultural products distribution route with the lowest distribution cost and the highest customer satisfaction under the two working conditions of smooth traffic and congestion.**

Keywords—Bee colony algorithm; fresh agricultural products; transportation; optimal route selection; road network model; spectral clustering

I. Introduction

Fresh agricultural products refer to primary products such as fresh fruits that can be sold directly on the shelf without further production. At present, fresh agricultural products mainly include fresh vegetables, fruits, flowers, eggs, milk, raw poultry, aquatic products and fresh meat products. These kinds of products occupy a major position in fresh agricultural products, which are traditionally called the three fresh products - fruits and vegetables, meat and aquatic products [1].

Facing the high demand of fresh agricultural products market, the problem to be solved is to reduce the operating cost in the material distribution process as much as possible on the premise of ensuring customer satisfaction. According to the existing research and exploration results, the logistics industry of fresh agricultural products has broad prospects, but the current situation is still relatively lagging behind. The development of the logistics industry related to the distribution of fresh agricultural products is still unbalanced, which needs to be further improved and explored [2]. It is the mission of all kinds of fresh agricultural products logistics parties to do a good job in the transportation and distribution of fresh agricultural products. This requires the promotion and combination of new electronic data tools and logistics industry to further narrow the gap between logistics. Therefore, for fresh agricultural products, we should not only pay attention to the “quality” and “freshness” distribution of fresh agricultural products, but also make full use of information and communication technology and Internet platform, and let the Internet deeply integrate with the sales of fresh food [3]. To solve various problems in the distribution of fresh agricultural products, we need to start with the vehicle route planning between the distribution of fresh agricultural products. At the same time, doing a good job in the route planning between the distribution of fresh agricultural products is also of great significance for solving the obstacles of material sharing and symbiosis between urban and rural areas [4].

The key to material sharing is to do a good job in logistics distribution. More exploration directions in the distribution mode of fresh agricultural products focus on the transportation of fresh agricultural products between urban and rural areas [5]. Joint distribution is a widely adopted logistics distribution method. In brief, it means that the goods distribution orders of multiple companies are distributed and transported by a special logistics company. The logistics company reasonably arranges the distribution time and the transportation path of each order according to the goods demand of different orders and the characteristics of its own means of transportation, so as to achieve the same effect as much as possible [6]. In foreign countries, crowdsourcing platforms are usually established to create relevant information databases to provide basic support for the whole distribution activities. It can exchange information between distribution centers, customers and merchants, so as to maximize distribution revenue and optimize efficiency. In terms of product logistics and distribution, Marcus Bowles studied the application possibility of nanotechnology in the logistics management of the circulation of fresh agricultural products [7]. Omar Ahumada and Rene Villalobos proposed a stochastic tactical planning model for the production and distribution of fresh agricultural products based on the distribution climate and the information of customers changing at any time, which reduced the uncertainty encountered by the fresh agricultural products industry when equation ting growth and distribution plans. As a consumable, the final value of fresh agricultural products depends on the product quality at the time of delivery, including perceived taste, freshness, etc. While the transportation costs, labor and other costs consumed in the whole distribution process affect the final profit and benefit of fresh agricultural products. Therefore, how to reasonably select the distribution mode on the basis of balancing many factors is the top priority, and many factors are interrelated. A good game between various influencing factors is very important for goods suppliers and final consumers to achieve a win-win situation.

Combined with the above background and research foundation, in order to improve the customer satisfaction and transportation cost of fresh agricultural products transportation and distribution, this paper constructs a model of optimal transportation route selection for fresh agricultural products based on bee colony algorithm, and verifies its effectiveness through experiments. The reason for choosing the bee colony algorithm is that it does not need to know the specific special information of the problem to be optimized, and its ability to solve multivariable function optimization problems is excellent. It can choose the fresh agricultural product distribution route with the lowest distribution cost and the highest customer satisfaction, providing a more valuable reference method for the industry to improve service quality and operational efficiency.

II. Related Works

In order to optimize the calculated effect of the path planning scheme in the logistics industry, experts and scholars in the industry have carried out a lot of relevant research. Y. In order to explore the impact of the free trade zone on regional logistics services, Gong et al. selected the adjacent area of a free trade zone in Chongqing as the research object, and used SWOT model to analyze the impact of the free trade zone on international logistics business. Combined with genetic algorithm, an international logistics route planning model is designed. The experimental results show that the model effectively reduces the time consumption of international logistics business [8]. S. O. Ekici et al. found that logistics performance is a key indicator to determine the operating efficiency of the logistics industry. Therefore, they used the enhanced naive Bayesian network and partial least squares method to build a path planning model that considers logistics performance. The experimental results show that the logistics transportation route designed with this model has higher customer satisfaction than that designed with traditional optimization methods [9]. D. T. Xiao's research team believes that the current agricultural product logistics in Heilongjiang Province is relatively inefficient due to the constraints of climate, transportation, supporting facilities and other factors, so it combines convolutional neural network algorithm to build Heilongjiang agricultural product transportation route planning algorithm. After testing, it is found that the transportation cost of the transportation route designed by this model is 15.9% lower than traditional methods [10]. 10. Zhao et al. found that the circulation efficiency of agricultural products in Liaoning Province is insufficient, and some agricultural products have suffered great losses after reaching the transportation destination. Therefore, the author team put forward a series of suggestions on improving transportation efficiency on the basis of understanding the logistics status of local fresh agricultural products [11]. 10. Huang et al. established a real-time and accurate cold chain logistics management system to solve the problems of loose circulation, inaccurate information transmission, untimely processing, and serious loss of fresh agricultural products in the traditional cold chain logistics management mode of agricultural products. In this system, the e-commerce platform is combined with the cold chain logistics network, and the physical real-time emergency management mode of the cold chain of agricultural products is divided into the sub mode of “production warehouse+cold chain”, the sub mode of “e-commerce+cold chain express+smart cabinet” and the sub mode of “cold chain storage+new retail chain”. The test results show that the performance evaluation score of emergency management of fresh agricultural product transport enterprises has been significantly improved after using this system [12].

