ISSN: 2710-0588

Research on the Optimization of Cold Chain Logistics Distribution Path Considering Carbon Emissions

Qian Liang[1, *]

[1]School of Economics and management, Southwest Petroleum University, Chengdu, Sichuan, China

* Corresponding author

Abstract

With the proposal of the "double-carbon" development goal, all walks of life are actively implementing the national green and low-carbon development requirements. As an important branch of the logistics industry, cold chain logistics is also a key area to achieve the goal of "double carbon". If the concept of low carbon is introduced into cold chain logistics and the distribution route is rationally planned, it can not only reduce logistics costs, but also reduce carbon emissions. Therefore, the minimization of the total distribution cost is taken as the optimization goal, Under the constraints of vehicle load and time window, the cold chain logistics distribution path optimization model is constructed with the goal of minimizing the total distribution cost. Then designed the genetic algorithm to solve, respectively from considering carbon emissions and carbon emissions two cases planning distribution route, and optimization before single temperature distribution scheme comparative analysis, the results show that the carbon emissions considering the cold chain distribution path optimization, and choose cold storage incubator type in distribution mode, not only can reduce the enterprise distribution cost, improve the distribution efficiency of distribution, but also can reduce the carbon emissions.

Keywords

Cold chain logistics, path optimization, carbon emission, genetic algorithm, multi-temperature co-allocation.

1. Introduction

With the proposal of the "dual-carbon" development goal, all walks of life are actively implementing the national green and low-carbon development requirements. As an important branch of the logistics industry, cold chain logistics is also a key area to achieve the goal of "double-carbon". If the concept of low carbon is introduced into the cold chain logistics and the distribution route is rationally planned, it can not only reduce logistics costs for enterprises, but also reduce carbon emissions. Therefore, the research of cold chain logistics distribution considering carbon emission has great theoretical and practical significance.

Scholars at home and abroad have conducted in-depth research on the problem of multi-temperature co-distribution of cold chain logistics and carbon emission in cold chain logistics, and many achievements have been made. Duan Beibei (2019) [1] For the cold chain goods of the chain convenience store, it deeply discusses its particularity and the characteristics of consumer demand. Based on this, a multi-temperature co-distribution model is constructed, and by comparing the data before and after optimization, it proves that this model can reduce the distribution cost and improve the distribution efficiency. Cheng Rong (2023) [2] For the diversified characteristics of multi-batch, less batch, multi-item and multi-temperature layer of chain supermarkets, it puts forward the cold chain logistics optimization strategy based on

ISSN: 2710-0588

multi-temperature co-distribution, and establishes the multi-temperature cold-storage co-distribution scheme of chain supermarkets. Martins et al. (2019) [3] In order for grocery stores to jointly transport products with different temperature requirements, reduce time and logistics costs, they have set up time Windows to indicate when distribution should be conducted, so as to better plan their in-store operations. Zhao et al. (2013) [4] conducted an in-depth analysis of the economic benefits and social benefits of the multi-temperature co-distribution mode. In view of the limitations of the single temperature storage mode of traditional cold chain logistics, a comprehensive cost model is constructed. Bao Chunling et al. (2018) [5] Based on the concept of green logistics development, they transform carbon emissions into costs into the optimization of cold chain logistics distribution path. The optimization model of the joint distribution path of cold chain logistics considering the time window, carbon emission cost and cargo loss cost.

2. Problem Description

This paper studied in Guangyuan ice king cold food co., LTD. Considering carbon emissions of cold storage type temperature with cold chain vehicle distribution path optimization problem can be described as: the company has a can realize collection, storage, packaging, sorting and distribution of the distribution center, distribution center is equipped with freezer, enough number of normal temperature distribution vehicle and enough number of incubator and accumulator, for the customer distribution of goods. In the case of known customer demand, geographical location and demand time, the distribution vehicles are delivered to customers in turn according to the distribution plan at a constant speed. After the distribution, the vehicle needs to return to the distribution center.

Based on the above problem description, the optimization model of multi-temperature cold chain logistics distribution path considering carbon emissions is established. Taking the minimization of distribution cost as the model goal, on this basis, the factors such as carbon emission and customer satisfaction are considered, and the costs such as fixed cost, refrigeration cost, carbon emission cost and transportation cost are comprehensively considered. Minimize distribution costs.

3. Model Building

3.1. Model hypothesis

Based on the problems described above, the following assumptions are made:

Hypothesis 1: The distribution center has a sufficient number of normal temperature delivery vehicles with the same vehicle model.

