Cold Chain Logistics Path Planning and Design Method based on Multi-source Visual Information Fusion Technology

Ke XUE[1], Bing Han[2]
School of Logistics and e-Commerce, Henan University of Animal Husbandry and Economy, Zhengzhou, 450044, China

***Abstract*—Complete cold chain logistics is needed to control the whole temperature of refrigerated and frozen food, including the closed environment, storage and transportation when loading and unloading goods. Studying how to optimize vehicle scheduling and reduce transportation time and transportation costs is very important. The research object of this paper is the path planning of urban cold chain logistics. This paper will consider the cold chain distribution of multi-vehicle coexistence, build an integer programming model, design a targeted ACO (Ant Colony Optimization) solution model, and verify it with an example. Based on multi-source visual information fusion technology, these independent heterogeneous data sources are accessed through cloud computing resource integration technology to establish a unified data integration middleware. The pheromone update model selected in this paper is the ant week model, which uses global information to record the optimal path of ants. The results show that the satisfaction of delivery time is far behind, and even the average satisfaction of key customers with high value is only 55.1%, which is 18.3% higher than that of the planning without considering value. This method can provide a real-time optimized path in an effective time range and improve the efficiency of distribution services, which has certain theoretical significance and practical value.**

Keywords*—Multi-source visual information fusion; cold chain logistics road; path planning; ant colony optimization

I. Introduction

Effective distribution has become the key link of cold chain logistics because agricultural products are greatly affected by natural conditions and easily spoiled. Logistics operations such as low-temperature production, low-temperature transportation and low-temperature storage are selected in the cold chain logistics distribution process, which is a key logistics project supported by the state in recent years [1]. At the present stage of China's development, the logistics platforms of various industries have become perfect, and only cold chain logistics is still in a new developing position. Then the demand for cold chain logistics for the Chinese market is objective, and the overall growth rate of the cold chain logistics market is gradually increasing. However, some fresh agricultural products have caused huge losses in the process of circulation and consumption due to their special quality, and people's requirements for cold chain logistics and transportation are constantly improving. The development of China's cold chain is facing unprecedented challenges.

The role of cold chain logistics in industries such as food, medical, and chemical is increasingly prominent. Ensuring that cold chain items are not damaged during the continuous process from production to consumption in low temperature environments is the core task of cold chain logistics. However, in practical operation, cold chain logistics faces many challenges, such as unreasonable path planning, high energy consumption, and insufficient real-time monitoring. To address these issues, this study applies multi-source visual information fusion technology to cold chain logistics path planning and design, aiming to improve the efficiency and reliability of cold chain logistics. Multi source visual information fusion technology is a method that comprehensively utilizes computer vision, image processing, and pattern recognition technologies to obtain and integrate visual information from multiple sources. In the field of cold chain logistics, multi-source visual information fusion technology can obtain multiple information such as temperature, humidity, and location of goods, and based on this information, path planning and design can be carried out to achieve optimal resource allocation. This model will obtain real-time status information of goods through computer vision and image processing technology, and classify and analyze the information through pattern recognition technology. Then, based on the obtained information, the model will use optimization algorithms for path planning and design, ensuring that the goods reach their destination with the shortest path and lowest energy consumption, while meeting temperature and other conditions.

In the cold chain delivery where multiple vehicles coexist, the contribution points of the integer programming model based on multi-source visual information fusion technology are as follows:

1) By integrating multi-source visual information, this model can obtain more comprehensive information on goods and vehicles, thereby better planning distribution routes. This helps to reduce transportation costs, reduce energy consumption, and improve on-time delivery rates and customer satisfaction.

2) Multi source visual information fusion technology can monitor the status and location of goods in real time, detect potential problems in a timely manner, and provide early warnings. This helps to reduce cargo losses, ensure food safety, and provide better customer service.

3) Through integer programming models, the number of vehicles, loading capacity and route arrangement can be optimized to improve resource utilization efficiency. In addition, different vehicles can collaborate and cooperate to achieve more efficient delivery and improve overall operational efficiency.

Section I of this study elaborates on the background of cold chain logistics to control the closed environment of refrigerated and frozen food, as well as the storage and transportation of goods during loading and unloading. Section II elaborates on the research achievements of scholars who have become a hot topic in cold chain logistics distribution. Section III considers the cold chain distribution of multiple vehicles coexisting, establishes an integer programming model, and designs a targeted ant colony optimization (ACO) solution model. Section IV accesses these independent heterogeneous data sources through cloud computing resource integration technology to establish a unified data integration middleware. The pheromone update model chosen in this article is the Ant Week model, which utilizes global information to record the optimal path of ants. The results show that this method can provide real-time optimization paths within an effective time range. Section V summarizes the entire article. The integer programming model based on multi-source visual information fusion technology is an innovative method that can promote technological progress and industrial upgrading in the cold chain logistics industry.