To sum up, although people have carried out a lot of research to improve the logistics transportation efficiency of all kinds of goods before, most of them only consider one aspect of improving logistics services, such as cost time, customer satisfaction, etc. And few of them consider multiple logistics transportation goals. This research hopes to optimize the cost of agricultural product transportation and customer satisfaction at the same time, which is also the scientific contribution of this research.

III. Optimal Route Selection Model of Fresh Agricultural Products Transportation Based on Bee Colony Algorithm

A. Transportation Network Model of Fresh Agricultural Products

According to the characteristics of the road network description of fresh agricultural products transportation, the road network model shall meet the following requirements:

1) Description of geometric characteristics and topological structure of fresh agricultural products transportation network. It includes the location, physical connection, number of lanes, length, width, curvature and intersection of fresh agricultural products transportation roads.

2) Expression of basic modeling unit of fresh agricultural products transportation network. The traffic organization remains unchanged as the principle of road network modeling, that is, the number of lanes in the modeling unit remains unchanged, the lane attributes remain unchanged, and the connectivity relationship between lanes remains unchanged.

3) Description of transportation lanes of fresh agricultural products and topological relationship between lanes. It describes the connectivity of lanes between different basic modeling units, including clarifying the upstream and downstream lanes of each turn, the connectivity of adjacent lanes, etc.

According to the above analysis, the transportation network of fresh agricultural products can be described as a layered network including sub sections, sub section nodes, directed sub sections, lanes and lane connectors. The road network model is divided into two parts: physical layer and logical layer. The graph is used to represent the physical layer Ω_q of the road network model. It is a non-empty set of vertices and edges.

$\Omega_q = (\Gamma, C)$ is the sub segment node set of $\Gamma = \{\Gamma_j\}$. Ω_q representing the endpoint of the sub segment. C is the sub segment set of $C = \{c_j = [\Gamma_p, \Gamma_q]\}$, Γ_p and Γ_q are the two endpoints of the sub segment c_j. Based on the physical layer of the model, the logical layer $\Omega_l = (\Gamma, \partial, Ka, \Omega_{Ka})$ of the model is defined to express the logical connectivity of fresh agricultural products transportation network. Among them, ∂ is the directed sub section, which represents the sub sections with different traffic flows. Based on the directed sub section, the lane elements are described, such as the directed sub section where the lane is located, the number of lanes in the driving direction, lane width, etc.

Based on the above theory, the first layer of the basic road network for the transportation of fresh agricultural products is composed of basic modeling units, including two elements: sub sections and sub section nodes. At the same time, on the basis of sub sections, the sub sections are divided into different directional sub sections according to the traffic flow direction; the second layer refines the lane description based on the first layer, including two elements: carriage lanes and lane connectors for fresh agricultural products. The structure of fresh agricultural products transportation network is shown in Fig. 1.

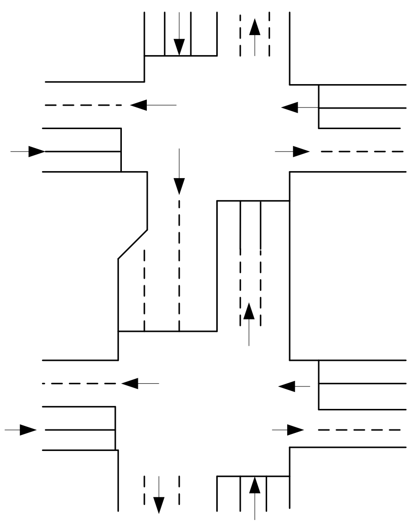

Fig. 1. Schematic diagram of road network.

B. Dynamic Zoning Method of Transportation Network Based on Spectral Clustering Algorithm

In the transportation network model of fresh agricultural products constructed in Section 2.1, the dynamic zoning method of transportation network based on spectral clustering algorithm is used to partition the transportation network of fresh agricultural products. The zoning is mainly to ensure that the transportation of fresh agricultural products can reasonably select the operation path and avoid the traffic congestion area, so as not to increase the transportation cost of fresh agricultural products, but also avoid excessive transportation time of fresh agricultural products and customer dissatisfaction.

Spectral clustering algorithm is a new research hotspot in the field of machine learning in recent years. It is based on the theory of spectral graph. Its essence is to transform the clustering problem into the optimal partition problem of graph, use the similarity relationship between data points to establish a similarity matrix, obtain the multi feature vectors of the matrix, and use them to cluster different data points. Compared with other algorithms, spectral clustering algorithm is simple, easy to implement and not easy to fall into local optimal solution, which is very suitable for many practical problems. The algorithm has been applied to image segmentation, speech recognition, computer vision, text mining and other research fields. Traditional clustering algorithms such as k-means algorithm and fuzzy clustering algorithm do not involve the connection relationship of graph in clustering. Spectral clustering algorithm can realize the segmentation of graph well and cluster a variety of spatial data in this paper. And the zoning research of urban road network needs to consider the connection relationship and distance of traffic flow, signal cycle and actual road network at the same time, so it is appropriate to use spectral clustering method.