Hypothesis 2: Known customer location, demand, and delivery window.

Hypothesis 3: There is only one distribution center, and the delivery vehicle will start from now on and return to the distribution center after serving all the customers.

Hypothesis 4: Known distribution center location.

Hypothesis 5: the speed of normal temperature car is not affected by external factors, assuming uniform speed.

Hypothesis 6: Each customer has and can only be served once.

Hypothesis 7: The distribution center has a sufficient number of cooler and incubator.

Hypothesis 8: The actual load of each vehicle cannot exceed the transportation capacity of the vehicle.

ISSN: 2710-0588

3.2. Symbol description

q indicates the maximum number of cold storage incubators that each room temperature delivery vehicle can carry; H represents A collection of company A products, H={1, 2,3}, h_1 means normal temperature goods, h_2 refine to refrigerated goods, h_3 refers to frozen goods; M represents the collection of all vehicles, M={1, 2,3,...... ,m}; N represents the collection of distribution centers and customer points, N={0, 1,2, 3,...... ,n}, 0 means that the distribution center, The remaining nodes represent the customer points; A is the weight of the cold storage incubator; P_m represents the fixed cost of the m m temperature delivery vehicle; The d_{ij} is the distance between the distribution center i and the customer store j; The p_2 represents the transportation cost of the unit delivery distance of the normal temperature delivery vehicle; X_{ijm} for 0, The 1 variable, When the normal temperature delivery vehicle m delivers from the distribution center to the customer store, x_{ijm}=1, Otherwise x_{ijm} = 0;F_a represents the fixed cost ofa cold storage incubator; The f_b represents the variable cooling cost of a cold storage incubator; N_{hm} means the number of incubators used by the m temperature delivery vehicle loaded with h cold chain goods; e_1 indicates the fuel consumption per unit distance when the normal temperature delivery vehicle is fully loaded; e_0 indicates the fuel consumption of the delivery vehicle at normal temperature; Q indicates the rated load weight of the normal temperature delivery vehicle; X indicates the actual load weight of the delivery vehicle delivered at normal temperature; P_c represents the price of the unit carbon tax; ρ Represents the carbon emission coefficient; K: represents the relationship between the fuel consumption and the actual load of the unit time of the normal temperature distribution vehicle; Q_{ij} means the amount of goods transported from store i to store j;

3.3. Cost analysis

3.3.1. Fixed cost

With vehicle transfers, fixed costs will arise. Fixed costs include the depreciation cost of the vehicle, the driver's salary, the vehicle maintenance costs, etc.

$$c_1 = p_m \sum_{m=1}^{M} G_m \tag{1}$$

p_m represents the fixed cost of the m th car, if G_m=1 means that m car is being used, otherwise G_m=0.

3.3.2. Transportation cost

Refers to a series of costs incurred in the process of transportation, mainly related to the distance of the vehicle, and is proportional, that is, the longer the distance of the vehicle, the higher the transportation cost generated.

$$C_2 = \sum_{m=1}^{M}\sum_{i=0}^{n}\sum_{j=0}^{n} p_2 d_{ij} x_{ijm} \tag{2}$$

p_2 represents the transportation cost of the unit distribution distance of the normal temperature delivery vehicle, and d_{ij} is the distance between the distribution center i and the customer store j; x_{ijm} is 0,1 variable, when the normal temperature delivery vehicle m delivers from the distribution center to the customer store, x_{ijm} = 1, otherwise x_{ijm} = 0.

ISSN: 2710-0588

3.3.3. Refrigeration cost

The distribution mode adopted in this paper is the multi-temperature co-distribution mode of the storage incubator, which ensures the low temperature environment of the commodity through the corresponding number of the storage incubator. Therefore, the refrigeration cost is divided into fixed cost and variable cost. Fixed cost refers to the depreciation cost of the cooling storage equipment, and the variable cost mainly refers to the cost of the accumulator to meet different temperature requirements.

$$C_3 = \sum_{m=1}^{M}\sum_{h=1}^{H}(f_a + f_b)N_{hm} \tag{3}$$

f_a represents fixed cost, f_b is variable cost, and N_{hm} represents the number of incubator used by the mth normal temperature delivery vehicle loaded with h class cold chain goods.