II. Related Work

In recent years, cold chain logistics and distribution has become a research hotspot, mainly focusing on single vehicle route optimization, such as Bittencourt et al. accurately depict the distribution scene and study the impact of real-time traffic on the cold chain logistics route optimization in the road network [2]; Ouyang comprehensively considered time window, food spoilage, equipment-energy consumption and traffic congestion, and to get the optimal vehicle route distribution scheme, a stochastic vehicle route model with time window was constructed [3]. Amaruchkul put forward a mixed integer linear programming model, which combined the food production chain and quality loss, and analyzed the application value of this model with a case [4]. Established a model based on perishable property and time constraint, which had a significant impact on the cost, and solved it by tabu search algorithm [5]; In view of the problems existing in Yu's cold chain logistics and distribution, some effective suggestions are put forward. While improving the distribution efficiency, we should also ensure the quality and safety of products and optimize the process from the whole [6]; Li et al. deduced the calculation formula of algorithm convergence based on the related theoretical research of multi-objective generalized ACO (Ant Colony Optimization) and verified the correctness of the convergence and time complexity theory of multi-objective generalized ACO according to two given examples [7]. Zhang et al. analyzed the optimization problem of the cold chain logistics distribution path with the process of return and recovery. They provided a reference for the decision-making operation of cold chain transportation and distribution enterprises [8]. Chen took into account the timeliness requirements of fresh products and, based on customer information feedback, studied and analyzed the feasibility of simultaneous delivery and pick-up processes to prevent the transport vehicles from driving back with no load [9]. Zhang et al. proved that the improved Dijkstra algorithm has better solution efficiency, and the quality of the final solution is improved compared with the traditional algorithm through simulation experiments [10]. Song et al. gave an effective distribution model to solve the distribution problem of cold chain perishable products in economically poor areas [11]. The purpose of the improved vehicle routing problem and optimal allocation is to reduce the pain and hunger in poor areas, not the distance and time.

In order to ensure the safety of food, a complete cold chain logistics is needed to control the whole temperature of refrigerated and frozen food, including the closed environment, storage and transportation when loading and unloading goods. In reality, due to the difference in delivery time and other factors, the delivery time may change, and the research of dynamic vehicle scheduling problems is still in the initial stage. The information on vehicle dynamic scheduling problem optimization is related to the travel time and the running speed of vehicles [12], [13]. Generally speaking, there is a positive correlation between vehicle transportation cost and vehicle mileage. Reasonable planning of vehicle transportation routes and minimizing vehicle mileage are the primary ways to reduce vehicle transportation costs. It is very important to study how to optimize vehicle scheduling, reduce transportation time and transportation cost [14].

Multi source visual information includes various information, such as vehicle position, speed, and cargo status is of great significance for path planning and design. However, in previous studies, this information was not fully utilized, resulting in the model being unable to make optimal decisions based on actual situations. Cold chain logistics has its unique characteristics, such as temperature control, shelf life of goods, etc. These characteristics have a significant impact on path planning and design. In cold chain logistics, the number of vehicles and goods that need to be considered may be very large, so efficient algorithms are needed to solve the problem. Therefore, it is of great practical significance to study vehicle optimal scheduling and route optimization as important contents. This paper will consider the cold chain distribution situation of multi-vehicle coexistence, build an integer programming model based on multi-source visual information fusion technology, design a targeted ACO solution model, and verify it with an example.

III. Research Method

A. Logistics VRP Analysis

The process of cold chain logistics includes four aspects: frozen processing, frozen storage, refrigerated transportation and distribution, and frozen sales [15], [16]. Logistics VRP(Vehicle Routes Planning) is generally defined as giving the location, distance, demand and other related information of one (or more) warehouses and multiple customers, seeking appropriate driving routes, so that vehicles can complete the delivery or pick-up work through them in an orderly manner, and achieve a certain purpose.

The products distributed in the cold chain logistics are generally fresh products, which are corrosive. Fresh product sellers often make a prior agreement on the delivery time of the products and restrict the distributor from delivering the goods within the agreed period. Therefore, cold chain logistics distributors must consider the change in air temperature when delivering. Cold chain logistics not only requires the minimization of the cost in circulation but also has certain requirements for time, and its response to the market should be sensitive.

VRP problem is the most studied VRP problem at present. Firstly, the basic elements of the transportation problem, the corresponding constraints, the total cost value target that the logistics enterprise hopes to achieve, etc., are defined. The artificial intelligence algorithm approaches the optimal solution step by step and has strong applicability in dealing with large-scale and multi-node transportation path problems [17]. The new hybrid algorithm and structure greatly improve the efficiency of problem-solving and enrich the feasibility of theoretical results and practical applications. In the context of the close combination of traditional algorithms, it is also helpful to discover the advantages, disadvantages and application scope of traditional nature-imitating algorithms. The inspiration for particle swarm optimization comes from this method.

The VRP problem is based on the TSP (Traveling Salesman Problem) problem, which assumes that the distance between customers is known and the quantity of goods delivered by vehicles to customers is the same. Then, the route is reasonably planned to make the total distribution route the shortest. The specific situation is shown in Fig. 1:

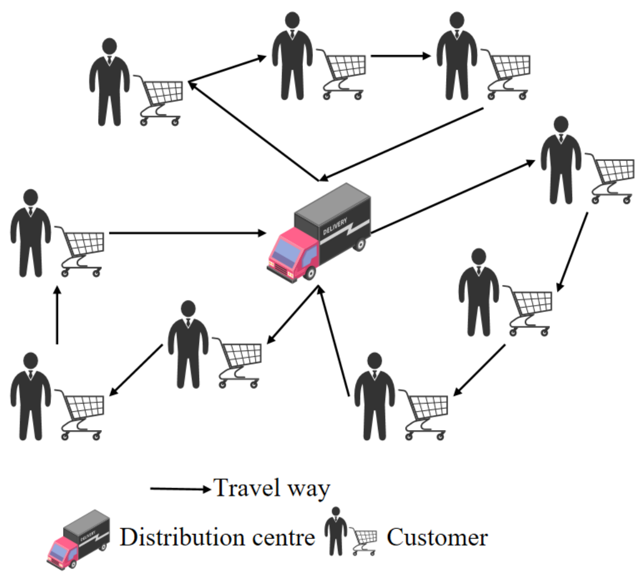

Fig. 1. Schematic diagram of vehicle scheduling problem.