Combined with the zoning principle of fresh agricultural products transportation network and the attributes of road intersections, this paper determines the relevant factors for constructing the spectral clustering similarity matrix, and selects the three factors of traffic flow saturation, signal cycle, geographical location of the intersection and the road connection relationship matrix for road network zoning. The first two indicators reflect the actual traffic flow attributes of the intersection, corresponding to the traffic flow saturation principle and the signal cycle principle, and the latter index reflects the topology attribute of the intersection, corresponding to the distance principle.

The traffic flow saturation BH of fresh agricultural products transportation network can be calculated by equation.

$$BH = \frac{CL}{TX} \tag{1}$$

Where, CL and TX are the traffic flow on the fresh agricultural products transportation road respectively. The actual traffic capacity, signal cycle and geographical location of the intersection can be obtained through actual investigation.

In this paper, the NJW algorithm in the k-way division criterion of spectral clustering algorithm is used for dynamic zoning of road network. According to the specific analysis process of NJW multi-channel spectral clustering algorithm and combined with the relevant factors of road network zoning, the specific steps of road network zoning based on spectral clustering algorithm are as follows:

1) Combined with Fig. 1, calibrate the topological structure of fresh agricultural products transportation network and the number of each intersection and road. JX and DL are the intersection and road in the study area.

2) Calculate the similarity matrix Bc. Standardize the original data of the three factors of traffic flow saturation, signal period and intersection geographical location of the road network model shown in Fig. 1, then calculate the similarity between nodes, and calculate the intersection similarity matrix Bc in combination with the road connection relationship matrix.

$$Bc_{ij} = \begin{cases} \exp\left(-\frac{\left\| ys_i - ys_j \right\|}{2\rho^2} \right) & i \neq j \\ 0 & i = j \end{cases} \tag{2}$$

Where, ρ is a parameter selected by people in advance. The larger its value is, the more significant the classification effect is. ys_i and ys_j represent the traffic factors of the i th and j th intersections respectively.

3) Calculate the Laplace matrix lp covering the transportation and traffic information of fresh agricultural products.

$$lp = JH^{-\frac{1}{2}} \left(lp \cdot JH \right)^{-\frac{1}{2}} \tag{3}$$

Where JH is the diagonalization matrix obtained from matrix Bc.

4) Calculate the first maximum eigenvalues tz_n and the corresponding traffic information eigenvector χ_n of the Laplace matrix lp. The transportation information of fresh agricultural products can be obtained, and the corresponding eigenvectors are arranged according to the order of eigenvalues to form a matrix υ.

5) Transform the row vector of the characteristic vector matrix υ of fresh agricultural product traffic information into the unit vector to obtain the matrix Ψ.

6) Regard each row of matrix Ψ as a data point in three-dimensional space, and K clusters are obtained by K-means algorithm.

7) Through step 6, the classification results of the best intersection are obtained, the classification results are visually displayed, and appropriate zoning adjustments are made according to the actual situation.

According to the above steps, the zoning results combined with the road network flow can be obtained. When the zoning results cannot meet the traffic flow performance of each road network area after zoning, the road network zoning needs to be adjusted according to the real-time data of traffic flow.

C. Establishment of the Optimal Route Selection Model for The transportation of Fresh Agricultural Products

Combined with the transportation traffic information of fresh agricultural products, the optimal route selection model of fresh agricultural products transportation is constructed, and the model is solved by bee colony algorithm to obtain the optimal route of fresh agricultural products transportation.

D. Description of Transportation Problems of Fresh Agricultural Products

The vehicle routing optimization problem of fresh agricultural products studied in this paper is to consider a distribution center. The distribution center uses multiple transportation vehicles for collaborative distribution. All vehicles start from the distribution center and distribute in the area composed of multi customer distribution nodes. The location of each distribution node is determined, the demand of each distribution node is known, and the distribution service to all customer distribution nodes is completed within the time window required by each customer. All vehicles eventually return to the distribution center.

A single distribution center is set to deliver goods to the k th customer (or distribution node). The freight volume of the j th distribution traffic route is Υ, the time window is $\left[FH_j, KH_j \right]$. The unloading time is αt_j, the delay cost per hour is s_j, and the average speed and shortest distance between customers and between distribution centers and customers are u_{ji} and e_{ji} respectively; n trucks can be used to transport goods, including m_q trucks in group q, with a loading capacity u_q, a driving cost g_q of per vehicle per kilometer, a waiting cost s of per hour, overtime allowance dr and baggage allowance r of per hour respectively; The vehicle must return to the original distribution center on the same day, and the demand point of p vehicle distribution of group q is expressed as m_{qp}.

IV. Construction of Objective Function

Compared with foreign countries, the domestic cold chain transportation of fresh agricultural products is still in the primary stage, but it has also achieved some results in the development of relevant distribution system and technology (Huang et al. 2020). Through the above analysis, it can be seen that distribution is an important part of the cold chain logistics system. Optimizing the distribution route helps to improve the efficiency of cold chain logistics. Due to the lack of scientific and reasonable planning for the distribution route of fresh agricultural products, it is difficult to meet the daily needs of customers in time. Considering the characteristics of distribution cost, distribution time and fresh agricultural products, an overall optimization model of distribution route with time window is established to minimize the distribution cost.

A. Customer Satisfaction

The delivery target customers of fresh agricultural products are required to receive their products within the specified time period. If they exceed the time period or deliver them in advance, they may be rejected or accept certain punishment measures as compensation. Therefore, only by timely delivering fresh agricultural products to customers according to the time window specified in the order can we meet the requirements of customers, improve the satisfaction with the distribution service of fresh agricultural products, and the online sales of fresh agricultural products can be more accepted by the market [13].

