Research on Fresh Produce Simultaneous Delivery and Pickup Vehicle Path Optimization

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Abstract: To address the two-way circulation problem of pickup and delivery of fresh agricultural products arising from the perishable characteristics of fresh agricultural products, a fresh agricultural products simultaneous delivery and pickup vehicle path optimization model is constructed with the goal of total cost optimization based on the start-up cost, transportation cost, carbon emission cost and time penalty cost of vehicles in the distribution process. To solve the problem that the ant colony algorithm is robust but easy to fall into local optimum, it is combined with genetic algorithm to improve the global search ability, and the proposed ant colony genetic algorithm's move probability selection rule, pheromone transfer strategy and crossover operator are improved to solve the model. The model and algorithm are simulated through examples, and the experimental results show that the optimized model and hybrid algorithm can propose a cost-optimal solution that can improve the vehicle loading rate while ensuring customer satisfaction, and can provide a reference for logistics companies to make vehicle path decisions for fresh produce delivery and pickup.

1 INTRODUCTION

Fresh agricultural products have high moisture content and are affected by temperature and humidity in the air, and are prone to spoilage and deterioration during storage (e.g. Zhou, 2022). The perishable nature of fresh agricultural products determines that in real life, customers not only have the demand for delivery, but also the demand for picking up unsold agricultural products due to the decline of freshness, so the two-way flow of picking up and delivering obviously has stricter requirements for fresh agricultural products cold chain logistics distribution.

The vehicle routing problem with simultaneous delivery and pickup (VRPSDP) describing the characteristic was first proposed by Min (1989), considering the pickup demand at each customer point on the basis of fresh agricultural products cold chain logistics distribution. Sebastian et al (2018) considered the delivery and pickup distribution path optimization problem with simultaneous delivery and pickup and demand divisible in different cases such as cluster backhaul, mixed route backhaul and backhaul, and proposed lateral loading and dividing the loading space into separate compartments for long-haul and backhaul customer shipments. Henriette et al (2018) developed a simultaneous delivery and pickup distribution model with time windows and 3D loading constraints for the warehouse-to-customer simultaneous delivery and pickup problem, and solved it using a hybrid algorithm of adaptive large domain search and heuristic algorithms. (Li et al., 2021) solved the distribution path problem for the combination of enterprise forward logistics distribution and scrap recycling by using a hybrid optimization algorithm combining simulated annealing and adaptive large-scale domain search (SA-ALDS). (Yao et al., 2019) constructed a single distribution center urban-rural two-way logistics distribution model with distribution cost, time window and vehicle empty rate as the objective functions based on the assumption that consumer goods and agricultural products can be transported in a mixed way, and solved it by genetic algorithm. Most domestic and foreign scholars have applied the simultaneous delivery and pickup path problem to material distribution and packaging or scrap recycling, and less research has been conducted in the cold chain logistics of fresh agricultural products. A rare study

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that considered the pickup and delivery operations of fresh produce proposed two distribution methods: the pickup and delivery separation service method of unified pickup followed by unified delivery and the simultaneous pickup and delivery mode. The results of the research show that the vehicle space is not well utilized and the distance traveled by the vehicle increases in the pickup and delivery separation mode, while the simultaneous pickup and delivery service mode can circumvent these problems well (e.g. Ji and Zhang, 2019).

In terms of vehicle path distribution optimization algorithms, some scholars have used heuristic algorithms to solve VRP and achieved good results (e.g. Haitam and Najat (2021), Puspitasari and Kurniawan (2021) and Ma et al. (2021)). Other scholars proposed the genetic ant colony algorithm (GAA) (e.g. Ding et al., 2003) and ant colony system genetic algorithm (ACSGA) (e.g. Mao et al., 2006) to integrate the advantages of ant colony algorithm and genetic algorithm. The ACSGA circumvents the inconvenience caused by the genetic ant colony algorithm that requires multiple experiments to determine the alternation time of the algorithm, and has its unique superiority. Considering that the freshness of fresh agricultural products will increase the carbon emission of the cold chain distribution process, in order to comply with the policy of energy saving and emission reduction in China and ensure the freshness of agricultural products, we construct a fresh agricultural products cold chain logistics simultaneous delivery and pickup distribution model considering carbon emission and time window, and solve the model by using ant colony system genetic algorithm. The research is done to enrich the research on fresh agricultural products cold chain logistics and to provide reference for logistics companies to carry out simultaneous delivery and pickup logistics and distribution services for fresh agricultural products.

2 PROBLEM DESCRIPTION

Due to the high cost of logistics infrastructure construction, logistics companies are restricted by costs and will not build multiple distribution centers (e.g. Fang et al., 2019). According to the circulation mode of fresh agricultural products with wholesale market as the distribution center, this paper studies the problem of single distribution center fresh agricultural products cold chain logistics with simultaneous delivery and pickup distribution paths, where refrigerated vehicles loaded with fresh agricultural products depart from the distribution center to each customer demand point for delivery, while recovering unsold agricultural products at each node due to decreasing freshness and returning to the distribution center.