It is the most basic carrier of cargo transportation and information transmission, and its main attributes include the maximum cargo load, the longest driving distance, whether it can be returned halfway, etc. The longest transportation distance of vehicles directly determines the coverage and size of the transportation network. With the distribution center as the dot, the radius of serviceable demand points and the longest distance between various demand points directly affect the number of serviceable demand points [18], [19]. Different types of distribution centers have different supporting facilities, different service targets and different service scopes, which can be aimed at a certain type of customer or a variety of customers. In violation of the time constraint, the customer has a certain probability of refusing to deliver the transport vehicle.

The vehicle routing optimization problem is based on the travelling salesperson problem with some restrictions, including limiting the quantity of product demand, delivery time, loading quantity of vehicles, driving distance of vehicles, etc. When multiple customer numbering schemes are selected to solve the problem, a satisfactory solution with higher quality can usually be obtained, but the amount of calculation will be doubled.

B. *Multi-source Data Information Analysis of Cold Chain Logistics VRP*

Logistics informatization refers to a series of processing such as collecting, classifying, querying, tracking and summarizing the information generated in the logistics distribution process by using Internet technology and modern information technology in the logistics supply chain, with the development of e-commerce and virtual business in modern enterprises. Cold chain logistics distribution center refers to the intermediate storage base set up to promote the rapid circulation of fresh products from the place of production to the place of sale. Enterprises or individuals hope to visit the optimized best-driving route in cold chain logistics distribution anytime and anywhere. At the same time, they also hope that the platform for optimizing the route can be dynamically upgraded.

There is a maximum cargo capacity of the vehicle, and there may be a time limit for delivery. It is necessary to arrange the picking-up time reasonably, organize the appropriate driving route so that the user's needs can be met, and at the same time, a certain cost function can be minimized, such as the minimum total working time, the shortest route and the minimum cost [20].

The ant colony system represents the feasible solution by the ant colony's advancing route, and each route of the ant colony's advancing route constitutes the solution space. The pheromones released by ants with shorter routes are more and move continuously. Under the action of positive feedback, the ant colony will take the optimal route, and the solution at this time is the optimal solution.

When the ant colony is moving, the pheromone is constantly evaporating, assuming that the parameter $\rho(0 < \rho < 1)$ represents the rate of pheromone volatilization, that is:

$$\begin{cases} \tau_{ij}(t+1) = (1-p)\tau_{ij}(t) + \Delta\tau_{ij} \\ \Delta\tau_{ij} = \sum_{k=1}^{n} \Delta\tau_{ij}^{k} \end{cases} p \in (0,1) \quad (1)$$

In the formula, $\Delta\tau_{ij}^{k}$ represents the pheromone concentration released by the kth ant between the route of town i and town j ; $\Delta\tau_{ij}$ represents the sum of pheromone concentrations released by all ants between the route of Town i and town j.

The determination of the distribution type of random variables is often the assumption of the distribution type after preprocessing the collected data. The theoretical distribution of many random variables in the system can be directly determined by experience. A triangle is a continuous probability distribution with the lower limit of a, the mode of b and the upper limit of c.

$$f(x|a,b,c) = \begin{cases} \frac{2(x-a)}{(b-a)(c-a)}, & a \leq x \leq b \\ \frac{2(b-x)}{(b-a)(b-c)}, & b \leq x \leq c \\ 0, & other \end{cases} \quad (2)$$

The mathematical expected value of the random variable x is:

$$E(X) = \frac{a+b+c}{3} \quad (3)$$

When using GPS data of floating cars to calculate road weight, the influence of invalid data points must be considered. Then, an average speed estimation model based on travel time is selected to calculate the average speed of each road section. At the same time, road quality and energy consumption loss are considered. Finally, the estimation method of road weight is obtained by combining these kinds of information. The estimation formula for the road weight of a single section is:

$$w(i) = \alpha \frac{L_i}{V_i} \beta Level_i \quad (4)$$

Where $w(i)$ is the road weight of the road section i, L_i is the distance travelled by the floating car in the road section$i$, $V_i$is the average speed of the road section i, and $Level_i$is the evaluation function of the comprehensive quality of the road section; α, β is the correlation coefficient.

New information will constantly appear, which will affect the driving path of vehicles to varying degrees. The quality of refrigerated products changes with the passage of time, weather and seasons, the traffic conditions during rush hour and the penalty cost when the distribution violates the time window. The traffic volume of different sections in a day also changes with time.

At present, the development direction of information processing mainly includes integration and fusion. Among them, the former is the basic premise and material basis of an information fusion system. Therefore, the realization of a multi-source visual information fusion service in the process of logistics distribution can effectively solve objective problems such as collaborative scheduling between the logistics center and logistics distribution, optimization of the logistics distribution path, logistics tracking and value-added information service under uncertain conditions.