3.3.4. Time window penalty cost

This paper uses a soft time window to calculate the cost, if the vehicle arrives at the customer point during [ETi, LTi] time, it will not suffer any punishment; if the vehicle arrives at the customer point before ETi and the customer accepts the goods before leaving, there will be a certain waiting cost; if the vehicle delivers the goods after LTi, it may bring some loss to the customer, thus causing a certain delay cost. Therefore, the time penalty cost incurred by Company A during the delivery process is as follows:

$$C_5 = k_1\sum_{i=1}^{n}\max[ET_i - t_i^k, 0] + k_2\sum_{i=1}^{n}\max[t_i^k - LT_i, 0] \tag{4}$$

k_1 is the waiting penalty cost per unit time of the normal temperature delivery vehicle, and k_2 is the delay penalty cost per unit time of the normal temperature delivery vehicle.

3.3.5. Carbon emission costs

Since this paper studies the problem of the normal temperature distribution vehicle carrying the incubator to complete the low temperature distribution, the carbon emission cost mainly refers to the cost of carbon dioxide emitted during the transportation process of the normal temperature distribution vehicle.

$$E(X) = \frac{e_1 - e_0}{Q}X + e_0 \tag{5}$$

e_1 is the unit distance fuel consumption when the normal temperature delivery vehicle is full; e_0 is the fuel consumption per unit distance when the normal temperature delivery vehicle is no-load; Q is the rated load weight of the normal temperature delivery vehicle, and X is the actual load weight of the normal temperature distribution vehicle.

During the delivery process, the amount of goods transported from store i to store j is Q_{ij}, and the carbon emissions generated by driving between stores can be expressed as: $K = \rho E(Q_{ij}) d_{ij}$ .Carbon emission cost is calculated by carbon tax, namely carbon emission cost = carbon tax carbon emission. The carbon emission cost generated by gasoline consumption during the distribution period is:

ISSN: 2710-0588

$$C_4 = \sum_{m=1}^{M} \sum_{i,j=0}^{n} p_c \rho E(Q_{ij}) d_{ij} x_{i,j}^{m} \tag{6}$$

p_c is the unit carbon tax price; ρ is the carbon emission coefficient; K is the function of the fuel consumption per unit time; Q_{ij} is the amount of goods transported from store i to store j.

3.4. Objective functions and the constraints

3.4.1. Objective function

$$\begin{aligned} \text{Min } Z = {} & P_m \sum_{m=1}^{M} G_m + \sum_{m=1}^{M} \sum_{i=0}^{n} \sum_{j=0}^{n} P_2 d_{ij} x_{ijm} + \\ & \sum_{m=1}^{M} \sum_{h=1}^{H} (f_a + f_b) N_{hm} + \sum_{m=1}^{N} \sum_{i,j=0}^{n} P_c \rho E(Q_{ij}) d_{ij} x_{i,j}^{m} + \\ & K_1 \sum_{i=1}^{n} \max[ET_i - t_i^k, 0] + K_2 \sum_{i=1}^{n} \max[t_i^k - LT_i, 0] \end{aligned} \tag{7}$$

3.4.2. Constraints

$$\begin{gathered} \sum_{m=1}^{M} \sum_{i.j=0}^{m} m x_{ij}^{m} \le M, \\ i, j = 0,1,2, \cdots, n; m = 1,2, \cdots, M \end{gathered} \tag{8}$$

$$\begin{gathered} \sum_{j=1}^{n} x_{ij}^{m} = \sum_{i=1}^{n} x_{ij}^{m} \le 1 \\ i, j = 0,1,2, \cdots, n; m = 1,2, \cdots, M \end{gathered} \tag{9}$$

$$\begin{gathered} \sum_{m=1}^{M} \sum_{i,j=0}^{n} X x_{ij}^{m} \le Q \\ i, j = 0,1,2, \cdots, n; m = 1,2, \cdots, M \end{gathered} \tag{10}$$

$$\begin{gathered} \sum_{m}^{M} \sum_{j=0}^{n} x_{ij}^{m} \\ i, j = 0,1,2, \cdots, n; m = 1,2, \cdots, M \end{gathered} \tag{11}$$

$$\begin{gathered} x_j^m = \{0,1\} \\ j = 0,1,2, \cdots, n; m = 1,2, \cdots, M \end{gathered} \tag{12}$$

$$x_{ij}^{m} = \{0,1\} \text{ - } i, j = 0,1,2, \cdots, n; m = 1,2, \cdots, M \tag{13}$$