Under the premise of satisfying the customer's demand for delivery and pickup, how to develop a vehicle path decision for the distribution center that minimizes the comprehensive cost consisting of vehicle fixed cost, transportation cost, carbon emission cost and time penalty cost under the constraints of the customer's specified time and vehicle load is the problem to be solved in this paper.

3 MODELING

3.1 Model Assumptions

Assumption 1: The location of the distribution center and each customer's demand node is known, and the quantity of each customer's delivery and pickup demand, service time and time window are known.

Assumption 2: The distribution center has the same vehicle type, i.e. all agricultural products are delivered by the same type of vehicle.

Assumption 3: The demand for fresh produce from each customer is within the maximum full capacity of the vehicle.

Assumption 4: Each path starts and ends at the distribution center, and each customer demand node can only be served by one vehicle.

Assumption 5: The logistics company will pay a penalty if the vehicle does not deliver the goods within the time specified by the customer.

Assumption 6: Each kind of fresh produce can be mixed, i.e., it can be loaded and delivered by the same refrigerated vehicle.

3.2 Analysis of Known Parameters and Decision Variables

(1) The known parameters are shown in Table 1.

Table 1: Description of VRPSDP problem parameters.

Symbols	Description
N	collection of distribution centers and customer demand points
N_i	collection of customer demand points, $i \in \{1,2,\ldots,n\}$
N_0	distribution center
K	collection of serviceable vehicles at distribution centers, $K=\{1,2,\ldots,m\}$
f_k	fixed costs for using a distribution vehicle
c	vehicle unit transportation cost
D_i	delivery volume of customer point i
P_i	pickup volume of customer point i
Q	refrigerated truck rated capacity
Q_{ij}	the weight of the cargo carried by the reefer truck travels from customer point i to customer point j , $i, j \in N_i$
d_{ij}	distance of reefer truck from customer i to customer j
ε_1	unit time penalty cost for vehicles arriving at customer i before the earliest time (ET_i)
ε_2	unit time penalty cost for vehicles arriving at customer i before the latest time (LT_i)
S_i	service hours for customer i
v	carbon taxes
ω	carbon emission factor

(2) The decision variables are analyzed as follows.

$$x_{ijk} = \begin{cases} 1, & \text{vehicle } k \text{ drives from customer point } i \text{ to customer point } j \\ 0, & \text{or else} \end{cases}$$

When vehicle k transports cargo from customer point i to customer point j, that is, x_{ijk} is 1 when the vehicle passes through path (i, j) and 0 otherwise.

$$y_{ik} = \begin{cases} 1, & \text{the demand of customer } i \text{ is satisfied by vehicle } k \\ 0, & \text{or else} \end{cases}$$

When the demand of customer i is satisfied by vehicle k, y_{ik} is 1, otherwise it is 0.

(3) Derivative variables

St_i denotes the start time of service at customer point i; T_{ij} denotes the time spent by the reefer truck from customer point i to customer point j; Q_{0k} denotes the loading of vehicle k when it departs from the distribution center; Q_{ik} denotes the loading of vehicle k when it leaves customer i, $i \in \{1,2,\ldots,n\}$.

3.3 Model Building

(1) Vehicle fixed costs (C_1)

The fixed costs required for vehicle activation generally include staff salaries, vehicle depreciation and maintenance costs, etc. As shown in equation (1).

$$C_1 = \sum_{k=1}^{m} \sum_{j=1}^{n} x_{0jk} f_k \tag{1}$$

In Eq. (1), $x_{0jk}=1$ when vehicle k leaves the distribution center for delivery to node j, otherwise it is 0.

(2) Vehicle transportation cost (C_2)

Vehicle transportation cost mainly refers to the cost of fuel consumption in transit, which is related to the distance traveled by the vehicle, and can be expressed as equation (2) according to the research content of this paper.

$$C_2 = c \sum_{k=1}^{m} \sum_{i=0}^{n} \sum_{j=0}^{n} d_{ij} x_{ijk} \tag{2}$$

(3) Carbon emission cost (C_3)

Vehicles consuming fuel in the distribution process will produce CO_2 gas, and distribution centers need to pay for the environmental pollution caused by the emission of CO_2 gas. In a study of the relationship between carbon emissions and climate, Ottmar (2014) proposed that carbon emissions = fuel consumption * CO_2 emission factor.

Fuel consumption is usually calculated using the load estimation method (e.g. Kang et al., 2019). The maximum vehicle load is Q. The fuel consumption per unit distance traveled when the vehicle is empty is ρ_0, and the fuel consumption per unit distance traveled when it is fully loaded is ρ^*. There is a certain linear relationship between fuel consumption and vehicle load, and the fuel consumption per unit distance traveled when the vehicle is loaded with A can be expressed by equation (3).

$$\rho(A) = \rho_0 + \frac{\rho^* - \rho_0}{Q} A \tag{3}$$

The carbon emissions generated during the distribution process of the vehicle from the distribution center to each customer point, if the goods with a cargo capacity of Q_{ij} are delivered from customer point *i* to customer point *j*, can be expressed as:

$$E_1 = \omega\rho(Q_{ij})d_{ij} \tag{4}$$

The carbon emission cost under the carbon tax mechanism is expressed as: carbon emission cost = carbon tax *carbon emission. Let the carbon tax be *v*, and the total carbon emission cost C_3 of the vehicle in the distribution process is:

$$C_3 = \omega v \sum_{i=0}^{n}\sum_{j=0}^{n}\sum_{k=1}^{m} d_{ij}x_{ijk}\rho(Q_{ij}) \tag{5}$$

