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Study on Dairy Distribution Path Optimization Considering Multicenter and Carbon Trading Mechanism

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Abstract: This study focuses on the perspective of low carbon economy and enterprise cost under multiple distribution center. Based on the method of operation research, based on the perspective of enterprise distribution cost, the dairy cold chain distribution path optimization model is built from the fixed cost, transportation and refrigeration cost, cargo loss cost, customer satisfaction cost and carbon tax cost, and the genetic simulation degradation algorithm is designed to conduct the result simulation. The research results are as follows: (1) compared with genetic simulation algorithms and simulated annealing algorithms that overcome the problems of population diversity and local convergence, and their operation time and optimization degree are greatly improved.(2) Comparing the results of the three multi-center distribution schemes, there is little optimization difference between administrative distribution and focus zoning distribution, and the joint distribution mode under the integration of distribution resources is better than other schemes under the total cost or segmentation cost.(3) Changes in carbon trading parameters have a significant impact on the path optimization under the joint distribution mode: carbon price changes lead to higher distribution cost and lower distribution mileage; carbon quota changes under the fixed carbon price are characterized by three stages of carbon cost pressure—carbon cost transition—carbon trading dividend. In short, enterprises should pay attention to the balance between cost, customer and environment, and the joint distribution mode has more cost pressure.

1. Introduction

Under the impact of COVID-19 and consumption upgrading, people's demand for, and quality requirements of low-temperature dairy products has been continuously improved, which has promoted the development of cold-chain logistics in China. As an industry with high energy consumption and high carbon emissions, cold chain transportation, on the one hand, makes enterprises face high cost pressure, and on the other hand, the contradiction with the current "low-carbon economy" has triggered the discussion in the academic circle on the relationship between its economic benefits and environmental influence. In addition, China's low-temperature dairy products are still in the pattern of market demand development and enterprise regional distribution pattern. The cold chain link limits the development of enterprises to some extent due to unreasonable route planning, product perishable, high distribution cost, short distribution radius and other problems. So need from the enterprise economic benefit-customer satisfaction-environmental protection optimization of dairy products cold chain logistics cost and distribution path, reduce the dairy enterprise cold chain distribution link distribution cost, improve customer satisfaction and social benefits of high quality development, this paper based on multiple cost perspective to build target optimization model, using intelligent optimization algorithm to solve, help cold chain distribution path more reasonable.

For a long time academia about the vehicle path (VRP) has done a lot of research, and the research content gradually rich, such as: single target to multiple target, single distribution center to multiple distribution center, bicycle to multiple models and no time window to hard time window to mixed time window of the extension of the problem, with the deepening of VRP research, the way to solve this problem is gradually transition from accurate algorithm to heuristic algorithm. Thibaut V et al [1], For a simple vehicle path problem with limited carrying capacity, a simple mixed-open-source genetic search can effectively explore the important contribution of SWAP movement to local search efficiency and accuracy. Based on this, Camilo F-G J et al [2] Considering the dynamic capacity vehicle path problem of random customers, a multi-agent system based on trajectory data mining technology is proposed to extract the territory mode, which can effectively solve the logistics distribution business of express logistics companies processing a large number of parcels. In order to solve the large-scale demand point distribution, enterprises can adopt three-party logistics cooperation or establish multiple distribution centers at most. The traditional scheme transforms the multi-center into a single center to implement the distribution. In recent years, the academic circle has done more research on the problem of joint distribution. Lei Kun et al [3]The end-to-end deep reinforcement learning framework is proposed, MDVRP is modeling as a Markov decision process, innovative coding and decoding methods, using improved REINFORCE algorithm to train the model, realize the size of the graph, can be used to solve the problem of any vehicle field and the number of customers. Pu Xujin et al [4]. We design an improved genetic algorithm to solve the multi-distribution center problem, and confirm the effectiveness of the algorithm through calculation examples. In addition, the simulated annealing algorithm, improved ant colony algorithm and the whale algorithm are used to solve the MDVRP problem [5-7].

It can be seen that the research on VRP and its expansion is mainly on the level of enterprise cost, and ignores the problems of satisfaction of demand side satisfaction and environmental benefits. Zhang Lin et al [8]. Based on consumer satisfaction and other factors, the dairy joint distribution mode can relieve traffic pressure and reduce energy consumption. Zou Yi et al[9]In view of how to select the appropriate production batch and inventory level of dairy manufacturers, the three-objective optimization model of cost-time-customer satisfaction is put forward, and the route of dairy product site selection-distribution is optimized. For the study of carbon emission reduction model, Zhang S and other companies established a decision model of low-carbon cold chain system based on the double-layer planning theory, and used the improved chaotic particle swarm algorithm to prove that the joint implementation of carbon subsidy and carbon quota is better than the one-way drive of the policy, and at the same time, the impact of carbon quota and carbon subsidy quota on the green transformation of enterprises should be avoided [10]. In addition, scholars will subsidize new energy vehicles [11] And, Carbon emission right trading [12]Add the model to start the study.

The current academic research on VRP and its expansion problems is relatively mature, adding carbon emissions, distribution center, time window and cargo loss cost into the traditional model, to meet the needs of enterprises and customers, find a new balanced distribution mode, can help enterprises solve the practical problems of cold chain distribution; in addition, the research of cold chain distribution path optimization scheme mainly includes technical equipment update and solution algorithm optimization, which provide rich solution tools for the optimization model of this research.

However, the research still has the following shortcomings: the establishment of: (1) optimization model mostly adds a single parameter on the basis of the traditional VRP model, and only studies the soft and hard time window, carbon emission or customer satisfaction has some one-sided in solving practical problems.(2)multi-distribution centers focuses on the research of solutions, including traditional adjacent zoning, center of gravity zoning or overall regional distribution, with less focus on the actual level of the enterprise, while the comparison of multiple partition solutions at the enterprise level is even scarce. The (3) solution algorithm focuses on a single algorithm. Modern heuristic algorithm has become the mainstream method of solving VRP and its expansion problems, many scholars through the improvement of a single algorithm, a variety of algorithms complementary build hybrid algorithm improves the accuracy of the solution, more distribution center research complexity is higher, solving difficulty increases and solution range becomes wider, using hybrid algorithm solution multiple center research on the accuracy of the results is very important.