ISSN: 2710-0588

Constraints (8) indicates that the number of distribution vehicles required for distribution does not exceed the total number of distribution vehicles owned by the distribution center M; Constraints (9) means that the distribution vehicle delivers to the store from the distribution center, Return to the delivery vehicle in the distribution center after the delivery is completed; The constraints (10) indicate that the actual load of the distribution vehicle is less than the maximum capacity of the distribution vehicle; Constraints (11) indicate that each delivery task must be delivered by a delivery vehicle, And each distribution point has and has only one delivery opportunity; Constraints (12) and (13) indicate that 0, 1 The constraint, The value is 0 or 1;

4. Algorithm Design

(1) Chromosomal coding

In this paper, the natural number encoding method is used to encode the chromosomes. Use N 1-N natural numbers to represent the number of customers, the number of natural numbers represents the order of service customers, and then the number of natural numbers between N 1-K to represent the vehicle arrangement, the combination of the two is a solution, that is, corresponding to a distribution scheme.

(2) Fitness function

The objective function in this paper is the minimum total cost, so in order to transform the objective function into a fitness function, the reciprocal load of the objective function can be changed to the fitness function.

(3) Select the strategy

In this paper, the roulette method is chosen. The concept of an individual is calculated by the fitness value of the individual, and the concept of an individual is proportional to the relative fitness.

(4) Cross strategy

The crossover operation is performed between children and parents, producing new individuals after ending the crossover operation. This paper adopts the PMX partial matching crossover method, and the crossover operation is as follows:

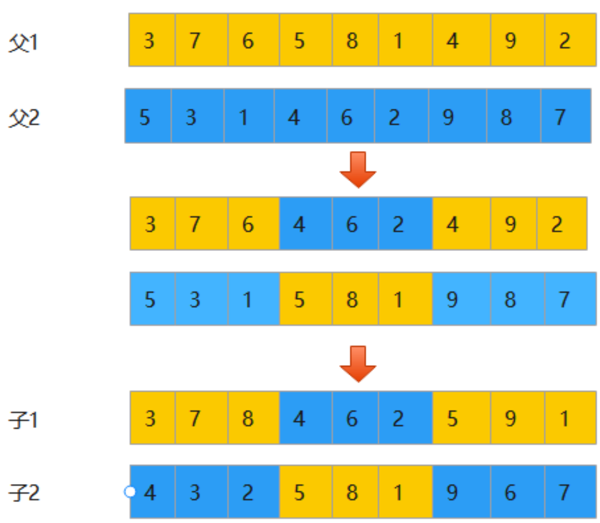

Figure 1. Schematic diagram of the crossover operation

ISSN: 2710-0588

(5) Variant strategy

This paper mainly adopts the two-bit swap method for the variation operation. The two positions are selected arbitrarily, and the corresponding genes at the two positions are used as the variant operation object, and then the genes in the two loci are used for the gene exchange operation. Assuming positions 3 and 6, then as shown in Figure 2.

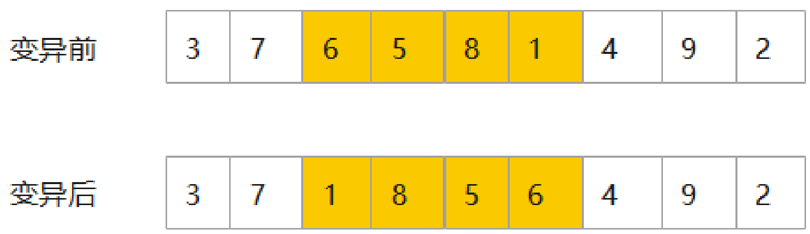

Figure 2. Flow chart of the variation operation

5. Example Verification

5.1. Distribution center and customer location information

Guangyuan Ice and Snow King Cold Food Co., Ltd. is located in Guangyuan City, Sichuan Province. This paper selects the data of Guangyuan Ice and Snow King Cold Food Co., Ltd. in Guangyuan City in 2024. The company has a distribution center, which has received 42 customers on this day. The following is the basic information of customers. Where "1-42" means the customer needing the service.