If t_j represents the arrival time of the means of transport and j represents the logistics node number, then $FH_j < t_j < KH_j$. FH_j and KH_j are the earliest and the latest starting time of the distribution service respectively. In the actual distribution process of fresh agricultural products, if the fresh agricultural products are delivered just at the distribution time point required by the customer and look at the time window immediately, the customer satisfaction will reach the maximum, that is, the optimal solution is realized; If the fresh agricultural products are not stuck when they are delivered, and the time is not at the time point required by the customer, that is, the goods may be delivered in advance or the goods may be in a timeout state when they are delivered, namely, the time window can be accepted. At this time, the customer's satisfaction with the service quality of distribution cannot be met [14].

Customer satisfaction can be expressed as a function of fuzzy reservation time. For customers, when the service start time is t_j, the customer satisfaction function can be expressed as:

$$g_j\left(t_j\right)=\begin{cases} 0 & t_j \le FH_j \\ \left[0.7\left(t_j - FH_j \Upsilon\right)/\left(FH_j^e - FH_j \Upsilon\right)\right]+0.3 & FH_j \le t_j \le KH_j \\ 1 & FH_j^e < t_j < KH_j^e \\ \left[0.7\left(KH_j \Upsilon - t_j\right)/\left(KH_j \Upsilon - KH_j^e\right)\right]+0.3 & KH_j^e \le KH_j^e \\ 0 & t_j > KH_j \end{cases} \tag{4}$$

Where, FH_j^e and KH_j^e are the earliest and the latest time window of the reservation in turn.

When driving to position i after completing the transportation task j of fresh agricultural products, the waiting time of the distribution vehicle at position i can be expressed as:

$$\varpi_j\left(t_j\right)=t_i - t_j - t_{ji}\alpha t_j \tag{5}$$

Where, t_{ji} represents the travel time of the distribution vehicle from customer j to customer i; $\varpi_j\left(t_j\right)$ represents the waiting time of the distribution vehicle at the customer i when the starting time is t_i; t_i and t_j are the time taken for the delivery vehicles to arrive at the customer i and j destinations respectively.

B. Loss of Fresh Agricultural Products

Different from other products, fresh agricultural products are perishable, and the fundamental value of fresh agricultural products lies in whether they reach the freshness and quality satisfactory to customers. Even if the current means and methods of transportation can improve the temperature in the transportation process and achieve constant temperature distribution, the final value of fresh agricultural products will continue to decrease with the extension of distribution time in the overall distribution process because the degree of decay of fresh agricultural products is closely related to the length of distribution time; as for the loss degree of fresh agricultural products, generally speaking, it consists of three stages: high value (freshness is the highest after picking) to acceptable value (loss of certain freshness after a period of time, but customers can finally accept) to invalid value (complete decay and damage, which cannot be accepted or eaten by customers). On the whole, fresh agricultural products cannot be delivered when they are obtained, placed an order, and then delivered to customers. More often, fresh agricultural products will be delivered within the stage of acceptable value, resulting in the loss of fresh agricultural products [15].

On the one hand, fresh agricultural products are lost due to the increasing time from the distribution center to the destination, that is, the distribution time has lost fresh agricultural products. The relevant variables are: when the value of vehicle state y_{hk}^v is 1, it means that the vehicle k of distribution center v serves customers h; when the value of y_{hk}^v is 0, which means that the vehicle k does not provide customer h service. The loss cost at this time is:

$$D_1=\sum_{k=1}^{k}\sum_{h=1}^{m+v}\sum_{v=m+1}^{v}\Upsilon f k_h y_{hk}^v \beta_2 t_h^k - \Upsilon f k_h y_{hk}^v \beta_2 t_h^k t_{h-1}^k \tag{6}$$

Where, f represents the unit price of fresh agricultural products; k_h represents the quantity of fresh agricultural products ordered by the customer h; β_2 represents the loss rate of fresh agricultural products during transportation; t_h^k represents the time when the vehicle k arrives at the customer h; t_{h-1}^k represents the time from vehicle k to customer $h-1$.

On the other hand, fresh agricultural products will be unloaded when they arrive at different distribution points in the distribution process. At this time, the opening of the transportation vehicle for unloading will produce internal and external air convection and change the internal air temperature, so as to accelerate the corruption speed of fresh agricultural products and the loss of fresh food in the loading / unloading process. The relevant variables are: when the value of y_{hk}^v is 1, it means that the vehicle k of distribution center v has delivered to point h; if the value of y_{hk}^v is 0, it means that the vehicle k has not delivered to point h. The loss cost at this time is:

$$D_2=\sum_{k=1}^{k}\sum_{h=1}^{m+v}\sum_{v=m+1}^{v} f \Upsilon k_h y_{hk}^v \beta_2\left(O_h^k\right) \tag{7}$$

Where O_h^k is the loading and unloading time of vehicle k at distribution point h.

Then the loss cost D of fresh agricultural products in the process of distribution is the sum of equations (6) and (7).

C. General Model Construction

To sum up, in order to build the model, when the values of the vehicle state judgment variables a_{jiqp}, a_{jqp} and a_{jiqp} are 1 during introducing the transportation of fresh agricultural products. It means that the vehicle k passes through the distribution point (j,i), and when the value of a_{jiqp} is 0, it means that the vehicle k does not pass through the distribution point (j,i); when the value of a_{jqp} is 1, it means that vehicle k serves customer j; when the value of a_{jqp} is 0, it means that vehicle k does not serve customer j.