(4) Penalty Cost (C_4)

The customer agrees with the distribution center on the delivery time when placing an order. If the vehicle dispatched by the distribution center does not deliver the goods within the agreed time of the customer, the customer will pursue the responsibility according to the right, that is, the distribution center needs to deliver the corresponding penalty C_4.

$$C_4 = \varepsilon_1 \sum_{j=1}^{n} max\left\{ET_j - St_j, 0\right\} + \varepsilon_2 \sum_{j=1}^{n} max\left\{St_j - LT_j, 0\right\} \tag{6}$$

In summary, the fresh produce simultaneous delivery and pickup vehicle path optimization model constructed in this paper is:

$$\begin{aligned} minZ &= C_1 + C_2 + C_3 + C_4 \\ &= \sum_{k=1}^{m}\sum_{j=1}^{n} x_{0jk} f_k + c\sum_{k=1}^{m}\sum_{i=0}^{n}\sum_{j=0}^{n} d_{ij}x_{ijk} \\ &+ \omega v \sum_{i=0}^{n}\sum_{j=0}^{n}\sum_{k=1}^{m} d_{ij}x_{ijk}\rho(Q_{ij}) \\ &+ \varepsilon_1 \sum_{j=1}^{n} max\left\{ET_j - St_j, 0\right\} \\ &+ \varepsilon_2 \sum_{j=1}^{n} max\left\{St_j - LT_j, 0\right\} \end{aligned} \tag{7}$$

s.t.

$$\sum_{i\in N}\sum_{k\in K} x_{ij}^{k} = 1, \forall j \in N \tag{8}$$

$$\sum_{j\in N} x_{0j}^{k} = \sum_{i\in N} x_{i0}^{k} = 1, \forall k \in K \tag{9}$$

$$Q_{0k} = \sum_{i=1}^{n}\left(D_i \sum_{j=0, j\neq i}^{n} x_{ij}^{k}\right), k \in K \tag{10}$$

$$Q_{ik} = Q_{(i-1)k} - D_i + P_i, i \in N \tag{11}$$

$$Q_{ik} \le Q, i \in N, k \in K \tag{12}$$

$$S_{t_j} = \begin{cases} S_{t_i} + S_i + T_{ij}, ET_i < St_i < LT_i, \forall i \in N \\ ET_i + S_i + T_{ij}, St_i \le ET_i, \forall i \in N \end{cases} \tag{13}$$

Equation (7) is the objective function; constraint (8) indicates that each customer point can only be served by one vehicle; constraint (9) indicates that all refrigerated vehicles depart from the distribution center and eventually return; constraint (10) indicates that the loading of a vehicle when it departs from the distribution center is the sum of the delivery volume of all customer points on a certain path; constraint (11) indicates that the loading of a vehicle when it leaves a certain customer = loading when it leaves the previous customer point - its own delivery volume + its own pickup volume; constraint (12) ensures that the vehicle is not overloaded at any moment in the distribution service; constraint (13) indicates that the vehicle delivers and picks up the goods within the time window of the customer point.

4 DESIGN OF ANT COLONY SYSTEM GENETIC ALGORITHM

The ant colony algorithm is more robust and can be easily combined with other algorithms, but it also has the disadvantages of long search time and easy to fall into local optimum (e.g. Chen et al., 2019). The cold chain distribution process of fresh agricultural products studied in this paper is different from the traditional distribution problem of decreasing vehicle load, in that there is simultaneous pickup and delivery, and the vehicle load presents dynamic irregular changes, which requires a higher global search capability of the algorithm. The basic ant colony algorithm cannot meet the research conditions. In order to improve the global optimization-seeking ability of the ant colony algorithm, the ant colony system genetic algorithm (ACSGA), combining the ant colony system algorithm with the genetic algorithm, is proposed to solve the model. The basic idea of the ant colony system genetic algorithm is to introduce the genetic algorithm into the iteration of the ant colony algorithm system, and the solution obtained by the ant colony system is used as the initial population of the genetic algorithm, and the genetic algorithm evolves for the optimal solution by multiple iterations.

4.1 Moving Probability Selection Rules

The ant selects the next client point j for transfer from client point i by a certain probability selection rule, which is expressed in equation (14).

$$p_{ij}^{k}(t)=\begin{cases}\dfrac{[\tau_{ij}(t)]^{\alpha}[\eta_{ij}(t)]^{\beta}}{\sum_{u\in tabu_k}[\tau_{iu}(t)]^{\alpha}[\eta_{iu}(t)]^{\beta}},\ j\in tabu_k \\ 0,\ j\notin tabu_k\end{cases} \quad (14)$$

In Eq. (14), $\tau_{ij}(t)$ denotes the amount of information on the path from node i to node j at moment t; $\eta_{ij}(t)=1/d_{ij}$ is the heuristic function; α and β denote the information heuristic factor and the expectation heuristic factor, respectively.