Table 1. Customer location information and demand information

number	Longitude	Latitude	Quantity demanded (t)			Expect time window	Acceptable time window	Service time (min)
			h=1	h=2	h=3			
1	105.88	32.65	0.12	0.15	0.22	7:30-8:30	6:30-8:30	12
2	105.78	32.6	0.09	0.14	0.24	8:00-8:30	7:00-8:30	10
3	105.53	32.28	0.1	0.08	0.20	8:15-8:45	7:15-8:45	9
4	106.11	32.62	0.14	0.12	0.22	9:30-10:00	8:30-10:00	13
5	105.51	32.28	0.08	0.1	0.20	7:45-9:00	7:15-9:00	10
...	...	...		...		...	...	...
...	...	...		...		...	...	...
...	...	...		...		...	...	...
...	...	...		...		...	...	...
39	105.62	32.13	0.08	0.2	0.12	7:30-8:30	6:30-8:30	9
40	105.62	32.12	0.08	0.09	0.14	8:00-9:00	7:00-9:00	8
41	105.87	32.41	0	0.11	0.14	10:00-11:00	9:00-11:00	7
42	106.28	32.22	0.08	0.1	0.2	8:30-9:30	8:00-9:30	8

The distribution center selects Futian G9 normal temperature vehicle as the cold chain distribution vehicle, and the maximum load of the distribution vehicle is 1.45t. It is assumed that the vehicle runs at a uniform speed of 60 km/h. The fixed cost of the normal temperature vehicle is 210 yuan / vehicle, and the transportation cost is 1 yuan / km. The specific vehicle data and parameter information are shown in Table 2 and Table 3.

ISSN: 2710-0588

Table 2. Vehicle data

parameter	value
nominal load capacity (kg)	1450kg
overall dimensions of a car (mm)	5400*1920*2320
Box size (mm)	3100*1600*1590
Fuel type	gasoline
Fuel consumption of 100 kilometers at full load (L)	12L
Fuel consumption of 100 kilometers during no-load time (L)	9L
nominal rated speed	60km/h

Table 3. Parameter Information Table

Base parameter setting	Parameter values	Unit
Vehicles to use fixed costs pm	210	Yuan / car
Unit distance cost of normal temperature delivery vehicle p2	1	Yuan/km
Fixed cost of per unit cold storage incubator fa	2	Yuan / pcs
Changing refrigeration cost of cooling incubator when storing h2 goods f1	0.27	Yuan / pcs
The variable cooling cost of the cooling incubator when storing h3 goods f2	0.81	Yuan / pcs
Normal temperature delivery vehicles can load the maximum number of cold storage incubator q	13	pcs
Weight of the cold storage incubator a	8	Kg/pcs
Maximum load capacity of cold storage incubator W	110	Kg/pcs
Maximum load weight of normal temperature delivery vehicle Q	1450	Kg/vehicle
No-load normal temperature delivery vehicle unit distance from fuel consumption e0	0.13	L/km
Full load normal temperature delivery vehicle unit distance fuel consumption e1	0.2	L/km
Carbon emission coefficient ρ	2.9	Kg/L
Cost per unit of carbon emissions pc	0.15	Yuan/kg
Waiting penalty cost per unit time of normal temperature delivery vehicle k1	0.1	Yuan/h
Delay penalty cost per unit time of a normal temperature vehicle k2	0.2	Yuan/h

5.2. Interpretation of result

5.2.1. A model solution regardless of carbon emissions

In order to verify the impact of carbon emission factors on the distribution path planning of Guangyuan Ice and Snow King Cold Food Co., LTD., only the fixed cost, transportation cost, time penalty cost and refrigeration cost were considered, and the program was written by MATLAB software for 10 times, and the best solution was taken as the solution of the model. Without considering carbon emissions, 12 normal temperature delivery vehicles are used to complete the distribution task, of which the fixed cost of 12 normal temperature delivery vehicles is 2520 yuan; the transportation cost is 1207 yuan; the penalty cost of time window is 8.3 yuan; a total of 117 incubators are used, of which 44.42 yuan, the refrigeration cost of 71 refrigerated incubators is 199.51 yuan, the total refrigeration cost is 303.93 yuan, and the total distribution cost is 4039.23 yuan.

ISSN: 2710-0588

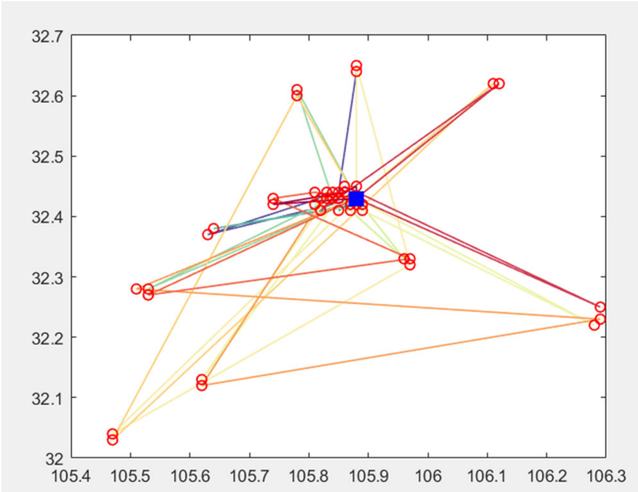

Figure 3. Multi-temperature co-distribution path diagram of cold storage incubator without considering carbon emissions

Through the operation of MATLAB software, the distribution path map of Company was obtained. There are 42 delivery customers. In order to complete the distribution task, 12 normal temperature delivery vehicles were used, with an average loading rate of 86.75%. The specific route and loading rate are shown in the table below.