The multi-source data information of the cold chain vehicle route optimization model is provided by different application resources of the cloud computing center, and the data formats of these different resources are quite different. These independent heterogeneous data sources are accessed through cloud computing resource integration technology to establish a unified data integration middleware as shown in Fig. 2.

The terminal acquisition layer is the data resources on which this information system relies, including the RFID system (to obtain goods information) and the GPS system (to obtain real-time in-transit position information of vehicles) under the unified management of the database management and control system.

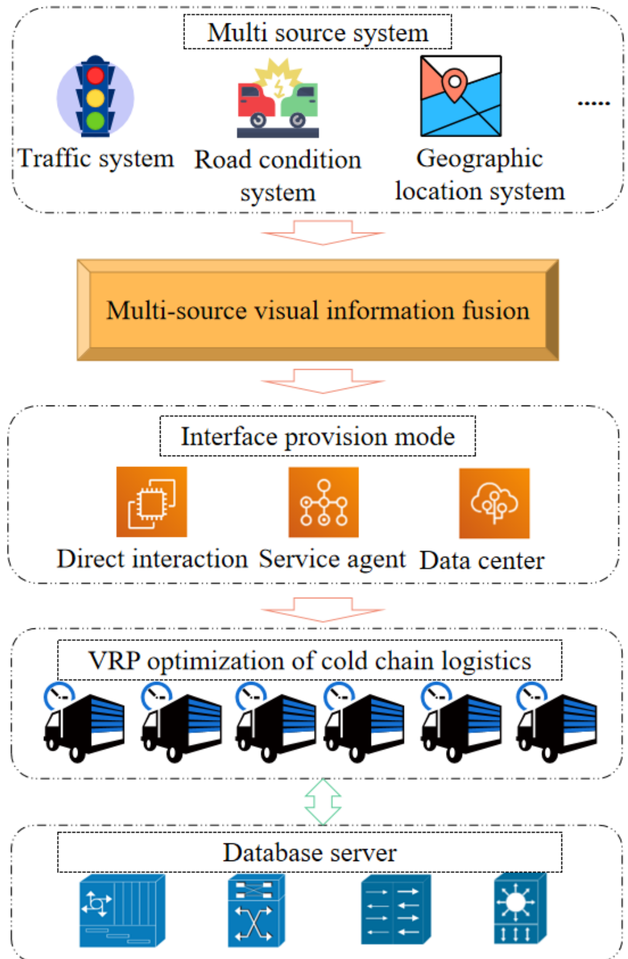

Fig. 2. Vehicle dynamic optimization model based on multi-source visual information fusion technology.

On the one hand, the system can plan the best route with time as a consideration; On the other hand, by sending different recommended routes to vehicles, the traffic efficiency is maximized, and the fuel loss caused by frequent braking and starting of vehicles is reduced, the waste of transportation resources is effectively reduced, and the environment is protected at the same time. These multi-source data can provide real-time data and make the calculated optimal path closer to the actual distribution service.

C. Vehicle Trajectory Analysis and Matching

The research object of this paper is the path planning of urban cold chain logistics, and its model is based on one or more logistics centers meeting multiple customer points in the region. In practice, the running unit is a truck with refrigeration equipment to transport fresh products. Make the objective function closer to reality according to the actual situation, and get further optimization.

A penalty function is introduced if refrigerated trucks deliver goods to customers over time. If it is delivered in advance, a reward function is introduced. Generally speaking, refrigerated vehicles' cost includes fixed and variable costs. In this paper, the former refers specifically to the precipitation cost of allowing each distribution vehicle to run normally, which is basically linearly proportional to the total time travelled by the vehicle, generally including wages, maintenance, fuel costs, etc., and is a known constant.

Which increases with the increase in transportation distance, and the two are in direct proportion.

Department:

$$C_1 = \sum_{i\in N}\sum_{j\in N}\sum_{k\in K} tcost_k * x_{ijk} * d_{ij} \quad (5)$$

$tcost_k$ represents the unit transportation cost of transport vehicle k , d_{ij} represents the distance from customer i to customer j,$tcost_k, d_{ij}$is known,x_{ijk} is a variable of 0-1, which represents the process of vehicle$k$ from point i to point j, if there is this process, it is 1; otherwise it is 0.

Set the upper and lower limits of the customer's patience time, and establish the correlation function between time and compensation within this time limit. Once the customer exceeds the lower limit of his time limit, the penalty will be calculated automatically. The Equation (6) is the general calculation formula of penalty cost:

$$K(t)_{ij} = \begin{cases} 0, & t_{ik} < a \\ M(j)(t_{ik} - a), & t_{ik} > a \end{cases} \quad (6)$$

Where, $K(t)_{ij}$ represents the time window penalty cost of the ith car serving customer j; $M(j)$ represents the penalty cost to be paid per unit time after exceeding customer j time tolerance. t_{ik} indicates the time when the kth car arrives at customer i.

In cold chain logistics, the main factors that cause goods damage are time, including transportation time and unloading time, and the cost of goods damage at node i is transportation loss cost plus unloading loss cost. Therefore, the total cost of goods damage can be expressed as:

$$Z = \sum_{i=1}^{N} C_{goods} \times q_i \times \left(\rho_1 D_{0\to i} + \rho_2 D_{off_i}\right) \quad (7)$$

ρ, ρ_2 is the loss ratio of transportation and unloading, and $D_{0\to i}, D_{off_i}$ is the time spent on transportation and unloading.