The following models are established:

$$MinW = \sum_{j=0}^{k}\sum_{i=0}^{k}\sum_{q=1}^{n}\sum_{p=1}^{m_q} e_{ji} f_q a_{jiqp} + \sum_{q=1}^{n}\sum_{p=1}^{m_q}\left(\varpi o_{qp} * r + d\varpi o_{qp} * r\right)$$
$$+ s_j * s\sum_{j=1}^{k}\max\left(t_j - \alpha t_j, 0\right)\left(\alpha t_j - t_j, 0\right) + \Upsilon DBH \quad (8)$$

The constraints are:

$$\frac{\Upsilon}{k}\sum_{j=1}^{k} g_j\left(t_j\right) \geq 80\% \quad (9)$$

$$\sum_{j=1}^{k} f_j a_{jqp}\Upsilon \leq u_q \quad (10)$$

$$\sum_{q=1}^{k}\sum_{p=1}^{m_q} a_{jqp}\Upsilon = 1 \quad (11)$$

$$\sum_{j=1}^{k} a_{jiqp} = a_{jqp}, i = 1, 2, ..., \mathrm{k} \quad (12)$$

Where, equation (8) is the objective function, which means that the distribution cost of fresh agricultural products is the smallest. Equation (9) is the constraint of customer satisfaction, which means that the average value of customer satisfaction should be more than 80%. Equation (10) is the vehicle loading capacity constraint. Equation (11) is used to ensure that customers only complete the distribution by the pth vehicle of group q. Equation (12) represents the only constraint on the vehicle arriving at a customer, that is, each customer has and only one vehicle to serve him. ϖo_{qp} represents the driving time of the pth vehicle in group q, and $d\varpi o_{qp}$ represents the overtime time of the pth vehicle in group q. e_{ji} represents the shortest distance between transportation logistics nodes of fresh agricultural products. s is the hourly waiting cost of the vehicle, and s_j is the delay cost of the j th hour.

D. Solving the Optimal Transportation Path of Fresh Agricultural Products based on Artificial Bee Colony Algorithm

Artificial bee colony algorithm is a new intelligent optimization algorithm proposed by Karaboga in 2005. In the artificial bee colony algorithm, the optimal food source is obtained through the cooperation and role transformation of leading bee, following bee and reconnaissance bee. The location of the food source corresponds to the possible solution of the optimal route for the transportation of fresh agricultural products. The income of the bee colony in the food source represents the fitness of the optimized problem [16].

At the beginning of the algorithm, the initial population M with solutions will be generated randomly, and each solution Y_j is a B-dimensional vector. Then, lead the bees to remember the optimal solution and search in the neighborhood of the food source. After initialization, three kinds of bees search circularly. The search equation is as follows:

$$u_{ji} = y_{ji} + \delta_{ji} y_{ji} - \delta_{ji} y_{\mu i} \quad (13)$$

Where, u_{ji} is the candidate food source and represents the candidate solution of the optimal transportation path of fresh agricultural products; $\mu \in \{1, 2, ..., M\}$, $i \in \{1, 2, ..., B\}$ are generated randomly and unequal. δ_{ji} is a random number uniformly distributed on [-1,1]. The leading bee adopts the greedy criterion to compare the search solution of the optimal route of fresh agricultural products transportation with the previous optimal solution. If the search solution of the optimal path is superior to the previous optimal solution, replace it; on the contrary, it remains unchanged. The probability of following bees to choose food source is:

$$\sigma_j = \xi_j \delta_{ji} / \sum_{j=1}^{M} \xi_j \delta_{ji} \quad (14)$$

Where, ξ_j is the fitness of the jth solution. If a food source remains unchanged after circulation, the food source will be abandoned, and the corresponding leading bee will become a reconnaissance bee, and the solution will be updated through the following equation:

$$\eta_j^i = \eta_{\min}^i + rand\left(0,1\right)\left(\eta_{\max}^i - \eta_{\min}^i\right)\sigma_j \quad (15)$$

Where, η_j^i is the i-th dimensional component of the new food source, which represents the component information of the new path during the transportation of fresh agricultural products; $\eta_{\max}^i$ and $\eta_{\min}^i$ are the maximum and minimum values of the i-th dimensional component respectively.

The classical artificial bee colony algorithm adopts the real number coding method for the transportation path coding of fresh agricultural products, which is obviously not feasible in the distribution route optimization of fresh agricultural products. Distribution center demand is decentralized, so the coding method needs to be reconsidered. In this study, if the natural number coding method is adopted for the demand point, a feasible transportation path of fresh agricultural products can be expressed as $(0, \vartheta_{11}, \vartheta_{12}, ..., \vartheta_{1m}, \vartheta_{21}, \vartheta_{22}, ..., \vartheta_{2v}; \vartheta_{n1}, \vartheta_{n2}, ..., \vartheta_{nu})$. The transportation route of this fresh agricultural products means that the first vehicle starts from the distribution center and returns to the distribution center after reaching the demand point $\vartheta_{11}, \vartheta_{12}, ..., \vartheta_{1m}$; The second vehicle starts from the distribution center and returns to the distribution center after reaching the demand point $\vartheta_{21}, \vartheta_{22}, ..., \vartheta_{2v}$. The m-th vehicle starts from the distribution center and returns to the distribution center after reaching the demand point $\vartheta_{n1}, \vartheta_{n2}, ..., \vartheta_{nu}$. If there are 3 vehicles and 9 demand points and the food source is $y = 023601789045$, it means that the first vehicle starts from the distribution center and returns to the distribution center after reaching demand points 2, 3 and 6. The second vehicle starts from the distribution center and returns to the distribution center after reaching demand points 1, 7, 8 and 9, and the third vehicle starts from the distribution center and returns to the distribution center after reaching demand points 4 and 5.