Table 4. Vehicle distribution routes and loading rates regardless of carbon emissions

Vehicle number	Distribution path	Number of refrigerated/ refrigerated incubators	Total number of storage incubators	Vehicle loading rate
1	0-25-17-32-0	3/6	9	80.70%
2	0-22-23-8-0	4/5	9	86.90%
3	0-21-28-33-19-0	6/4	10	93.10%
4	0-13-10-14-9-0	4/7	11	92.86%
5	0-15-35-36-6-0	4/5	9	88.48%
6	0-30-31-39-5-0	4/7	11	93.80%
7	0-20-24-1-0	3/8	11	76.55%
8	0-4-16-2-0	4/6	10	91.72%
9	0-3-12-11-0	3/6	9	82.07%
10	0-18-37-26-34-0	4/4	8	87.86%
11	0-29-41-42-40-0	4/6	10	83.45%
12	0-27-38-7-0	3/7	10	84.14%

5.2.2. A model considering carbon emissions

The MATLAB program was run 10 times and the optimal solution was taken for 10 times to obtain the optimal distribution scheme. The specific distribution path of the vehicle is as follows: In the consideration of carbon emission, 12 normal temperature delivery vehicles are used to complete the distribution task, of which the fixed cost of 12 vehicles is 2520; the vehicle transportation cost is 1147 yuan; total 111 incubators are used, of which 44 refrigerated incubators have the refrigeration cost 99.88 yuan, 67 refrigerated incubators cooling cost 188.27 yuan, the total cooling cost is 288.15 yuan and the total cost is 4052.05 yuan.

ISSN: 2710-0588

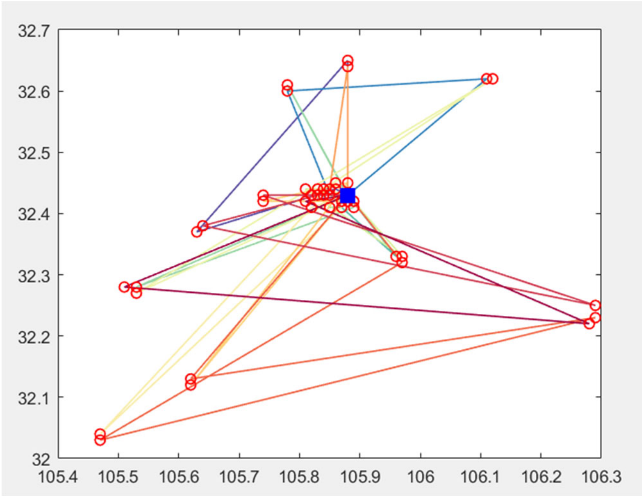

Figure 4. Multi-temperature co-distribution path diagram of the cold storage incubator considering carbon emissions

Through the operation of MATLAB software, the optimal distribution scheme of Guangyuan Snow and Ice King Cold Food Co., Ltd. was obtained for 42 customers this time. In order to complete the distribution task, 12 normal temperature distribution vehicles were used, and the average vehicle loading rate was 87.70%. The specific route and loading rate are shown in the table below.

Table 5. Vehicle distribution routes and loading rates considering carbon emissions

Vehicle number	Distribution path	Number of refrigerated/ refrigerated incubators	Total number of storage incubators	Vehicle loading rate
1	0-1-25-20-0	3/8	11	85.51%
2	0-16-2-4-0	3/6	9	91.72%
3	0-10-19-41-12-0	5/6	11	88.97%
4	0-7-26-3-0	3/6	9	82.76%
5	0-15-38-37-18-0	3/7	10	92.41%
6	0-34-11-6-0	3/3	6	82.76%
7	0-28-32-21-27-0	5/4	9	93.80%
8	0-9-14-23-40-0	4/7	11	93.80%
9	0-22-8-24-0	3/6	9	86.90%
10	0-39-30-31-13-0	5/4	9	88.90%
11	0-33-36-17-35-0	4/7	11	93.70%
12	0-5-42-29-0	3/3	6	71.03%

In the vehicle distribution scheme that does not consider carbon emissions, because the fixed costs, transportation costs, time penalty costs and refrigeration costs are only considered, so the total distribution cost is reduced by the elimination of carbon emission costs. But energy consumption produces carbon emissions, so the cost of carbon emissions is calculated into the distribution scheme.