Customers' demand is often affected by factors such as the brand, quality, marketing methods, personal preferences, different seasons, after-sales and so on of dairy products, resulting in uncertain changes. In this paper, the demand for urban dairy cold chain logistics distribution is regarded as a random variable, and the premise of its optimization is to obey the normal distribution of customer demand. When the customer demand is higher than the actual vehicle load, the order will be cancelled, and at the same time, customer satisfaction will be reduced, resulting in out-of-stock costs. The specific formula is as follows:

$$C = \tau \sum_{k=1}^{m} max\{d_k - s_k\} \quad (8)$$

Where, τ is the shortage cost per unit cold chain product; d_k the actual total demand of the retailers served by the k - car;s_k is the actual load capacity of the vehicle k.

Time is very important for customers, and customers hope that goods can be delivered on time within the agreed time. In this paper, it is assumed that the service attitude satisfaction of the delivery staff is 1, and the customer's satisfaction with the delivery time is calculated according to the customer's requirements for the delivery time window.

In this paper, it is assumed that customer satisfaction is linearly related to time, when the vehicle arrives in the best time window agreed by the customer, $e_j \le t_j \le l_j$, and when the vehicle arrives at the customer point outside the best time window of the customer point $E_j \le t_j \le e_j, l_j \le t_j \le L_j$. The delivery time satisfaction expression can be expressed as:

$$U(S_j) = \begin{cases} \left(\frac{t_j - E_j}{e_j - E_j}\right)^{\alpha}, & E_j \le t_j < e_j \\ 100\%, & e_j \le t_j < l_j \\ \left(\frac{L_j - t_j}{L_j - l_j}\right)^{\alpha}, & l_j \le t_j < L_j \end{cases} \quad (9)$$

Where $[e_j, l_j]$ is the customer's expected time window, $[E_j, L_j]$ is the customer's acceptable time window, and α is the customer's sensitivity coefficient to time.

The methods for solving objective programming problems can be divided into exact and heuristic algorithms. It is an important idea of a modern, improved heuristic algorithm to search the neighborhood of the current solution many times according to a fixed search strategy. It constantly feeds back the results of the solution to improve the process of the initial solution continuously.

The remaining pheromones on the road section will gradually weaken with the continuous accumulation of time. Every time each ant visits all the cities, the number of pheromones on the road section will change accordingly. The following formula can describe the change and adjustment of pheromones on the path, namely:

$$\tau_{ij} = (t+1) = (1-\rho)\tau_{ij}(t) + \Delta\tau_{ij} \quad (10)$$

ρ is the attenuation coefficient of pheromone, and $\Delta\tau_{ij}$ is the amount of pheromone released by ants from node i to node j.

In this paper, the mathematical model of dairy products' logistics and transportation problems is established, and the best path selection scheme is obtained by solving the problem model with related algorithms. ACO has the advantages of fewer iterations, a relatively stable solution process and relatively high solution quality in this paper.

Generally speaking, many models can calculate the pheromone concentration. This paper takes the ant week model as the basic model.

$$\Delta\tau_{ij}^{k} = \begin{cases} \frac{Q}{L_k}, If\ the\ kth\ ant\ passes\ through\ sec\ t\ ion\ (i,j)\ in\ this\ cycle \\ 0, \quad other \end{cases} \quad (11)$$

ACO is inspired by the behavior of ants seeking the shortest path to get food in the foraging process. The simple behavior rules of ants make the whole ant colony present intelligent behavior, which makes it diverse and positive. In the process of foraging, diversity can prevent ants from entering a dead end and falling into an infinite cycle.

It has a unique positive feedback mechanism of iteration results and parallel calculation method, strong compatibility between algorithms, stable iteration results, etc. The specific implementation process of the improved ACO is shown in Fig. 3.

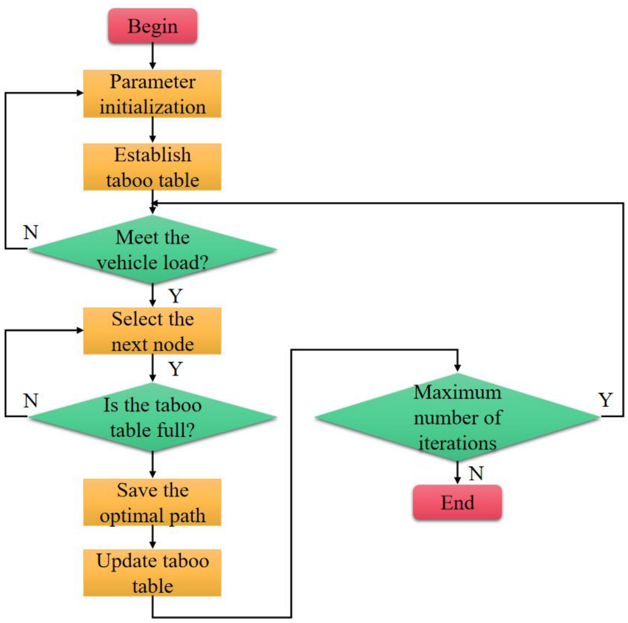

Fig. 3. Improve the calculation process of post-ACO.

Therefore, in order to make it more likely that customers with shorter waiting times will be selected as the next transportation point when selecting the next customer point, the waiting factor is added to the rules for selecting the next node.

$$w_{ijk} = \frac{1}{rt_j - t_{ik}} \quad (12)$$

t_{ik} is the moment when the k -th car arrives at point i.