4.2 Pheromone Update Strategy

The residual pheromone of each path will diminish with time, and when k ants have traveled the full distance, the pheromone on each pathway needs to be adjusted as follows.

$$\tau_{ij}(t+n)=(1-\rho)\tau_{ij}(t)+\Delta\tau_{ij} \quad (15)$$

$$\Delta\tau_{ij}=\sum_{k=1}^{m}\Delta\tau_{ij}^{k} \quad (16)$$

ρ denotes the degree of pheromone $\tau_{ij}(t)$ weakening over time, $\rho\in(0，1)$; $\Delta\tau_{ij}^{k}$ denotes the pheromone left by ant k between client nodes i and j in this cycle, which is generally calculated using the Ant-Cycle model.

$$\Delta\tau_{ij}^{k}(t)=\begin{cases}\frac{M}{L_k},\text{if the } k\text{th ant in this cycle passes through } ij \\ 0，\text{ or else}\end{cases} \quad (17)$$

M denotes the total amount of pheromones produced by the ant k cycles in one turn, and L_k denotes the cycle route of the kth ant.

4.3 Adaptation Function

The fitness function is a criterion for evaluating the merit of the solution in the genetic algorithm and is set according to the study as shown in equation (18). Z denotes the objective function cost.

$$f=\frac{1}{Z} \quad (18)$$

4.4 Crossover Operator Improvement

The crossover operation in the genetic algorithm is performed by exchanging some genes of two mutually paired individuals to obtain two new individuals to improve the algorithm's merit-seeking ability. Assuming that there are 9 customer nodes, 0 represents the distribution center. This paper adopts the partial mapping crossover method to improve the crossover operation. The execution steps are as follows.

1) Selecting two parent chromosomes and choosing a complete path at random for each will result in path 1 and path 2, as shown in Figure 1(a).

2) Precede path 1 and path 2 and remove duplicate genes, swap the positions of path 1 and path 2, and get offspring chromosomes 1 and 2, as shown in Figure 1(b).

3) Perform conflict detection and establish a mapping relationship between genes of path 1 and path 2 using the partial crossover method, and map all genes with conflicts until there is no conflict, thus forming new offspring chromosomes, as shown in Figure 1(c).

Paternal chromosome 1
Paternal chromosome 2

Path 1

0	3	1	9	7	0	4	2	8	0	6	5	0
0	9	7	5	0	1	2	6	3	0	8	4	0

Path 2

(a) Randomly selected paths of parental chromosome parts

Offspring chromosome 1
Offspring chromosome 2

Path 1

0	9	7	5	0	3	1	9	7	0	6	5	0
0	4	2	8	0	1	2	6	3	0	8	4	0

Path 2

(b) Successive prepending, deleting and swapping operations on chromosomes

The mapping relationship between the chromosomal genes generated by paths 1 and 2 is:

9↔4 7↔2 8↔5

Offspring chromosome 1
Offspring chromosome 2

0	9	7	5	0	3	1	4	2	0	6	8	0
0	4	2	8	0	1	7	6	3	0	5	9	0

(c) Partial chromosomal gene mapping crossover

Figure 1: Schematic diagram of chromosome crossover.

4.5 Ant Colony Genetic Algorithm Process

The hybrid algorithm relies on the global search ability of the genetic algorithm to determine the optimal solution range in the early stage of operation, and mainly relies on the local search ability of the ant colony algorithm to precisely locate the optimal solution in the later stage. In order to avoid the phenomenon of degradation of good individuals caused by useless iterations of already premature populations due to the existence of premature disadvantage of genetic algorithm (e.g. Liang et al., 2014) the adjustment rule of the number of iterations is introduced in the hybrid algorithm so that it only performs mutation operation at the later stage to improve the convergence speed. The specific algorithm design flowchart is shown in Figure 2, and the steps are as follows.

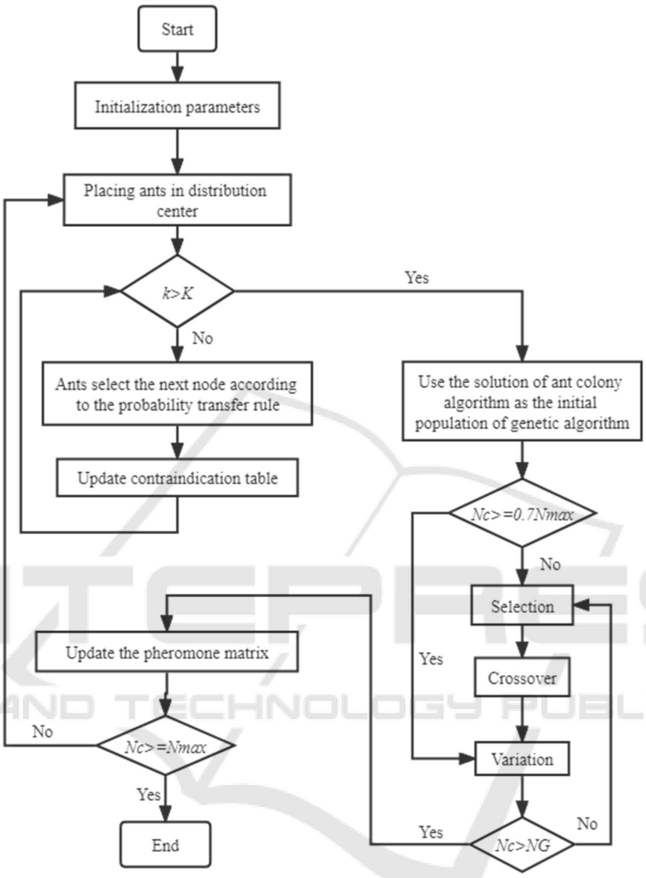


Figure 2: Flow chart of ant colony system genetic algorithm.