2. Problem Description and Assumptions

2.1. Problem Description

Dairy cold chain logistics is not simply to complete the supply side to the demand side distribution, but should ensure the product quality while saving the distribution time. As daily consumer goods, most enterprises establish multiple distribution centers in regional distribution. How to choose the multi-center scheme is the problem that enterprises must pay attention to. In addition, with the proposal of "double carbon" target and the establishment of carbon trading market, China's high energy consumption and high emission industries are gradually transforming to green and low-carbon high-quality development. In 2021, air transportation industry is listed as one of the carbon trading market industries, which shows that the logistics industry is ushering in the era of carbon inclusion. Therefore, it is of practical significance to choose the scheme of multi-distribution centers, and to take the carbon trading mechanism, customer satisfaction and other issues into the distribution cost.

Therefore, this paper considers that in multiple distribution centers, the demand points and demand requirements are known, and each distribution center has a set of refrigerated trucks with known load capacity. In the multi-distribution center solution, the traditional method of multi-center into single center (administrative division, center division) and joint distribution scheme are used for cost comparison, so as to ensure the completion of distribution within the acceptable time range of customers, so as to achieve the purpose of reducing the total cost.

2.2. Conditional Assumptions

Carbon trading mechanism reference, makes the optimization of vehicle path is more complex, in order to facilitate research, need to abstract practical problems into a mathematical model, multicenter scheme of different assumptions and mathematical model partial differences, can be divided into demand side resources of single center model and supply side resource sharing joint distribution model.

2.2.1. Mathematical Optimization Model under the Customer Resource Integration Mode

The single-center model of demand-side resource division will take into account the following important assumptions and constraints:

(1) The flow direction of the goods delivered by the vehicles is one-way, that is, the vehicles are only delivered, without considering the receipt; and the cold chain products delivered are the same commodity, and the price is consistent.

(2) The distribution center is only one, and the starting point of each transport loop of each distribution vehicle is expressed by the distribution center with 0, and the geographical location of the distribution center and the customer point is known;

(3) The same types and equipment of cold chain transport vehicles. Single customer demand or the same path of total customer demand must be less than or equal to the maximum load of the vehicle.

(4) Each customer is only served by one vehicle or one distribution center, and it can not be served by multiple vehicles, or by one car for multiple times. Single customer demand or the same path total customer demand must be less than or equal to the maximum load of the vehicle.

(5) The vehicle runs at a uniform speed with no traffic jams, vehicle damage and other accidents.

(6) The vehicle starts from the distribution center and returns to the initial distribution center after completing the distribution task.

2.2.2. Mathematical Optimization Model under the Resource Integration Mode of the Distribution Center

The establishment of the joint distribution model of supply-side resource sharing will take into account the following important assumptions and constraints:

(1) The resources of multiple distribution centers are deployed to cold chain products and transport vehicles by a unified dispatching platform to realize information sharing. And think that the distribution of cold chain products is the same commodity, the price is the same.

(2) The information of the customer demand point, product demand and delivery time limit is known, and the relevant information will not change during transportation.

(3) The same types and equipment of cold chain logistics transportation vehicles. Single customer demand or the same path of total customer demand must be less than or equal to the maximum load of the vehicle.

(4) Each customer can only have one vehicle, one distribution center for distribution service, which can not be served by multiple cars, nor by one car for service for multiple times.

(5) The vehicle runs at a uniform speed with no traffic jams, vehicle damage and other accidents.

(6) The vehicle starts from the distribution center and returns to the nearest distribution center after completing the distribution task.

3. Mathematical Model

3.1. Problem Analysis and Formulation

The mathematical optimization model established in this paper not only generates the labor, transportation and refrigeration cost of the cold chain logistics distribution, but also includes the time penalty cost of violating the customer time window, the delivery cargo loss cost and the carbon emission cost of violating the customer time window.

3.1.1. Fixed Cost

The size of the fixed cost has nothing to do with the business volume and the service time. The fixed cost of distribution in the logistics industry is mostly concentrated in the labor cost and vehicle depreciation, which are both related to the number of vehicle services and change linearly.

$$C_1 = P_1 K \tag{1}$$

3.1.2. Transportation and Refrigeration Costs

Driving distance has a positive impact on the changing cost in transportation, mainly including the cost of transportation and refrigeration. The transportation cost is the basic cost of realizing the distribution point to the demand point, while refrigeration is the additional cost generated in the cold chain logistics distribution.

$$C_2 = P_2 \sum_{k \in K} \sum_{i,j \in M \cup N} x_{ijk} d_{ij} + P_3 \sum_{k \in K} \sum_{i,j \in M \cup N} x_{ijk} \left(f_1 \frac{d_{ij}}{v_1} + f_2 \frac{q_j}{v_2} \right) \tag{2}$$

3.1.3. Cost of Goods Loss

Due to the perishable characteristics of dairy products, the cargo damage cost caused by transportation mainly comes from the deterioration of food freshness caused by the prolonged time of delivery and the product quality loss caused by the internal and external air convection during the unloading process. This paper constructs the corruption function of cold chain products to describe the corruption law of products $\varepsilon(t) = \varepsilon_1 e^{-\delta t}$.

$$C_3 = P_4 \sum_{k \in K} y_{ijk} \sum_{i,j \in M \cup N} \left[q_j \left(1 - \sigma_1 e^{-\delta(t_{jk} - t_{dp})}\right) + Q_{in} \left(1 - \sigma_2 e^{-\delta \frac{q_j}{v_2}}\right) \right] \tag{3}$$