The pheromone update model selected in this paper is the ant week model. Using the global information, the pheromone increment is only related to the overall search route and has nothing to do with the specific route. After all the ants have gone through one traversal, the best route for recording the ants is L_best, and the pheromone matrix is updated:

$$Tau = Rho * Tau + \Delta Tau \quad (13)$$

$$\Delta Tau = \Delta Tau + \frac{Q}{L\_best} \quad (14)$$

Rho represents the pheromone residual coefficient, $\Delta Tau(i,j)$represents the pheromone increment of all ants on the route from the ith city to the jth city, and Q represents the pheromone increase intensity coefficient.

The core idea of vehicle trajectory analysis and matching is to fully consider and analyze the relationship between the front positioning point. When the GPS positioning point of the floating car is far away from the road intersection, it is a common situation to determine the optimal road section that matches it through the weight calculation model, which is the most common in map matching.

Assuming that the two endpoints of the road section are $P_1(x_1, y_1), P_2(x_2, y_2)$ and the position coordinates of the current GPS positioning point are $P_0(x_0, y_0)$, the distance between the positioning point and the road section to be matched can be directly obtained by using the distance formula from point to line, which is marked as dis. Then the function of calculating the distance weight through this distance is as follows:

$$w_{dis} = h_1 * f(dis) \quad (15)$$

Where h_1 is the distance weight coefficient, and $f(dis)$ is the quantization function of the distance weight.

In this paper, the objective function is a combination of the lowest cost and the largest repurchase degree, so the objective function is directly defined as the fitness function. The fitness function is defined as:

$$f_i = z_i = \sqrt[2]{d_1 d_2} \quad (16)$$

f_i represents the fitness of the ith chromosome and z_i is its corresponding function value.

IV. Result Analysis

On the basis of the optimization mentioned above analysis, model construction and algorithm research and analysis of urban dairy products logistics distribution under uncertain demand, this paper selects F enterprise as an example to analyze its demand for dairy products distribution optimization, understand its distribution reality, and introduce MATLAB software to program ACO, then make a solution, and finally verify the scientificity of the algorithm and the effectiveness of the model.

Take a certain distribution service as an example. The F Enterprise Distribution Center provides distribution services for its 15 stores, and the distribution center has 8 refrigerated trucks. The more ants there are, the more accurate the optimal solution will be. As the algorithm converges closer to the optimal solution, the positive feedback of information decreases, resulting in a large number of repeated solutions, which consumes resources and increases the time complexity.

In this paper, the number of ants is set to 50. Before the service, the potential value of each customer is mainly determined by the breadth and depth of their social circle. Therefore, when classifying customers, the potential value of customers is determined by the product of the coverage of the customer's social circle and the importance of the customer in the social circle.

First of all, we set the geographic location information. For the convenience of calculation, we set the origin of the plane's geographic coordinates as the logistics center itself. Please see Table I below.

The dynamic data taken in the simulation refers to the road conditions, traffic congestion and vehicle speed. These changes in dynamic data may cause changes in the delivery time and cost of refrigerated vehicles, and the dynamic data of each journey can be obtained periodically. Fig. 4 shows the speed of the vehicle in a certain period of time.

TABLE I. GEOGRAPHICAL LOCATION INFORMATION OF A LOGISTICS COMPANY AND ITS CUSTOMERS

Customer name	Geographic information
Logistics centre	(0,0)
A customer	(30.1,2.1)
B customer	(22.6,-2.2)
C customer	(35,0)
D customer	(24.1,5.5)
E customer	(29.8,2.3)
F customer	(31.5,1.8)
G customer	(33.6,1.5)
H customer	(30.8,2.7)
I customer	(29.5,2.2)

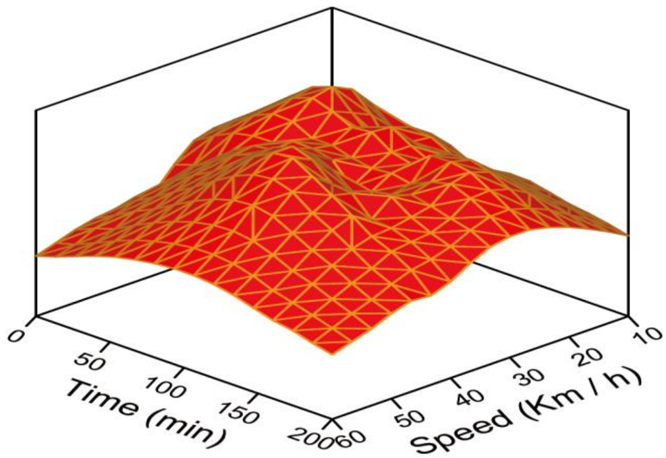

Fig. 4. Vehicle speed map.

TABLE II. TIME WINDOW ARRANGEMENT AND SERVICE TIME OF EACH CUSTOMER

Distributor number	Time window	Service time
0	6:00-12:00	0
1	7:00-10:00	22
2	7:00-10:00	29
3	7:00-90:30	30
4	7:10-8:00	13
5	8:00-10:00	24
6	7:00-8:30	16
7	7:00-8:00	28
8	7:00-9:00	11
9	7:00-11:00	23
10	7:00-8:50	35

The goods are distributed as daily necessities for citizens, such as fresh shrimp, ice cream, fresh milk and other perishable products. And ensure that it will not smell bad within 12 hours. The maximum loading capacity of each incubator is about 80 kg, i.e., 0.0 8 tons. In the case of freezing, three cold accumulators are needed, and in the case of refrigerating, two cold accumulators are needed. The holding time is 12 hours. For the distribution of products at room temperature, there is no need to use an incubator. The time window arrangement and service time of each customer are shown in Table II.