Step1: Initialize the parameters, N_c=0, set the maximum number of cycles N_{max} and the number of genetic algorithm iterations NG.

Step2: Initialize the ant positions and place K ants in the distribution center.

Step3: Determine whether a complete path is formed, if yes, proceed to step 5, if not, proceed to step 4.

Step4: The ants select the next customer node according to the movement transfer probability formula (14) and update the contraindication table.

Step5: The solution obtained from the ant colony system is used as the initial population of the genetic algorithm, and then we determine whether $N_c \geq 0.7N_{max}$ holds, if it does, proceed to step 7, if it does not, proceed to step 6.

Step6: The population obtained by the ant colony algorithm is selected and crossed to generate the new generation of individuals.

Step7: Perform mutation operation on the population to generate new generation of individuals.

Step8: Determine whether the genetic algorithm reaches the set maximum number of iterations NG, if yes, proceed to step 9, otherwise return to step 6.

Step9: Update the pheromone matrix according to the pheromone update strategy formula (15).

Step10: Determine whether the algorithm reaches the maximum number of cycles N_{max}, if yes, output the optimal solution and end the algorithm, if not, return to step 2.

5 SOLVING AND ANALYSIS OF ALGORITHMS

In order to verify the effectiveness of the ant colony system genetic algorithm, the distribution task of one day in Taiyuan city R.Q fresh fruit wholesale distribution center is used as an example for solution testing. The distribution center is responsible for supplying the fresh fruit counters of large supermarkets such as Metropolis, Wal-Mart and Wang, F.-J Department Store in Taiyuan. 20 supermarkets served by the distribution center are selected and the coordinate locations are obtained in the map, as shown in Figure 3.

The refrigerated truck departs from R.Q fresh fruit distribution center at 6:00 a.m., and delivers the fruits and vegetables to the customer within the specified time, and sends some of the customers' fruits and vegetables that need to be recycled back to the distribution center for secondary processing due to the decline in freshness, and the vehicle will be fined 50 or 100 RMB per hour if it delivers the goods earlier or later than the specified time. Reefer start-up cost is 150 yuan, unit transportation cost is 4 yuan per kilometer, maximum load capacity is 3.7 tons, fuel consumption is 0.165 and 0.377 liters per kilometer when empty and full load respectively; considering the city 7:00 a.m. to 9:00 a.m. for traffic congestion, the vehicle speed is calculated at 30 km/h throughout; CO_2 emission factor is 2.63 kg per liter, carbon tax is 43 yuan per ton. The location of R.Q fresh fruit wholesale distribution center and each customer node is known. The customer specified time window and delivery-pickup requirements are shown in Table 2, with the number 0 representing the distribution center and each customer node numbered 1, 2, ...20 in order, and the Matlab R2015b software is used to solve the algorithm.

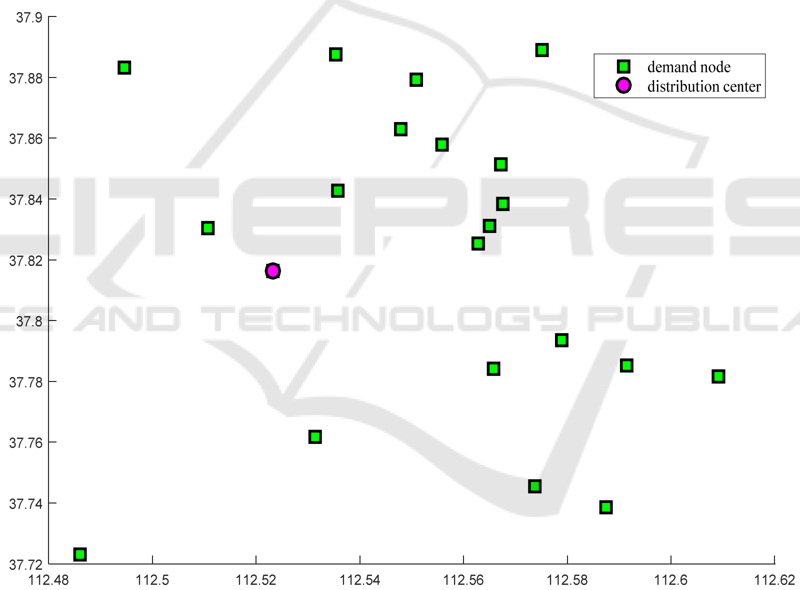


Figure 3: Map location of distribution center and each super node.