3.1.4. Time Penalty Costs

In addition to affecting the quality of the product itself, the timeliness of cold chain logistics has a direct relationship between customers' inventory, sales and re-distribution, that is, the time when the transport vehicles reach the demand point too early or too late will produce additional costs for both supply and demand. Therefore, this study set up the corresponding time penalty cost function according to the service period requirements of the customer, assuming that the ideal accepted service time period of the customer j is $T_{\mathrm{m1}} \le t_{jk} \le T_{\mathrm{m2}}$ The time penalty cost is 0, and the earliest and late arrival time is T_{E} and T_{L}, If in $T_{\mathrm{E}} \le t_{jk} \le T_{\mathrm{L}}$ Did not arrive,Customer will refuse service; if not arriving at the ideal time, in $T_E < t_{jk} < T_{\mathrm{m1}}$ and $T_{m2} < t_{jk} < T_L$ During the time period, the corresponding penalty cost will occur. The specific time penalty cost model is as follows.

$$C_4 = P_5 \sum_{j \in m} \sum_{k \in K} max\left(T_{m1} - t_{jk}, 0\right) + P_6 \sum_{j \in m} \sum_{k \in K} max\left(t_{jk} - T_{m2}, 0\right) \tag{4}$$

3.1.5. Carbon Transaction Costs

Under the carbon emissions trading mechanism, cold-chain logistics companies will have to pay extra money to buy more carbon quotas if they exceed their set limits. But cold-chain logistics companies can sell carbon quotas if their emissions are below the prescribed limit.

Fuel consumption per unit distance can be expressed as:

$$f(X) = f_0 + \frac{f^* - f_0}{Q_z} X \tag{5}$$

The fuel consumption during the cold-chain distribution process is:

$$F_c = \sum_{i,j\in M\cup N}\sum_{k\in K} x_{ijk}\left[\left(f_0 + \frac{f^* - f_0}{Q_z}Q_{ij}\right)d_{ij} + \left(f_1\frac{d_{ij}}{v_1} + f_2\frac{q_j}{v_2}\right)\right] \quad (6)$$

Specific carbon emission costs can be expressed as follows:

$$\begin{aligned} C_5 &= P_7\left(EM - F_i\right) \\ &= P_7\left\{\rho\sum_{i,j\in M\cup N}\sum_{k\in K} x_{ijk}\left[\left(f_0 + \frac{f^* - f_0}{Q_z}Q_{ij}\right)d_{ij} + \left(f_1\frac{d_{ij}}{v_1} + f_2\frac{q_j}{v_2}\right)\right] - F_i\right\} \end{aligned} \quad (7)$$

3.2. Distribution Path Target Optimization Model

To sum up, the mathematical optimization model considering the carbon trading mechanism is divided into a single distribution center and a multi-distribution center model according to the different multi-distribution center solutions. The specific model is as follows.

3.2.1. Single-Center Model of Demand-Side Resource Division

3.2.1.1. Objective Function

$$\begin{aligned} \min C &= C_1 + C_2 + C_3 + C_4 + C_5 \\ &= P_1K + P_2\sum_{k\in K}\sum_{i,j\in M\cup N} x_{ijk}d_{ij} + P_3\sum_{k\in K}\sum_{i,j\in M\cup N} x_{ijk}\left(f_1\frac{d_{ij}}{v_1} + f_2\frac{q_j}{v_2}\right) \\ &+ P_4\sum_{k\in K} y_{ijk}\sum_{i,j\in M\cup N}\left[q_j\left(1 - \sigma_1 e^{-\delta\left(t_{jk} - t_{dp}\right)}\right) + Q_{in}\left(1 - \sigma_2 e^{-\delta\frac{q_j}{v_2}}\right)\right] \\ &+ P_5\sum_{j\in m}\sum_{k\in K} max\left(T_{m1} - t_{jk}, 0\right) + P_6\sum_{j\in m}\sum_{k\in K} max\left(t_{jk} - T_{m2}, 0\right) \\ &+ P_7\left\{\rho\sum_{i,j\in M\cup N}\sum_{k\in K} x_{ijk}\left[\left(f_0 + \frac{f^* - f_0}{Q_z}Q_{ij}\right)d_{ij} + \left(f_1\frac{d_{ij}}{v_1} + f_2\frac{q_j}{v_2}\right)\right] - F_i\right\} \end{aligned} \quad (8)$$

3.3.1.2. Constraint Condition

Each customer can only be served by one car and only once:

$$\sum_{k\in K}\sum_{i,j\in M\cup N} x_{ijkm} = 1,\ j\in M \quad (9)$$

The vehicle starts from the distribution center, and needs to return to the original distribution center after serving the customers:

$$\sum_{i=1}^{n} x_{jik} = \sum_{i=1}^{n} x_{ijk} \le 1, \forall k\in K \quad (10)$$

Avoid vehicles from moving directly from one warehouse to another:

$$\sum_{i=1}^{m}\sum_{j=1}^{m}\sum_{m=1}^{m} x_{ijkm} = 0, \forall k\in K \quad (11)$$

Vehicles shall not be overloaded during transportation:

$$\sum_{i\in M\cup N}\sum_{j\in m}\sum_{k\in K}\sum_{m\in M} qx_{ijkm} \le Q_z \quad (12)$$

There may be cargo damage during transportation, so limiting customer demand is less than the actual arrival volume of refrigerated vehicles:

$$\sum_{k\in K} Q_{ijk} \geq q_i \text{ , } \forall i \in M \cup N \text{ , } \forall j \in M \tag{13}$$

The delivery process is continuous:

$$t_{jk} = t_{jk} + \frac{d_{ij}}{v_1} + \frac{q_i}{v_2} \tag{14}$$

Ensure that the delivered vehicles are less than the existing quantity:

$$\sum_{i=1}^{m}\sum_{j=1}^{m}\sum_{m=1}^{m} x_{ijk} = K \tag{15}$$

The probability of meeting all customer needs is not less than the set confidence level:

$$\sum_{i\in M\cup U}\sum_{k\in K} Q_{ijk} \geq \phi^{-1}(\Im)\bullet\sqrt{D(q_i)} + E(q_i) \tag{16}$$

3.2.2. Joint Distribution Model of Supply-Side Resource Sharing

In this section, the model optimizes the minimum total distribution cost, and the constructed objective function agrees with the previous section cost function, judging from the relevant cost analysis of the previous section.