ISSN: 2710-0588

Table 6. Considers the comparison table of schemes before and after carbon emissions

Cost category	Consider the carbon emission model	No carbon emission model is considered	Differential rate
fixed costs	2520	2520	0%
transportation cost	1147	1207	-4.97%
Refrigeration cost	288.15	303.93	-5.19%
Time window penalty cost	9.4	8.3	13.25%
Carbon emission costs	87.5	102.73	-14.82%
total cost	4052.05	4141.96	-2.17%

According to the table, in addition to the fixed cost and the time window penalty cost, the total cost, transportation cost, cooling cost, and carbon emission costs are lower than the model that does not consider carbon emissions. Among them, the transportation cost was reduced by 4.97%, the refrigeration cost was reduced by 5.19%, the carbon emission cost was reduced by 14.82%, and the total cost was reduced by 2.17%.When considering carbon emission, the carbon emission cost is mainly related to the distribution distance and the actual load of the vehicle, while the transportation cost is closely related to the distribution distance. The transportation cost is the largest proportion of the total distribution cost except the fixed cost, and the transportation cost increases with the increase of the distribution distance. Therefore, when considering carbon emissions, the delivery distance will be shortened as much as possible, so the transportation costs related to the delivery distance will be reduced.

5.3. Comparative analysis

5.3.1. Original distribution plan

Before optimization, Guangyuan Ice and Snow King Cold Food Co., Ltd. used the distribution mode of single temperature special car delivery. In this mode, normal temperature vehicles, D class refrigerated vehicles and F class refrigerated vehicles are used to provide distribution services to customers. The relevant parameters of the vehicle are shown in the table below, respectively.

Table 7. Vehicle parameter information sheet

vehicle type	nominal load	Unit transportation cost	fixed cost	Refrigeration cost
Normal temperature van	1450kg	1Yuan/km	210Yuan	0
Class D refrigerated truck	1415kg	1.2Yuan/km	215Yuan	24/h
Class F freezer car	1495kg	1.5Yuan/km	230Yuan	30/h

The original distribution plan arranged normal temperature vans, D refrigerated vehicles and F refrigerated vehicles to deliver goods to 42 customers, with a total of 4 normal temperature vans, 5 D refrigerated vehicles and 7 F refrigerated vehicles. The average loading rate was 66.04%. Fixed cost is 3525; transportation cost is 2318.5; refrigeration cost is 1132.2; total cost is 6974.7.

ISSN: 2710-0588

Table 8. Distribution route and loading rate

Vehicle number	Distribution path	Vehicle loading rate
Normal temperature van1	0-21-26-12-18-13-42-36-0	45.5%
Normal temperature van2	0-14-17-3-5-6-32-31-40-39-0	56.5%
Normal temperature van3	0-15-8-16-34-35-22-28-29-37-33-0	73.1%
Normal temperature van4	0-23-27-2-7-1-4-11-0	52.4%
Class D refrigerated truck1	0-28-29-14-33-17-25-5-3-6-0	72.4%
Class D refrigerated truck2	0-15-41-19-39-40-31-32-0	62.9%
Class D refrigerated truck3	0-4-11-24-1-7-2-37-0	60.8%
Class D refrigerated truck4	0-23-27-8-16-10-34-35-22-0	67.8%
Class D refrigerated truck5	0-9-21-26-12-13-18-30-36-42-0	69.3%
Class F freezer truck1	0-26-12-13-18-42-30-36-0	80.3%
Class F freezer truck2	0-9-41-39-40-31-32-0	62.9%
Class F freezer truck3	0-15-16-19-29-14-3-5-6-0	73.6%
Class F freezer truck4	0-10-35-22-25-17-0	68.9%
Class F freezer truck5	0-20-27-23-4-11-0	75.8%
Class F freezer truck6	0-21-8-34-1-24-0	58.9%
Class F freezer truck7	0-38-37-33-2-7-0	75.6%