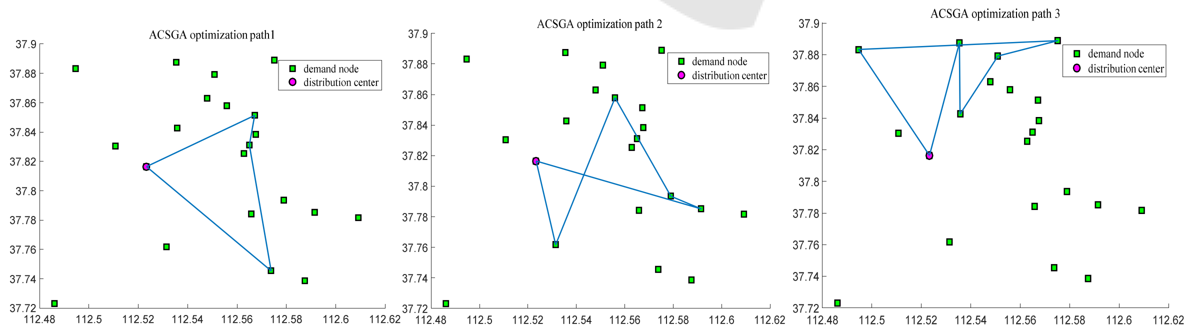
Table 2: Information table of R.Q Fresh Fruit Wholesale Distribution Center and the demand for each superstore.

Node number	Node Name	Longitude and Latitude	Delivery and pickup demand（t）		Service Time /min	Time Window
			Delivery volume	Pickup volume		
0	R.Q Fresh Fruit Wholesale Distribution Center	112.523320，37.816424	-	-	-	-
1	Wang, F.-J. Department Store	112.565022，37.831129	1.20	0.24	20	（6：30-8：30）
2	Wal-Mart (Hutchinson Fashion Mall)	112.562784，37.825208	0.75	0.00	10	（6：30-8：30）

3	Wal-Mart (Taiyuan S. Road)	112.575213，37.888957	0.75	0.16	15	（7:30-10:00）
4	Metropolis (X.D District)	112.565867，37.784022	0.54	0.00	9	（7:20-10:00）
5	Metropolis (K.Z Ten Mile City)	112.587438，37.738523	0.80	0.00	12	（7: 25-9: 40）
6	Metropolis (Crescent Moon International Store)	112.573819，37.745356	1.42	0.40	20	（7: 30-8: 30）
7	Metropolis (W.C Mall Store)	112.567605，37.838313	0.65	0.08	16	（6: 20-8: 00）
8	Metropolis (Z.E Lane)	112.609162，37.781732	0.40	0.00	8	（6: 40-7: 40）
9	Metropolis (YZ District)	112.547865，37.863072	0.95	0.20	18	（6: 30-8: 00）
10	Metropolis (T.Y North Road Store)	112.550985，37.879256	0.65	0.00	10	（6: 30-8: 30）
11	Metropolis (Connaught Street)	112.555893，37.857877	0.80	0.15	15	（7: 20-8: 20）
12	Metropolis (W.C South Road)	112.591506，37.785145	1.00	0.35	20	（7: 00-9: 00）
13	Metropolis (Poly Lily Store)	112.494598，37.883346	0.75	0.00	10	（8:10-10:00）
14	Metropolis (W, B.-L. District)	112.535420，37.887478	0.60	0.00	10	（6: 20-8: 30）
15	Metropolis (YJ West Road)	112.510691，37.830578	1.25	0.27	20	（7: 00-9: 00）
16	Metropolis (JY District)	112.486144，37.722930	1.50	0.32	20	（7: 00-9: 00）
17	Metropolis (Z.D Branch)	112.531407，37.761645	0.86	0.14	15	（7: 30-9: 00）
18	Metropolis (YSMZ Store)	112.578954，37.793417	0.70	0.00	10	（6: 40-8: 00）
19	Metropolis (South Inner Ring West Street)	112.535699，37.842549	0.55	0.00	8	（6: 30-9: 00）
20	Metropolis J.F South Store	112.567166，37.851265	0.96	0.24	16	（6: 00-8: 00）

5.1 Analysis of Results

The proposed optimization model is solved according to the actual arithmetic example and the ant colony system genetic algorithm. The number of ants is set as 6, α=1, β=1, ρ=0.8, the total number of pheromones is 100, and the number of iterations is 100, resulting in the optimal vehicle distribution path as shown in Figure 4.



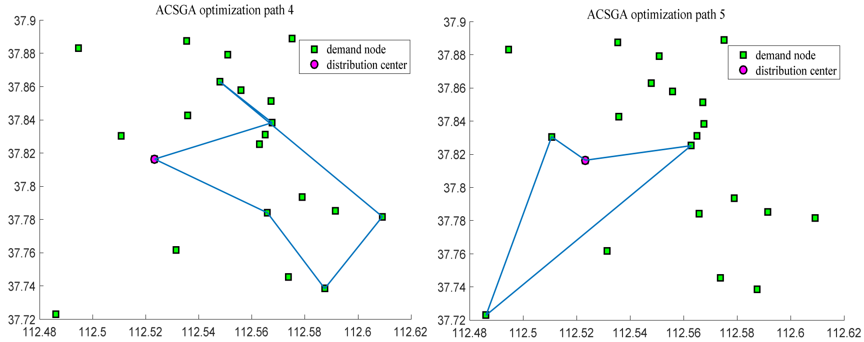


Figure 4: Ant colony system genetic algorithm vehicle path optimization diagram.