$$\begin{aligned}
\min C &= C_1 + C_2 + C_3 + C_4 + C_5 \\
&= P_1 K + P_2 \sum_{k\in K}\sum_{i,j\in M\cup N} x_{ijk} d_{ij} + P_3 \sum_{k\in K}\sum_{i,j\in M\cup N} x_{ijk}\left(f_1\frac{d_{ij}}{v_1} + f_2\frac{q_j}{v_2}\right) \\
&+ P_4 \sum_{k\in K} y_{ijk} \sum_{i,j\in M\cup N}\left[q_j\left(1-\sigma_1 e^{-\delta\left(t_{jk}-t_{dp}\right)}\right) + Q_{in}\left(1-\sigma_2 e^{-\delta\frac{q_j}{v_2}}\right)\right] \\
&+ P_5 \sum_{j\in m}\sum_{k\in K} max\left(T_{m1}-t_{jk},0\right) + P_6 \sum_{j\in m}\sum_{k\in K} max\left(t_{jk}-T_{m2},0\right) \\
&+ P_7\left\{\rho \sum_{i,j\in M\cup N}\sum_{k\in K} x_{ijk}\left[\left(f_0 + \frac{f^* - f_0}{Q_z}Q_{ij}\right)d_{ij} + \left(f_1\frac{d_{ij}}{v_1} + f_2\frac{q_j}{v_2}\right)\right] - F_i\right\}
\end{aligned} \tag{17}$$

The constraint condition adds the vehicle yard opening constraint on the basis of the previous section constraint:

$$\sum_{i\in N} x_{ijk} = 1, \forall k \in K \tag{18}$$

3.3. Transformation of Stochastic Constraints

In order to reduce the interference of the path decision due to customers' randomness in the demand for fresh products, the opportunity constraint planning model is established, assuming that the probability of meeting the minimum requirement of customer demand is $\Im$,Due to the constraint (16) in the model, the equivalent conversion method is referred to. The process is as follows.

suppose $S = q_i - \sum_{i\in M\cup U}\sum_{k\in K} Q_{ijk}$, The expected value and the variance of the available S, respectively is $E(S) = E(q_i) - \sum_{i\in M\cup U}\sum_{k\in K} Q_{ijk}$, $D(S) = D(q_i)$ .suppose $\eta = \frac{S-E(S)}{\sqrt{D(S)}}$ because $S = q_i - \sum_{i\in M\cup U}\sum_{k\in K} Q_{ijk} \leq 0$,Its equivalent

$\eta=\frac{S-E(S)}{\sqrt{D(S)}}\leq\frac{-E(S)}{\sqrt{D(S)}}$ So the constraint (16) can be expressed as $P\left\{\eta\leq-\frac{E(S)}{\sqrt{D(S)}}\right\}\geq\Im$ suppose $\phi(\eta)$ is η The probability density function, when the constraint (16) at the confidence level is $\Im$ is established at the time,When and only when $\phi^{-1}(\Im)\leq-\frac{E(S)}{\sqrt{D(S)}}$,Based to the expected value and variance formula: $\sum_{i\in M\cup U}\sum_{k\in K}Q_{ijk}\geq\phi^{-1}(\Im)\bullet\sqrt{D(q_i)}+E(q_i)$,In the formula $\sqrt{D(q_i)}$ and $E(q_i)$ Separate customers Variance and expected mean of the demand of i .

In summary, stochastic constraints (16) can be translated into determination constraints $\sum_{i\in M\cup U}\sum_{k\in K}Q_{ijk}\geq\phi^{-1}(\Im)\bullet\sqrt{D(q_i)}+E(q_i)$.

3.4. Symbol Description

Set the parameters according to the requirements of the model building: N Set up for customers; M Collection for distribution centers; k For the vehicle number; i, j For the node on the distribution network; d_{ij} denotes the node i , j Distance between; q_i Demand for a single customer; P_1 The fixed cost of the unit vehicle; P_2 Change cost of transportation per unit distance; P_3 For diesel prices; P_4 Price of cold chain products per unit weight; P_5 The penalty price for the unit of waiting time; P_6 Punishment price for the unit of late time; P_7 Carbon price; σ_1 Goods loss factor during transportation; σ_2 cargo loss factor during door opening; δ perishable rate of cold chain products; v_1 vehicle transportation speed; v_2 unloading speed; f_1 refrigeration fuel consumption at unit time; f_2 unit time during unloading; f^0 fuel consumption of vehicle at full load; f^* maximum cargo capacity; Q_z quantity of cold chain products from node to node; Q_{ij} quantity of cold chain products when i vehicle leaves the j node; Q_{in} earliest time window for the j customer requirements; T_{m1} Is the latest time window required by the customer; T_{m2} is the carbon quota; F_i is the conversion efficiency of carbon emission; t_{jk} is the time when the vehicle k reaches the customer j ; t_{k0} is the departure time of the vehicle; C_n represents the first cost; X_{ijk} and Y_{ijk} is the decision variable when the refrigeration vehicle k transports the product from the node i to the node j , $X_{ijk}=1;\ Y_{ijk}=1$; otherwise, $X_{ijk}=0; Y_{ijk}=0$.

4. Genetic Simulation Annealing Algorithm (GS-SA)

This study combines the advantages of the genetic algorithm and the simulated annealing algorithm to construct the genetic simulated annealing algorithm and provide a more accurate heuristic algorithm. The algorithm is mainly divided into three parts: ① during the initial solution construction, the chromosome code and initial population are used to enhance the ability of parallel search of simulated annealing algorithm; ② to select, cross and vary, and ③ to avoid the neighborhood search method of simulated annealing algorithm, and to strengthen its optimization ability.

4.1. Algorithm Design

(1) Parameter initialization: set the population size of Nmax, the maximum number of iterations (n), the initial crossover probability (Pc), the variation probability (Pm), and the initial temperature (T) and cooling coefficient (τ) of the simulated annealing.

(2) Coding and decoding: the integer coding is used to avoid the repair process that the traditional binary coding produces unfeasible solutions. The length of the chromosome is the number of customers, and the location of the genes on the chromosome is the service order of the customers. The vehicle starts from any distribution center closest to the first customer and is accessed in the service order. When the load and customer service time constraints cannot be met, it returns to any distribution center close to the last customer and sends a new vehicle to continue the service.