5.3.2. Comparative analysis of the scheme before and after optimization

Table 9. Comparison table of the schemes before and after optimization

Index	Traditional distribution mode	Multi-temperature co-allocation mode
Number of vehicles (vehicles)	16	12
Vehicle loading rate	66.04%	87.70%
Fixed cost (Yuan)	3525	2520
Transportation cost (Yuan)	2318	1147
Refrigeration cost (Yuan)	1132.2	288.15
Total distribution mileage (km)	1856	1147
Total cost of distribution (Yuan)	6974.7	4052.05

(1) Total distribution cost

Comparing the cost before and after optimization, the fixed cost was reduced by 1005 yuan, 43.35%; transportation cost decreased by 1171 yuan, 50.51%; refrigeration cost decreased by 844.05 yuan, or 74.51%; the total cost was reduced by 2922.4 yuan, 41.9%. The refrigeration cost and maintenance cost of refrigerated vehicles are higher than that of ordinary cars. Therefore, the use of multi-temperature co-distribution mode of cold storage incubator can not only reduce the fixed cost of vehicle use, but also reduce the cost of repair and maintenance.

(2) Vehicle loading rate

Before the optimization, the average loading rate of the delivery vehicles in the single-temperature distribution mode was only 67.8%. However, after optimization, the average loading rate of multi-temperature co-equipped vehicles increased significantly to 87.7%. The multi-temperature co-distribution mode not only improves the distribution efficiency, but also is an important reason to reduce the number of distribution vehicles.

ISSN: 2710-0588

6. Conclusion

By comparing the cold-storage multi-temperature cocoordination model that considers carbon emissions and does not consider carbon emissions. After the results are obtained, the multi-temperature co-distribution scheme considering carbon emissions is compared with the multi-temperature co-distribution scheme without carbon emissions and the original single-temperature distribution scheme. It is found that the multi-temperature co-distribution scheme considering carbon emissions has a lower total distribution cost and higher vehicle loading rate and higher distribution efficiency than the other two schemes. In addition, considering carbon emissions, enterprises can effectively reduce carbon emissions, helping to promote the realization of the "double carbon" target.

References

[1] Duan Beibei. B Research on the optimization of cold chain logistics distribution in chain convenience stores [D]. Beijing Jiaotong University, 2019.

[2] Cheng Rong. M Research on multi-temperature co-distribution optimization of cold chain logistics [D]. Hebei University of Science and Technology, 2023.D

[3] Martins S ,Ostermeier M ,Amorim P , et al.Product-oriented time window assignment for a multi-compartment vehicle routing problem[J].European Journal of Operational Research, 2019, 276(3): 893-909.

[4] Wang S ,Zhao M .Impetus of Multi-temperature Joint Distribution Based on Storage-type Cold-chain Logistics[J].Journal of Highway and Transportation Research and Development (English Edition), 2013, 7(2): 94-99.

[5] Bao Chunling, Zhang Shibin. Optimization of the joint distribution path of cold chain logistics considering carbon emissions [J]. Industrial Engineering and Management, 2018,23 (05): 95-100 + 107.

[6] Era[J]. Journal of E-commerce (Both Chinese and English), 2019,8 (1): 13-17

[7] Li Zhang.Research on Optimizing the Distribution Path of Agricultural Cold Chain Logistics in Green Consumption Era[J]. Journal of E-commerce (Both Chinese and English), 2019,8 (1): 13-17

[8] Huang Xingxing, Hu Jiankun, Huang Youfang. Optimization of the cold-chain distribution path of fresh agricultural products under the carbon tax and carbon limit rules [J]. Journal of Shanghai Maritime University, 2018,39 (01): 74-79 + 110.

[9] Deng Hongxing, Zhou Jie, Hu Yi. Optimization model of cold chain logistics distribution path of fresh agricultural products considering carbon emissions [J]. Journal of Chongqing University of Technology (Natural Science), 2023,37 (02): 289-297.

[10] Jiang Yuanyuan. Research on the path optimization of multi-temperature co-distribution vehicles in chain convenience stores of G Company [D]. Shandong University of Finance and Economics, 2024.

[11] Wang Feng, Zhang Lingrong, Lu Bo. Study on the time-varying path of cold chain logistics considering carbon emissions [J / OL]. Management Science in China, 1-12 [2024-09-14].

[12] Zhang Qianqian. Research on the optimization of cold storage multi-temperature co-distribution path of A chain convenience stores considering carbon emissions [D]. Liaoning Engineering and Technical University, 2023.