From Figure 4, it can be seen that five refrigerated trucks are required for distribution using the ant colony genetic hybrid algorithm to solve the model. Combined with Table 2 and Figure 3, the distribution vehicles departed from R.Q fresh fruit wholesale distribution center, vehicle 1 carried 3.58 tons of fruits and vegetables in order to customers 20, 1, 6 for delivery and pickup service and then returned to the distribution center; vehicle 2 carried 3.36 tons of fruits and vegetables in order to customers 12, 18, 11, 17 for delivery and pickup service and then returned to the distribution center; vehicle 3 carried 3.3 tons of fruits and vegetables in order to customers 14, 19, 10, 3, 13 for delivery and pick-up service and then returned to the distribution center; vehicle 4 carried 3.34 tons of fruits and vegetables in order to customers 7, 9, 8, 5, 4 for delivery and pick-up service and then returned to the distribution center; vehicle 5 carried 3.5 tons of fruits and vegetables in order to customers 2, 16, 15 for delivery and pick-up service and then returned to the distribution center. The total comprehensive cost was 1422.31 yuan.

5.2 Experimental Comparison

In order to verify the effectiveness of the ant colony system genetic algorithm, it was solved and compared with the basic algorithm for the cases separately, and the total distribution cost and optimal routes obtained from 10 runs are shown in Table 3.

Table 3: Optimal distribution strategy corresponding to each algorithm.

Algorithm	Optimal distribution cost (yuan)	Optimal Distribution Path
ACO	1619.76	0→20→14→5→17→ 0
		0→2→1→0
		0→10→7→19→3→11→0
		0→9→8→12→4→13→0
		0→16→15→0
		0→6→18→0
GA	1617.66	0→20→1→6→0
		0→12→18→11→17→0
		0→19→14→10→3→13→0
		0→7→9→8→5→4→0
		0→16→15→0
		0→2→0
ACSGA	1422.31	0→20→1→6→0
		0→12→18→11→17→0
		0→14→19→10→3→13→0
		0→7→9→8→5→4→0
		0→2→16→15→0

As can be seen from Table 3, for the fresh produce with time window while picking up and delivering vehicle path optimization problem, both basic ant colony algorithm and genetic algorithm need 6 vehicles, and ant colony genetic algorithm only needs 5 vehicles, from the situation of vehicle scheduling, ant colony system genetic algorithm can reasonably allocate vehicles and effectively reduce the vehicle empty rate; from the comprehensive optimal cost, the comprehensive cost obtained by ant colony system genetic algorithm is 1422.31 yuan, which is nearly 200 yuan less than the basic algorithm. If based on the same conditions and number of distribution tasks, using the hybrid algorithm can save nearly 6000 yuan a month. In summary, the ant colony system genetic algorithm designed in this paper is effective in reducing the vehicle empty rate and the integrated cost. Specifically, the distribution cost components and convergence curves of each algorithm are shown in Table 4 and Figure 5.

Table 4: Cost Analysis of Optimal Distribution Solution.

Algorithm	Total distribution cost/yuan	Vehicle fixed cost/yuan	Transportation cost/yuan	Carbon emission cost/yuan	Time penalty cost/yuan
ACO	1619.75	900	455.27	3.44	261.04
GA	1617.67	900	421.86	3.16	292.65
ACSGA	1422.31	750	427.92	3.37	241.02

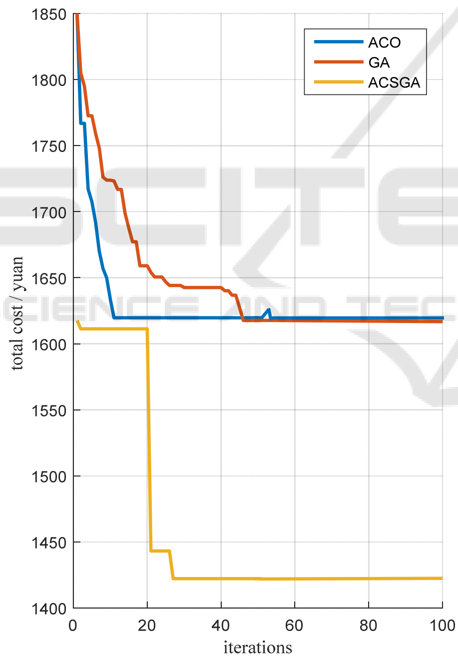


Figure 5: Convergence curve.