(3) Fitness function. In the genetic algorithm, the chromosome fitness value is used to evaluate the merits of the individual. This paper uses the inverse of the total cost to represent the fitness function value of the chromosome, that is, the smaller the target function value, the greater the fitness value of the chromosome is, the better the individual, the greater the probability of being selected, and the smaller the probability of being selected. The fitness function of f_R a chromosome R can be expressed as:

$$f_R = \frac{1}{C_R} \tag{18}$$

C_R is the target function value of chromosome R.

(4) Select the operation. To ensure the diversity of the initial population, the elite retention strategy and roulette strategy. Let the population size be L , and keep the elite individuals to the next generation with the elite retention strategy, and then the remaining individual-selected individuals are retained with the roulette strategy $(L-1)$ in each iteration to be inherited to the next generation along with the elite individuals. The formula for calculating the selected probability is:

$$S_z = \frac{f_i}{\sum_{i=1}^{NIND} f_i} \tag{19}$$

f_i is indicates the fitness values of individual No i .

(5) Cross over and variation.The better group obtained by the selection operation, The crossover operation needs to be done with probability P_c , Commonly used crossover operators are partial matching crossing, two-point crossing, sequential crossing and average crossing, In this paper, the "selection of chromosomes and crossover positions (random)-the natural number of repeats after deleting crossover regions" is used to complete the recombination of chromosome segments; Variiation operation is simultaneously with crossover operation, The probability of P_m variation is, To ensure the validity and full alignment properties of the chromosomes C ,The variation used in this study were: random selection of one chromosome and two locations, Interchanging the numbers on the two positions, To get a new chromosome C' ,Finally, the newly generated offspring, If there is no overload present, Consider as a valid child, Otherwise the remutation.

(6) Genetic initialization. After crossover and variant processing based on genetic algorithm, An

initial solution is randomly selected x_0 Make the current solution $x_a = x_0$, current iterative steps $S = 0$, current annealing temperature $t_k = t_{\max}$, and the target function is calculated $C(x_a)$.

(7) Acceptance criteria. In the neighborhood of the initial solution x_a, a solution is randomly x_b chosen as the new solution $C(x_b)$ to calculate the objective function value $\Delta C = C(x_a) - C(x_a)$;if the new solution $\Delta C < 0$ is accepted, then $\Delta C > 0$ the probability is $e^{C(x_b)+C(x_a)/T}$ calculated as, which represents the T is current temperature.

(8) Determine whether the number of iterations is reached, then execute step (2); determine whether the iterations are reached, and then determine whether the termination conditions are met. If not satisfied, slowly reduce the annealing temperature, update the number of iterations, continue step (2), end the cycle and output the optimal solution.

4.2. Algorithm Validity Test

The CVRP standard examples are used to verify the performance of the algorithm. The specific parameters of the GA-SA algorithm are set as follows: population number (NP) 200, cross probability (Pc) 0.9, variation probability (Pm) 0.1, maximum iterations (Maxgen) 800 generations, initial temperature (T) 5000℃, etc. In this study, GA-SAP algorithm was used to solve 20 CVRP standard examples in the case library, and compared the results with the traditional GA and SA algorithms. As can be seen (Table 1), the convergence rate of GA-SA algorithm is within 20s on average, and the results have good optimization ability and stability, which can effectively solve the VRP problem.

Table 1: Comparison table of the calculation and example simulation results

Instances	*M*	*K*	*Q*	*BKS*	*CA*		*SAP*		*GA-SAP*	
					Best(%)	*Avg(%)*	*Best(%)*	*Avg(%)*	*Best(%)*	*Avg(%)*
A-n53-k7	52	7	100	1010	2.26	4.51	3.52	6.48	0.15	0.47
A-n54-k7	53	7	100	1167	3.54	5.36	4.33	7.29	0.07	0.16
A-n55-k9	54	9	100	1073	3.25	6.14	4.17	6.36	0.20	0.35
A-n60-k9	59	9	100	1354	2.41	4.57	3.38	5.17	0.11	0.29
A-n61-k9	60	9	100	1034	4.35	4.89	3.57	4.89	0.13	0.34
A-n62-k8	61	8	100	1288	3.56	5.21	4.58	5.35	0.24	0.40
A-n63-k9	62	9	100	1616	4.01	6.12	4.18	6.62	0.35	0.52
A-n64-k9	63	9	100	1401	2.82	3.78	3.47	5.18	0.19	0.46
A-n65-k9	64	9	100	1174	1.33	2.69	2.35	4.87	0.33	0.63
A-n69-k9	68	9	100	1159	3.47	5.43	4.89	6.54	0.26	0.47
Average	-	-	-	-	3.10	4.87	3.84	5.88	0.20	0.41