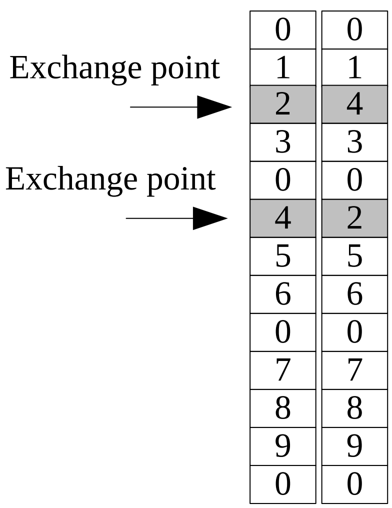

Fig. 2. Food sources before and after exchange.

Since a new food source coding method is adopted in the artificial bee colony, the update of the candidate food source location (transportation path of fresh agricultural products) cannot adopt the mode of equation (15). In this study, by exchanging two neighborhood points in the food source (fresh agricultural product transportation path) are randomly exchanged to obtain the candidate food source. It is illustrated by 9 demand points and 3 vehicles. Fig. 2 shows the food sources before and after the exchange. It can be seen that the candidate food sources can be obtained by exchanging the third and sixth points. The change of food source before and after exchange is small, so many excellent characteristics of food source before change can be maintained; At the same time, the random location exchange increases the diversity of food source selection and avoids falling into local optimization and failing to obtain the global optimal solution of the transportation path of fresh agricultural products [17].

The fitness function is obtained by transforming the objective function of the established transportation route selection model of fresh agricultural products. Since the objective function pursues the minimization of cost and the maximization of customer satisfaction, its reciprocal is taken and transformed into the fitness function of artificial bee colony algorithm:

$$\xi = 1/\min\mathrm{W} = 1/\Bigg[MinW = \sum_{j=0}^{k}\sum_{i=0}^{k}\sum_{q=1}^{n}\sum_{p=1}^{m_q} e_{ji} f_q a_{jiqp} + \sum_{q=1}^{n}\sum_{p=1}^{m_q}\big(\varpi o_{qp} * r + d\varpi o_{qp} * r\big) + s_j * s\sum_{j=1}^{k}\max\big(t_j - \alpha t_j, 0\big)\big(\alpha t_j - t_j, 0\big) + DBH \Bigg] \quad (16)$$

The specific steps of using artificial bee colony algorithm to solve the optimization of cold chain logistics distribution route of fresh agricultural products are as follows:

1) Generate a certain number of food sources, that is, the initial solution of the transportation path of fresh agricultural products. The initial solution is allocated to each leading bee, and the fitness of the transportation path of each fresh agricultural product is calculated;

2) Set the maximum number of iterations, cycles and the cycles of each solution;

3) Leading bees search the neighborhood of the transportation path of fresh agricultural products, generate new solutions of the same scale, and compare the fitness of the old and new solutions. If the fitness of the optimized new solution for the transportation path of fresh agricultural products is greater than that of the old solution, the new solution will replace the old solution, otherwise the old solution of the transportation path of fresh agricultural products will remain unchanged [18].

4) Following bees choose the transportation path of fresh agricultural products with probability σ_i, and conduct the neighborhood search to generate a new solution and calculate its fitness. Select the maximum fitness value of the new solution and compare it with the fitness value of the old solution. If the fitness of the new solution is greater than that of the old solution, the new solution will replace the old solution, otherwise the old solution will remain unchanged [19].

5) Judge whether the number of iterations reaches the maximum value [20-21]. If it is the maximum value, the optimal solution of the transportation path of fresh agricultural products will be output, that is, the distribution route of fresh agricultural products with the lowest distribution cost and the highest customer satisfaction will be obtained. If not, skip to step (3) and continue the iteration [22]. So far, the transportation route optimization model for fresh agricultural products has been built, and the steps for calculating the transportation route are shown in Fig. 3.

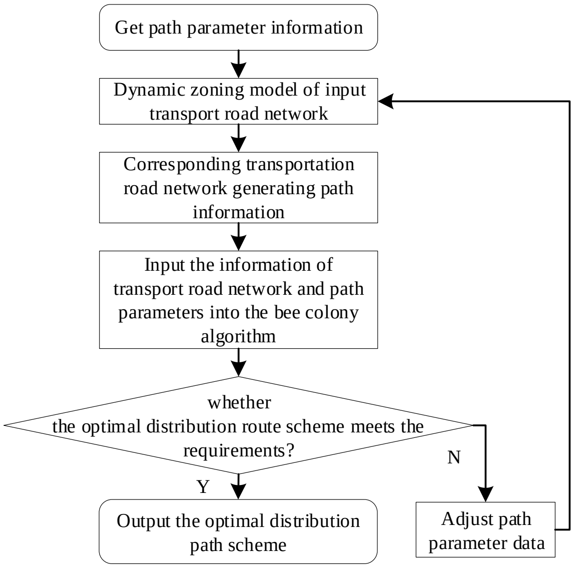

Fig. 3. Flow chart of transportation route optimization model for fresh agricultural products.

V. Results and Analysis

In order to test the effectiveness of the model established above, aiming at the model, this paper will take 18 order information about the distribution process of fresh agricultural products in a city's fresh agricultural products distribution center on a certain day as the research object for analysis and comparison [23-24]. The total transportation cost is 644.1 yuan [25]. Get the optimal transportation route scheme by inputting the data into the program written in Python language.