According to the analysis of distribution cost composition in Table 4, all the costs of the ant colony algorithm are higher, and combined with Figure 5, we can see that the ant colony algorithm is trapped in the local optimum and difficult to jump out in the process of finding the best. The carbon emission cost and transportation cost obtained by the genetic algorithm are slightly lower than the ant colony system genetic algorithm, but the local search ability is weak and the search process is slow in the late stage of the solution process, the fixed cost of the vehicle and the time penalty cost are higher, and the genetic algorithm cannot make full use of the vehicle space and cannot guarantee customer satisfaction. The ant colony system genetic algorithm integrates the advantages of the basic algorithms, using the global search ability of the genetic algorithm to lock the optimal solution range in the early stage of the solution, and using the local search ability of the ant colony algorithm to find the optimal solution precisely in the later stage of the solution. The hybrid algorithm converges faster, improves the on-time delivery rate while making full use of the vehicle space, ensures the customer satisfaction and reduces the comprehensive cost. In summary, the ant colony system genetic algorithm designed in this paper can find the optimal solution faster and ensure customer satisfaction, which is effective for solving the fresh produce simultaneous delivery and pickup vehicle path problem.

6 CONCLUSIONS

As the demand for freshness of fresh agricultural products improves, the short timeliness of fresh agricultural products determines that important fresh agricultural products sales entities such as fresh supermarkets not only have the demand for delivery but also the demand for recovery of agricultural products that are not sold in time due to the decline of freshness. In this paper, we study the optimization of fresh agricultural products cold chain logistics with time windows for simultaneous delivery and retrieval vehicle paths under the consideration of energy saving and emission reduction, and construct an optimization model with the objective function of minimizing comprehensive cost. In order to improve the global search capability of the basic ant colony algorithm, a hybrid ant colony system genetic algorithm is proposed and the crossover operator is improved to solve the model. In order to verify the validity of the model and the algorithm, simulation experiments are conducted on the actual cases and the hybrid algorithm is compared with the basic algorithm. The results show that the constructed optimization model and the hybrid ant colony system genetic algorithm can arrive at the lowest comprehensive cost and the most optimal path, which can reduce the vehicle empty rate and improve customer satisfaction at the same time. It is suitable for solving the problem of simultaneous delivery and pickup of fresh agricultural products, and can provide methodological support for logistics companies to distribute fresh agricultural products, which has certain practical significance and reference value.

REFERENCES

Chen, Z., Jiang, Z.-J., Liu, Y., 2019. Research on low carbon logistics path optimization based on improved ant colony algorithm for different road sections. *Ecological Economics* 35(12):53-59+66.

Ding, J.-S., Chen Z.-Z., Yuan Z.-Z., 2003. Fusion of genetic algorithm and ant algorithm. *Computer Research and Development* 40(9):1351-1356.

Fang, W.-T., Ai, S.-Z., W, Q., Fan, J.-B., 2019. Research on cold chain logistics distribution path optimization based on hybrid ant colony algorithm. *China Management Science* 27(11):107-115.

Haitam, E., Najat, R., Jaafar, A., 2021. Metaheuristics methods for The VRP in Home Health Care by minimizing fuel consumption for environmental gain. *E3S Web of Conferences* 234, 94-101.

Henriette, K., Andreas, B., Gerhard, W., 2018. A hybrid algorithm for the vehicle routing problem with backhauls, time windows and three-dimensional loading constraints. *OR Spectrum* 40(04): 1029-1075.

JI, J.-H., ZHANG, X., 2019. Optimization model and algorithm for fresh produce distribution path considering pickup and delivery operations. *Journal of Systems Science* 27(01):130-135.

Kang, K., Han, J., Pu, W. et al., 2019. Research on the optimization of low-carbon distribution path for fresh agricultural products cold chain logistics. *Computer Engineering and Applications* 55(02):259-265.

Li, J., Duan, Y., Hao, L.-Y.et al., 2021. Hybrid optimization algorithm for solving simultaneous delivery and pickup vehicle path problems. *Computer Science and Exploration* 1-12.

Liang, X., Huang, M., Ning, T., 2014. Modern intelligent optimization hybrid algorithms and their applications. *Beijing: Electronic Industry Press.*

Ma, Y.-F., Li, B.-Y., Yang Y.-F., Feng C.-Y., 2021.Research on two-level path problem and algorithm for fresh food delivery under customer classification. *Computer Engineering and Applications* 57(20):287-298.

Mao, N., Gu, J.-H., Tan, Q. et al., 2006. Ant colony genetic hybrid algorithm. *Computer Applications* (07):1692-1693+1696.

MIN H. 1989. The multiple vehicle routing problem with simultaneous delivery and pick-up points. *Transportation Research Part A: General* 23 (5): 377-386.

Ottmar R.-D., 2014.Wildland fire emissions, carbon, and climate: Modeling fuel consumption. *Forest Ecology & Management*, 317(2) 41-50.

Puspitasari, F.- H., Kurniawan, V.-R.-B., 2021. Designing Optimal Distribution Routes using a Vehicle Routing Problem (VRP) Model in a Logistics Service Provider. *IOP Conference Series: Materials Science and Engineering* 1071(01):120-131.

Sebastian, R., Andreas, B., Lars, M., 2018. Heuristics for vehicle routing problems with backhauls, time windows, and 3D loading constraints. *European Journal of Operational Research* 266 (03): 877-894.

Yao, G.-X., Wu, J., Zhu, C.-J.et al., 2019. Research on urban-rural logistics distribution based on two-way circulation under fuzzy environment. *Business Economics Research* (20):107-109.

Zhou, L.-L., 2022. Expert Forum-Quality Control of Perishable Fruits and Vegetables. *China Fruit and Vegetable* 42(09), 1.