5. Example Analysis

5.1. Example Calculation and Parameter Introduction

Table 2: Basic data of distribution nodes and customer requirements

Node information	Node coordinates x/km	y/km	service time /min	[Ej , Lj]	[Gj , Hj]	Expected mean/t	variance
A	10.79	11.02			[4:00-17:00]		
B	18.37	13.05			[4:00-17:00]		
C	7.43	5.19			[4:00-17:00]		
1	7.78	10.70	6	[5:30-10:20]	[4:30-11:00]	0.35	1
2	9.67	10.98	4	[5:30-11:10]	[5:00-12:00]	0.23	1
3	7.96	14.23	3	[5:00-10:50]	[4:30-12:00]	0.54	1
4	10.03	14.53	3	[6:10-10:20]	[5:10-11:10]	0.14	1
5	11.94	14.84	4	[6:00-11:10]	[5:00-12:00]	0.22	1
6	13.27	14.98	3	[5:50-10:50]	[4:50-12:00]	0.18	1
7	7.42	9.32	6	[6:30-10:20]	[6:00-11:30]	0.34	1
8	4.86	10.34	4	[6:30-10:10]	[5:30-10:30]	0.20	1
9	1.46	11.83	9	[6:10-10:10]	[5:00-11:00]	0.51	1
10	8.22	9.36	4	[5:50-9:20]	[4:50-10:30]	0.23	1
11	21.38	11.79	3	[5:30-9:10]	[4:30 - 9:50]	0.17	1
12	22.04	13.35	9	[6:20-11:00]	[6:00-12:00]	0.52	1
13	21.80	10.35	7	[6:30-10:50]	[5:50-11:40]	0.41	1
14	12.23	8.81	5	[6:30-9:30]	[5:30-10:20]	0.25	1
15	17.06	7.78	6	[6:40-10:50]	[6:00-12:10]	0.34	1
16	14.24	8.85	4	[5:20-11:10]	[4:50-13:00]	0.21	1
17	15.36	8.94	8	[6:10-8:30]	[5:20-9:20]	0.43	1
18	19.23	13.26	3	[6:10-10:20]	[5:10-11:10]	0.18	1
19	17.30	11.16	5	[5:50-9:30]	[4:50-10:20]	0.29	1
20	10.08	1.19	5	[6:30-11:20]	[5:30-14:00]	0.27	1
21	6.59	5.61	6	[7:20-11:50]	[6:20-13:00]	0.31	1
22	11.60	3.50	3	[6:10-10:20]	[5:00-11:00]	0.16	1
23	13.07	0.3	5	[6:40-10:00]	[5:40-10:40]	0.26	1
24	8.13	6.02	4	[5:50-10:40]	[4:50-11:20]	0.24	1
25	11.04	5.20	2	[6:30-11:10]	[4:30-12:00]	0.1	1
26	5.37	12.08	2	[7:00-10:10]	[5:10-11:10]	0.09	1
27	10.02	4.09	3	[6:00-10:30]	[5:00-12:00]	0.13	1
28	9.08	5.16	8	[5:50-11:10]	[4:50-12:00]	0.47	1
29	6.26	6.83	3	[6:00-9:00]	[5:20-9:20]	0.16	1
30	17.34	18.61	5	[6:30-10:00]	[5:10-11:10]	0.25	1
31	14.74	17.64	5	[5:20-9:20]	[4:50-10:20]	0.27	1
32	17.20	12.90	4	[6:30-12:30]	[5:30-14:00]	0.19	1
33	12.88	10.33	3	[6:50-12:10]	[6:20-13:00]	0.18	1
34	18.80	11.38	4	[6:10-10:20]	[5:00-11:00]	0.24	1
35	14.85	14.21	6	[5:40-10:10]	[5:10-11:10]	0.34	1
36	22.35	16.10	4	[5:30-9:20]	[4:50-10:20]	0.21	1

This article selects a self-built cold chain logistics dairy company, D Company now has certain regional market advantages, Set up multiple distribution centers in Shandong Province, To carry out centralized distribution to the community self-run stores, Jinan city is an important market for the company, Three distribution centers have been established, Multi-center distribution plan of the internship administrative division division, To verify the feasibility of the algorithm and optimize the multi-center scheme and distribution path, This paper selects D company Jinan distribution as a research example, It includes A, B, C three distribution centers and 36 demand points, The information about the distribution center and demand point coordinates, demand (Table 2) and related parameter information are the results of enterprise field research.

For 10 refrigerated vehicles, Maximum load weight of an individual vehicle is 2t, Use cost is 210 yuan/vehicle, Transportation change cost per unit distance is 1.61yuan/km, The price of cold chain products per unit weight is 20.5 yuan/kg, Diesel price per unit weight is 7.84 yuan/kg, The penalty price of the unit arriving in advance is 20 yuan/ h, The penalty price of the unit late time is 40yuan/h, Vehicle transport speed of 40km/h, No-load and full-load fuel consumption was 0.13 and 0.16, respectively, Cooling fuel consumption per unit time during transportation and unloading is 4.6L/h and 6L/h, respectively, The carbon emission conversion efficiency is 3.06; Carbon trading parameter-carbon quota is 100kg, The carbon price is 0.058 yuan/kg. In addition, the distribution of a single category of products is considered, so the perishable rate of dairy products in the distribution process is 0.002.

5.2. Selection of Multi-Center Distribution Scheme

In this paper, using the genetic simulated annealing algorithm, Under the premise of the multi-center distribution problem, Considering vehicle path optimization at multiple costs of fixed costs, transportation and cooling costs, cargo loss costs, time penalty costs and carbon emission costs, Using the HP OMEN by HP Laptop 15-dc0008TX as the experimental computer, The system is the Windows 10 flagship 64-bit operating system, Intel (R) Core (TM) i7-8750H CPU @ 2.20GHz processor, 8GB comes with a native RAM, Conduct calculations, Multi-center distribution schemes excluding carbon trading (Table 3) and carbon trading, Total distribution costs and the impact of distribution costs under changes in carbon trading parameters.

Table 3: Noconsider the cost comparison under the multicenter solution of the carbon tax policy

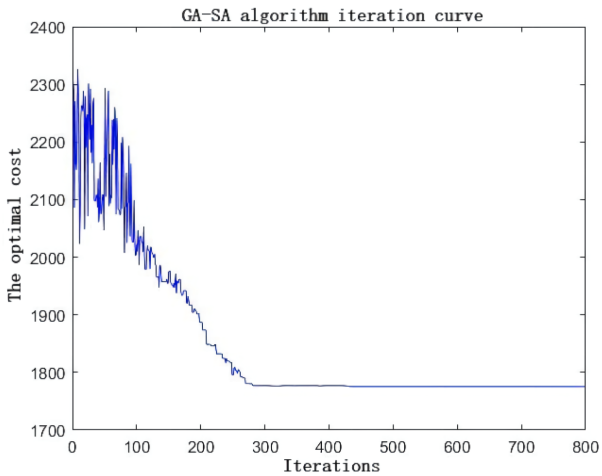
Cost category	actualcost	According to the administrative division		According to the center of gravity method		Joint distribution	
		primecost	optimize	primecost	optimize	primecost	optimize
constant cost	1680	1260	25%	1260	25%	1050	37.5%
Transportation and refrigeration costs	813.18	725.47	10.78%	729.166	10.33%	699.73	13.95%
Cost of goods loss	51.47	21.852	57.54%	21.159	58.89%	18.897	63.29
Time penalty costs	14.22	0	100%	5.295	62.76%	0	100%
Total distance	135.45	112.424	16.99%	113.877	15.93%	105.869	21.84%
Number of vehicles	6	6	0	6	0	5	16.67%
total cost	2694.32	2119.75	21.33%	2129.497	20.96%	1774.496	34.14%