The logistics center operation system is a queuing system, and the random arrival of orders accords with the characteristics of the exponential distribution. See Table III for the occurrence times of order arrival time intervals obtained through actual observation.

TABLE III. NUMBER OF NUMERICAL OCCURRENCES OF ORDER ARRIVAL TIME INTERVAL

Arrival time interval (min)	Frequency of occurrence	Arrival time interval(min)	Frequency of occurrence
1	7	11	1
2	2	12	3
3	4	13	3
4	5	14	2
5	5	15	1
6	4	16	3
7	10	17	1
8	4	18	1
9	3	19	2
10	6	20	3

After the histogram is used to determine the theoretical distribution of sample data, it is necessary to judge how close the observed sample distribution is to the estimated theoretical distribution, that is, to determine the fitting degree of the estimated theoretical distribution. Fig. 5 shows the comparison between the histogram and probability density curve.

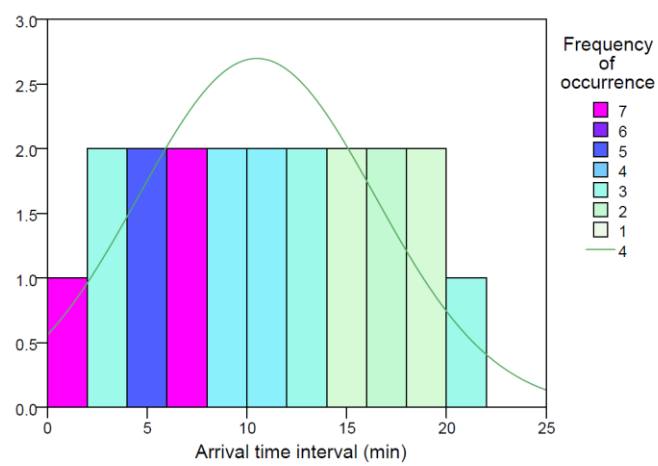

Fig. 5. Compare with histogram and probability density curve.

It can be seen from the Fig. 5 that the estimated exponential distribution is in good agreement with the observed samples, so the exponential distribution function can be used to set the parameters of the model and simulate the real system.

According to the basic ACO principle and algorithm flow, this model is solved by MATLAB programming. The best results in 10 experiments are shown in Fig. 6 and 7 below.

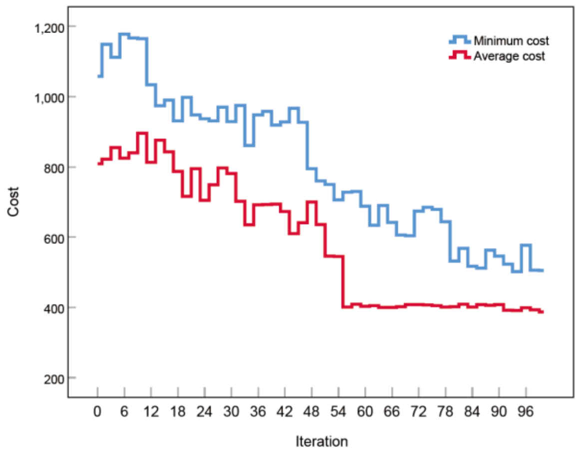

Fig. 6. Basic ACO iterative process.

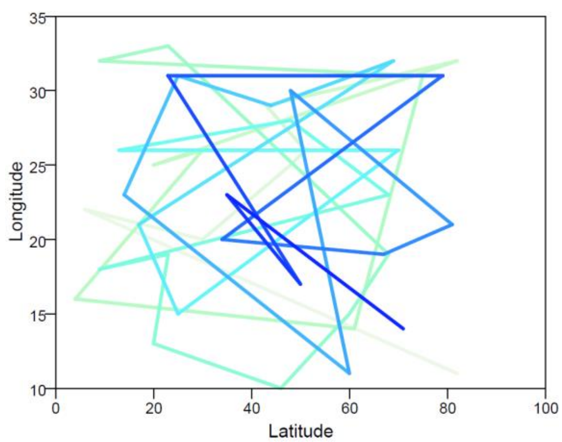

Fig. 7. Basic ACO optimal path.

At the beginning of the algorithm iteration, with the increase in iteration times, the quality of the current optimal solution rises sharply. The total cost of the current optimal solution changes relatively little after the 20^{th} iteration until the total cost of the current optimal solution stops decreasing at the 55^{th} iteration, and the global optimal solution is obtained.

Taking the processed target benefit function as the final goal, after running in MATLAB, the display results are shown in Fig. 8.

Compared with VRP, which does not consider customer value, VRP, which does not consider customer value lags far behind in customer satisfaction with delivery time. Even the average satisfaction of key customers with high value is only 55.1%, which is 18.3% higher than that of the planning that does not consider value. The improvement in resource allocation efficiency is obvious.