The basic information of each distribution node is shown in Table I.

TABLE I. Coordinate Nodes of Distribution Points

Distribution node code	Abscissa/m	Ordinate /m
1	19	16
2	17	10
3	21	11
4	20	14
5	26	15
6	23	11
7	26	18
8	16	16
9	17	13
10	15	19
11	18	18
12	24	14
13	20	19
14	23	13
15	12	12

Relevant parameter settings are shown in Table II.

TABLE II. Related Parameter Settings

Parameter name	Parameter value
Vehicle transportation cost (yuan / vehicle / time)	2.2
Vehicle running speed (km / h)	70
Normal salary of driver (yuan / hour)	17
Overtime pays for drivers (yuan / hour)	30
Vehicle waiting cost (yuan / hour)	20
Customer delay fee (yuan / hour)	110

Under the condition of smooth traffic, the path results optimized by the model in this paper are shown in Fig. 3.

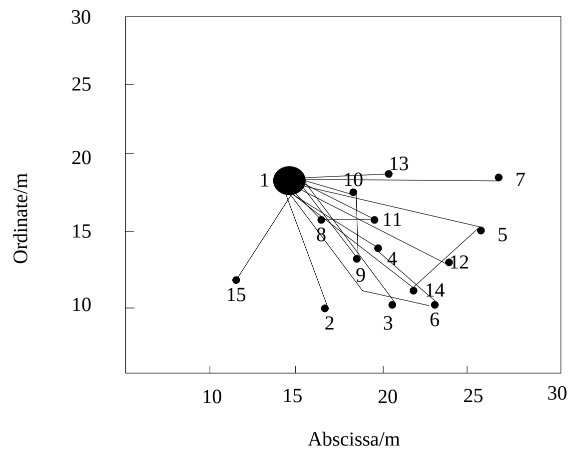

Fig. 4. Path results of 10 vehicles.

The calculation results show that under the use of 10 vehicles, the optimal feasible solution obtained after operation is 1-10-9-1-7-1-8-11-1-12-1-13-1-2-1-14-5-1-15-1-4-6-1-3-1. The transportation time of each vehicle is relatively average, which does not cause excessive use of some vehicles, and the transportation time of each vehicle is not long, which is basically about 12 hours, which can maintain the freshness of fresh agricultural products. From the above results, it can be seen that the model constructed in this paper can effectively reduce the distribution cost and meet the customer satisfaction needs. Table III shows the specific results.

TABLE III. Route Delivery Results of 10 Vehicles

Vehicle code	Route	Journey time/h	Delay waiting/min	Transportation cost / yuan
1	1-10-9-1	12	0	33
2	1-7-1	12	0	23
3	1-8-11-1	11	0	34
4	1-12-1	11	0	35
5	1-13-1	9	0	44
6	1-2-1	10	0	32
7	1-14-5-1	12	0	21
8	1-15-1	11	0	54
9	1-4-6-1	12	0	22
10	1-3-1	12	0	11

As shown in Table III, after the model in this paper is used and fresh agricultural products are transported, the delayed waiting time of the distribution target is 0, and the total transportation cost is 309 yuan, saving 335.1 yuan.

In the case of traffic congestion, after the model in this paper is used, the time-sharing diagram of path optimization is shown in Fig. 4. Among them, the straight line represents the current solution and the wavy line represents the optimal solution. It can be concluded from Fig. 4 that the distribution cost is optimized from 644.1 yuan to about 350 yuan.

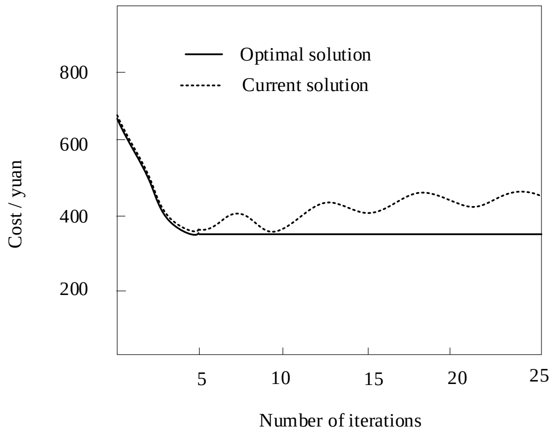

Fig. 5. Time sharing diagram of route optimization in this model under traffic congestion conditions.

In the two working conditions, the test results of customer satisfaction rate are shown in Fig. 5.

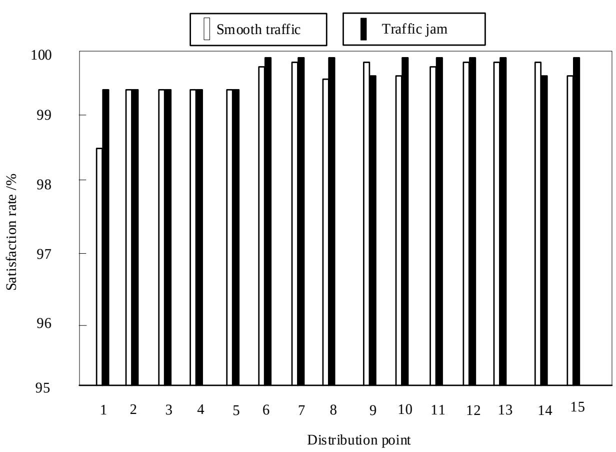

Fig. 6. Test results of customer satisfaction rate under two working conditions.