According to the results of Table 3, the cost of gravity method (2129.497)> administrative division cost (2119.75)> Overall synchronous optimization distribution (1774.496); from the perspective of vehicle use, administrative division (6 vehicles) = gravity division (6 units)> overall synchronous optimization (5 vehicles). Based on the existing results, the synchronous optimization and processing of multiple distribution center problems under resource sharing can save the total cost of distribution personnel, vehicles and distribution. Compared with the actual cost of the original distribution, the total cost and the subdivision cost under the three modes have been improved to a certain extent, and the joint distribution mode significantly saves the total distribution distance and the cargo loss cost. The penalty cost of joint delivery is 0 yuan, which is better than the center of gravity method (5.295), and can meet the ideal time of 36 demand points. Due to the limited length of the article, The specific distribution route and vehicle arrival time are not shown, According to the query result, Compared to joint distribution, According to the administrative region and the center of gravity law zoning distribution mode is prone to the vehicle loading rate is too low phenomenon, If the distribution route under the current zoning scheme is [C2] --> 13--> 34---> [C2], and the distribution route is [C3] --> 21--> 29--> [C3] are 32.5% and 23.5%, respectively, The number of joint vehicles was five, The loading rate of each route is above 94%, Two of them had loads of up to 97%, It can be seen that the joint distribution mode can make full use of the distribution resources. To sum up, without considering the carbon trading mechanism, the joint distribution solution has more cost advantage in solving the multi-center problem of D company.

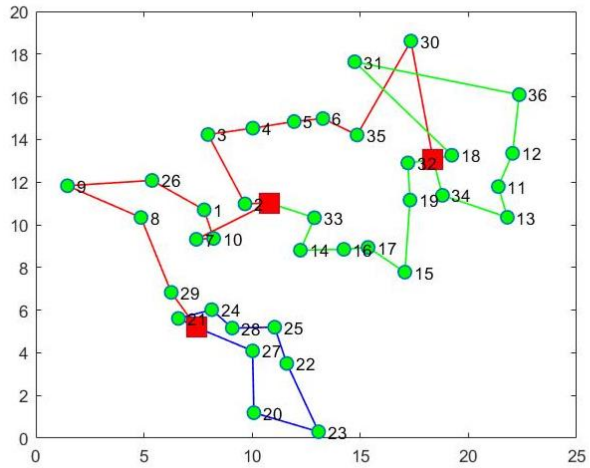
Table 4: Considers the cost comparison under the multi-center solutions of carbon tax policies

Cost category	Original distribution	According to the administrative division		According to the center of gravity method		Joint distribution	
		prime cost	optimize	prime cost	optimize	prime cost	optimize
constant cost	1680	1260	25	1260	25	1050	37.5%
Transportation and refrigeration costs	813.18	733.793	9.76	725.575	10.77	719.616	11.51%
Cost of goods loss	51.47	21.114	58.98	21.96	57.33	23.963	53.44%
Time penalty costs	14.22	2.451	82.76	3.272	76.99	0	1
Carbon emission costs	17.415	11.231	35.51	11.215	35.60	11.032	36.65%
Total distance	135.45	115.763	14.53	112.15	17.20	113.85	15.95%
Number of vehicles	6	6	0	6	0	5	16.66%
Consider carbon trading	2694.32	2028.589	24.71	2022.022	24.95	1804.611	33.02%
Don't consider carbon trading		2119.75	21.33	2129.497	20.96	1774.496	34.14%

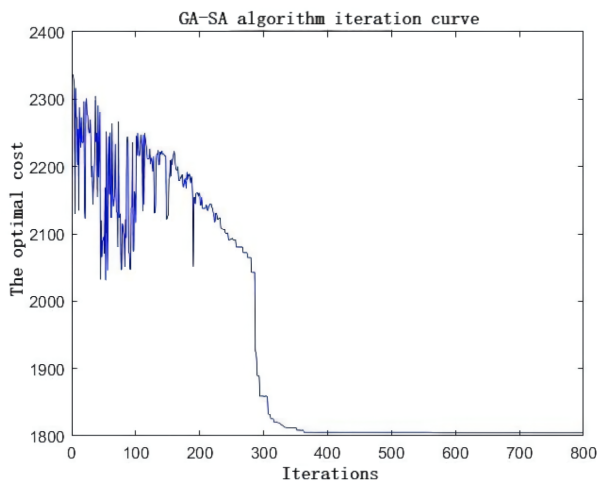
According to Table 4, considering the total cost of the cold chain vehicles under the carbon tax policy scenario is better than the actual distribution cost, and better than the cost under the carbon trading mechanism. Specifically, it is divided (2028.589 <2119.75)> center of gravity method division (2022.22<2029.497)> Joint distribution (1774.496<1804.611). Joint distribution mode is also the optimal solution. According to the query cost details, considering the carbon trading scenario, the algorithm is more inclined to save transportation and cooling costs and reduce fuel consumption. To sum up, joint distribution is the best solution for D company multi-center problems, based on this paper will optimize the route for visual processing (Figure 1).