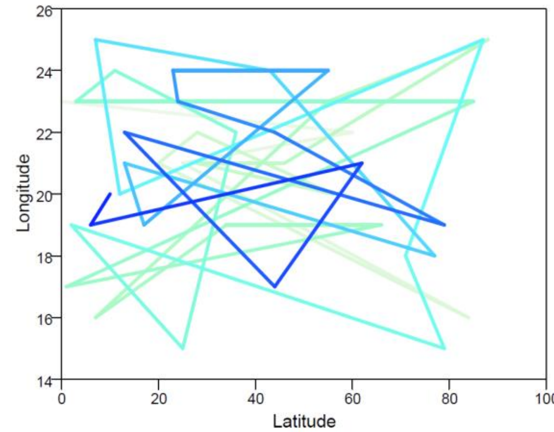

Fig. 8. Vehicle distribution route considering customer value.

It can be seen that the time and expense of the calculated results are different according to the degree of attention to vehicle delivery cost and delivery time. The evolutionary algebra of the improved ACO model solution and the classical ACO solution in the cloud computing environment are shown in Fig. 9.

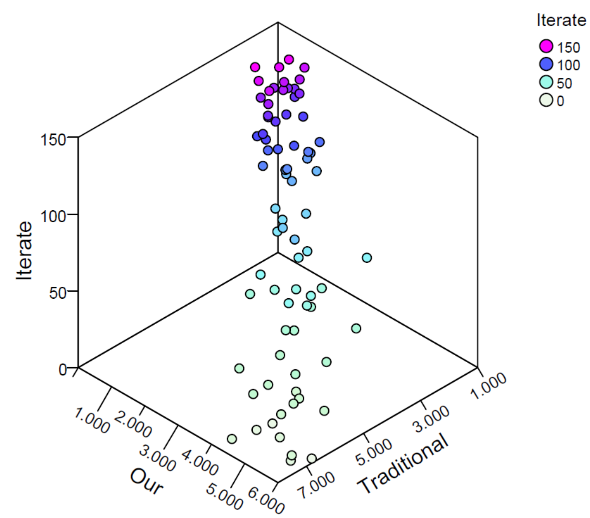

Fig. 9. Comparison between improved ACO and classic ACO.

When different processors are used, the execution time of the algorithm is different. To a certain extent, the more processors, the shorter the calculation time. It is proved that the shortest path calculation is correct, which can effectively solve the path planning problem on the road network with traffic rules.

In practical applications, we can evaluate the performance of models by comparing the performance of different algorithms. However, for cold chain logistics, due to issues related to food quality, safety, and other aspects, we still need to consider some additional factors. For example, different foods have different temperature requirements, and some foods need to be stored or transported at specific temperatures, otherwise it may affect their quality or safety. Therefore, when establishing integer programming models and designing targeted ant colony optimization (ACO) solving models, we need to fully consider these factors to ensure that the model can meet practical needs.

In addition, we should also note that the ant colony optimization algorithm itself has some limitations. For example, during the ant search process, they may fall into local optima and cannot find global optima. Therefore, when designing targeted ant colony optimization (ACO) solving models, we need to take some measures to avoid this situation. For example, suitable heuristic information can be set to guide ants in their search direction, or random factors can be introduced to jump out of the local optimal solution.

V. Conclusion

Logistics operations such as low-temperature production, low-temperature transportation and low-temperature storage are selected in the cold chain logistics distribution process, which is a key logistics project supported by the state in recent years. In reality, the delivery time may change due to the difference in delivery time and other factors, and the research on dynamic vehicle scheduling problems is still in the initial stage. The information on vehicle dynamic scheduling problem optimization is related to the travel time and speed of vehicles. This paper will consider the cold chain distribution situation of multi-vehicle coexistence, build an integer programming model based on multi-source visual information fusion technology, design a targeted ACO solution model, and verify it with an example. The results show that the satisfaction of delivery time is far behind, and even the average satisfaction of key customers with high value is only 55.1%, which is 18.3% higher than that of planning without considering value. The improvement in resource allocation efficiency is obvious. And it shows the correctness in calculating the shortest path, which can effectively solve the problem of cold chain logistics path planning with traffic rules constraints.

However, this study still has certain limitations. The acquisition and processing of multi-source visual information requires a large amount of manpower and technical support. Planning models may involve complex algorithms and data processing processes, resulting in reduced interpretability of the model. This may affect the user's trust and acceptance of the model results. In the future, while ensuring model performance, try to simplify the complexity and computational complexity of the model as much as possible. Visualization techniques and interpretive algorithms can be used to make the model results more intuitive and understandable. In addition, domain experts can also be invited to evaluate and validate the model, improving its credibility and acceptance.

Competing of Interests

The authors declare no competing of interests.

Authorship Contribution Statement

Ke Xue: Writing-Original draft preparation, Conceptualization, Supervision, Project administration.

Bing Han: Methodology, Software, Validation.

Project

1) 2024 Henan Province University Humanities and Social Sciences General Project: Research on the bottleneck and implementation path of the cold chain logistics industry development under the "dual carbon" goal, 2024-ZZJH-049.

2) Henan University of Animal Husbandry and Economy discipline construction project at the school level: Cold chain logistics, XJXK202205.

3) 2022 Doctoral Research startup funds project at Henan University of Animal Husbandry and Economy: Research on high-quality development path and implementation mechanism of fresh agricultural product supply chain in county area of Henan Province, 2022HNUAHEDF053.

4) Purchasing faced topic of China Society of Logistics: Research on high-quality development path and implementation mechanism of cold chain logistics in county areas, 2023CSLKT3-134.

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