As shown in Fig. 6, in the two working conditions of smooth traffic and traffic congestion, after the use of the model in this paper, the customer satisfaction is greater than 95%, and the satisfaction is high.

VI. Discussion

Combined with the research content of this paper, the suggestions to improve the matching effect of fresh agricultural products are as follows:

A. Accelerate the Construction of Agricultural Products Logistics Infrastructure

The rapid development of agricultural products logistics is inseparable from infrastructure construction. All regions make reasonable planning and purposeful construction according to the actual situation. The following suggestions are mainly put forward:

1) Cold storage construction: The temperature in the cold storage is mainly adjusted according to the different types of agricultural products. The construction of cold storage in cities is closely related to the distribution of agricultural products. The characteristics of fresh agricultural products determine that the cold storage in cities must reach a certain scale in order to ensure that agricultural products are not damaged. Only by investigating the output, types and distribution of urban agricultural products, planning the layout and optimizing the location can we promote the development of agricultural products logistics.

2) Construction of distribution center: The main purpose of distribution center is to distribute to customers at various points, which plays a vital role in the impact of distribution. The distribution cost is directly related to the number of urban distribution centers. There are few distribution centers, resulting in high distribution cost and long distribution distance, and the decay rate of fresh agricultural products is high. Reasonable planning and uniform distribution of distribution centers is an effective measure to effectively reduce the loss in distribution.

3) Transformation and upgrading of cold chain transport vehicle: The cold chain transport vehicle is mainly used for the distribution of agricultural products. Whether the cold chain equipment on the vehicle is advanced or not will also affect the cost. At present, many cold chains transport vehicles in China are refitted through ordinary vehicles. The technical level is relatively backward and the distribution cost is high, which cannot be compared with developed countries. Therefore, it is necessary to introduce advanced cold chain transportation technology from developed countries and upgrade cold chain transportation vehicles.

B. Expand the Scope of Green Channel

At present, the transport channel of fresh agricultural products has been expanded to all parts of the country, and the varieties that meet the requirements are given free passage. However, in order to increase taxes, some local governments have not strictly implemented the government documents, which has caused some obstacles to the circulation of fresh agricultural products. In view of the green channel of agricultural products, we should still strive to do a good job in the following aspects.

1) We will continue to implement the policy of exemption and reduction for fresh agricultural products that meet the requirements, and expand this scope to every region and every toll road.

2) Due to the large number of social vehicles, when the agricultural product transport vehicle passes through the toll station, it needs to stop and accept the inspection of the security personnel. It can be released only if there is no problem, resulting in longer transportation time and higher loss rate of agricultural products. Therefore, it is necessary to build a set of security inspection system, which can automatically check whether the products loaded in the vehicle meet the transportation requirements of agricultural products, shorten the vehicle transportation time and effectively ensure the quality of agricultural products.

3) Individuals take advantage of the preferential policy of agricultural product transportation and borrow the green channel to cause some obstacles to the implementation of security inspection personnel. It needs to build a set of credit system and integrate such people into the integrity system, so as to ensure the smooth transportation of agricultural products.

C. Make Full use of Information Technology to Build a Network Information Platform for Cold Chain Distribution

The particularity of fresh agricultural products determines the importance of its distribution link. The optimization of the distribution route of cold chain logistics for fresh agricultural products is to effectively avoid the deterioration and decay of agricultural products and reduce economic losses. Logistics distribution is an important part of the cold chain system, which has high requirements for the timeliness and fresh-keeping function of distribution. In the information age, in order to optimize the cold chain logistics transportation system, we need to make full use of advanced information technology, effectively connect all links of logistics distribution, monitor the status of logistics distribution in real time, and realize the intelligent management of logistics distribution. Through the construction of corresponding network information platform, the collection, sorting and feedback of logistics information are managed in an integrated way, so as to grasp the transport status of fresh agricultural products in real time and improve the safety and freshness of fresh agricultural products. In the implementation of distribution management, big data and other technologies are used to automatically manage logistics transportation and improve the level of distribution management. The one-stop cold chain logistics distribution includes the whole process from production to sales of agricultural products. The intelligent management of the whole service process through the application of information technology can avoid the disadvantages of traditional logistics distribution and meet the optimization requirements of the cold chain logistics distribution route of fresh agricultural products.

VII. CONCLUSION

In recent years, with the continuous development of logistics industry and the increasing variety and output of fresh agricultural products, higher requirements are put forward for cold chain logistics distribution. In the cold chain logistics system, distribution is a very key link, which has high requirements for transportation technology and transportation environment. However, compared with developed countries, China's cold chain logistics started late, the technology is not mature, the cost of fresh produce distribution is still high, and the corresponding preservation equipment is not perfect. Once the food goes bad or rots, it will seriously affect the surrounding environment. People's income is increasing, and the demand and quality requirements for fresh agricultural products are increasing. In order to better meet people's needs, we must take effective strategies to optimize the distribution route of cold chain logistics of fresh agricultural products. When optimizing the distribution route, we can make full use of information technology to build a network information platform for cold chain distribution; strengthen the implementation of relevant policies to provide a good environment for the development of cold chain logistics; optimize the supply chain of fresh agricultural products and build a large distribution center; strengthen alliances of fresh produce-related organizations to promote the long-term stable development of China's cold chain logistics industry. In this context, this paper constructs the optimal route selection model of fresh agricultural products transportation based on bee colony algorithm, and verifies its application value in experiments. However, due to the limitation of personal energy, this study failed to select more data to verify the model performance of the design, which is also the key point to be noted in the follow-up study.

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