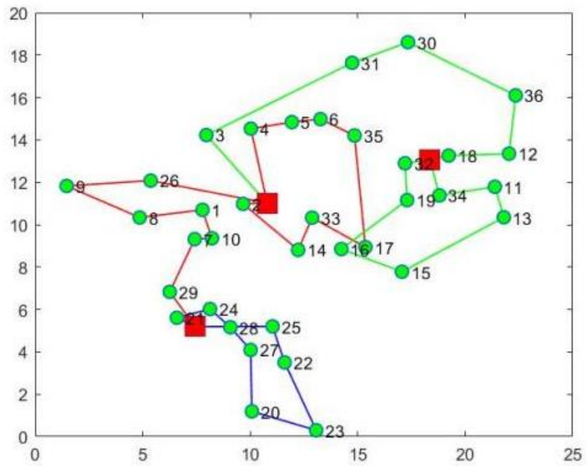
A 1. An iterative curve of algorithms not considering carbon trading



A 1. An iterative curve of algorithms not considering carbon trading



B1. An iterative curve of algorithms considering carbon trading



B2. Roadmap for joint distribution optimization considering carbon trading

Figure 1: Joint distribution Roadmap

5.3. Sensitivity Analysis of Changes in Carbon Trading Parameters

Carbon emission parameters mainly include carbon quota and carbon price, policy and market factors and other environment will affect the two types of parameters: quota and pricing, that is, different carbon emission parameters at different times. Therefore, this paper will discuss the impact of carbon quota and carbon trading price changes on the cold chain distribution path of the D company under the joint distribution mode, which can provide a reference for enterprises to make decisions in different carbon tax conditions.

Table 5: Results under different carbon prices and different quotas

Carbon Price (Yuan / kg)	Carbon quota (kg)	carbon emission (kg)	Carbon cost (Yuan)	Total distance distance (Km)	Total cost (YUAN)
0	0	258.27	0	105.869	1774.496
	100	240.45	2.809	116.211	1800.418
	200	244.1	0.882	124.431	1820.405
20	300	245.7	-1.086	129.587	1830.845
	400	245.55	-3.089	129.396	1827.824
	500	240.4	-5.192	116.099	1793.8
	100	237.08	6.854	108.89	1786.215
	200	240.76	2.038	116.254	1800.255
50	300	243.8	-2.810	121.844	1809.749
	400	241.3	-7.935	116.615	1791.800
	500	242.16	-12.892	118.344	1791.792
	100	243.44	11.475	120.604	1821.126
	200	238.78	3.102	111.416	1789.464
80	300	243.25	-4.540	123.182	1811.741
	400	241.47	-12.682	117.264	1790.344
	500	238.19	-20.945	111.046	1763.759
	100	242.03	15.623	121.852	1828.754
	200	237.68	4.145	108.924	1783.318
110	300	243.45	-6.220	124.331	1814.726
	400	243.05	-17.265	121.149	1793.110
	500	238.97	-28.713	113.305	1761.593
	100	246.21	20.469	128.87	1853.203
	200	242.89	6.004	121.868	1824.861
140	300	244.92	-7.711	126.91	1817.239
	400	239.35	-22.486	113.49	1769.296
	500	244.51	-35.769	123.171	1780.508

This study adopts the control variable method to ensure the same data and parameters, solve the optimal results under different parameters, set the reasonable difference of parameters into 20-140 yuan / ton, and the difference is 30; the carbon quota is 100-500 tons and the difference is 100. Based on this, the code was run 30 times to take the optimal result and record the relevant information, as detailed in Table 5. From the results, different carbon prices, different quotas of optimal results have certain differences, there are the following characteristics:①overall, joint distribution mode, carbon trading parameter change on D company distribution cost, and considering the carbon trading mechanism cost is not considering the carbon trading optimization cost, thus, the carbon emissions cost into D company cold chain distribution path optimization model, is conducive to reduce distribution cost, carbon emissions cost not only has a direct relationship, is also affected by the specific service customer point, refrigeration and other factors. In addition, the value of carbon emissions (230-250), total distance (100-125), carbon emission cost (235-245) is stable and have little difference, which indirectly reflects the effectiveness of the comprehensive optimization model and GS-SA algorithm established in this study.②From the perspective of fixed carbon price and carbon quota change: carbon quota, as the "free" emission quota in transportation, is directly related to the cold chain transportation cost of enterprises, that is, the larger the carbon quota quota, the more favorable it is to the enterprise operation. The data in the table can be roughly divided into three stages: the cost burden of the enterprises under the pressure of the carbon tax-The carbon quota is located near the actual carbon emission range of theenterprise—under the carbon tax dividend. Under carbon tax pressure, enterprises should take effective measures to reduce carbon emissions; when the carbon quota is near the actual carbon emissions, the project is lower than the carbon tax dividend, Company D can focus on other costs, or it can continue to reduce carbon emissions according to the cost weight, sell the remaining carbon quota for more profits, when the carbon price is high.③From the perspective of fixed carbon quota and carbon price change: with the increase of carbon price, the carbon emissions under the same carbon quota gradually decrease, and under different carbon prices, the proportion of the total cost reduction in the same carbon quota change range increases with the increase of carbon price.

6. Conclusion

This paper studies the enterprise level of low temperature dairy products cold chain distribution vehicle path, according to the particularity of the product perishable and high emissions of distribution process and multiple distribution center distribution model established mathematical optimization model, according to the problems of a single optimization algorithm, established genetic simulation return algorithm, overcome the initial population richness and local convergence, make the algorithm more robust, using CVRP examples after comparison optimization results and search speed is significantly better than GA and SA and single algorithm calculation. Select D company cold chain distribution of actual data and parameters, multiple solutions, by comparing administrative division, center of gravity partition division and joint distribution optimization results, considering the current carbon trading mechanism can help enterprises reduce the cost of cold chain distribution, and whether to consider the carbon tax policy, joint distribution mode is better than the two partition mode. Finally, the influence of the change of carbon trading parameters on enterprise distribution cost is analyzed. The results show that the change of carbon quota in carbon trading parameters shows carbon cost pressure-carbon cost pressure-carbon trading dividend, and the change of carbon price has a significant impact in the stage of carbon cost pressure and carbon trading dividend. Therefore, for enterprises, considering the comprehensive optimization of multiple cost segments will reduce the total cost expenditure and improve customer recognition to some extent. The implementation of carbon trading policy will promote the environmental friendliness of enterprises, and some enterprises will also profit in low-carbon transportation. This paper enriches the research of dairy cold chain logistics, comprehensively discusses the advantages and disadvantages of the solutions in multiple distribution centers, and considers the selection of the distribution solutions under the carbon trading mechanism, which has practical reference significance for D Company reference documentation.

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