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Optimization of Seafood Cold Chain Distribution Path Based on Ant Colony Algorithm

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Abstract: Based on the policy environment of carbon neutralization and carbon peak, in order to ensure the high quality and freshness of seafood, this paper constructs the seafood cold chain distribution path optimization model from the perspectives of carbon emission, distribution vehicle transportation and seafood loss. The results show that when the information heuristic factor α= 1. Expected heuristic factorβ= 4. Pheromone volatilization factorρ=0.75, the number of ant colony m=100, pheromone intensity coefficient q=3, N_f=1, N_{max}=400, the iteration tends to be stable at 250.

Keywords: Seafood; Cold Chain Distribution; Ant Colony Algorithm; Optimization Model; Carbon Emissions

Introduction

With the improvement of people's living standard,the quality of seafood in the process of distribution and transportation has been paid more and more attention by the public,and it can be improved by studying the quality safety of seafood, improving the quality management and building a quality control system[1][2].In recent years, the negative impact of excessive carbon emissions on the environment has become increasingly significant.Scholars at home and abroad have studied this and made great contributions.Anna Sobltka (1990) aimed to reduce the cost of logistics distribution and transportation, aiming at the low level of logistics management in the construction industry, established an optimization model for improving the internal logistics system of construction enterprises, so as to reduce the cost of logistics distribution[3].Bozorgi Converted the cost of carbon emissions into economic cost, and established a path optimization model with fuzzy time on the premise of considering inventory[4].Stodola P proposed an ant colony algorithm with deterministic optimization process to solve the multi site path mode[5].

Based on the current large demand market for high-quality seafood and considering the carbon emission cost, controls the cost of enterprise distribution of seafood by optimizing the distribution path.

1. Model construction

1.1 Model assumptions

(1)there is only one distribution center. (2) the external conditions are consistent; (3) The cold chain distribution center has enough cold chain vehicles of the same type to meet the distribution needs, and the demand at each customer does not exceed the maximum rated load of a single cold chain vehicle; (4) The specific information of each customer are known and fixed; (5) ensuring the fuel consumption required for the operation of the cold chain car will not change due to subjective factors.

1.2 Objective function of distribution cost

1.2 Known parameters

The known parameter assumptions of the marine cold chain logistics path optimization model are shown in Table 1:

Table 1 description of symbols and parameters

symbol	description
M	Total number of cold chain cars owned by the distribution center
N	Total number of customers to be delivered by the distribution center
m	Cold chain vehicle, and m $\in$ [1, M]
i，j	customer, and i, j $\in$ [1, N]
Q	Rated maximum load capacity of cold chain car
d_{ij}	Distance from customer i to j
q_i	Demand for chilled aquatic products at customer i
f_m	Fixed cost required for deployment and use of unit cold chain car
a	Refrigerant loss coefficient of unit cold chain car during transportation
b	Refrigerant loss coefficient of unit cold chain truck during loading, unloading
v	Carbon tax rate
w	Carbon emission coefficient
P	Unit price of chilled aquatic products
c	Unit fuel price
T_i^m	Time when the cold chain car m reaches the customer i
T_i	Distribution service duration of cold chain car m for customer i
e_1	Penalty coefficient when the time that the cold chain car arrives at the customer is earlier than the time window agreed by the customer
e_2	Penalty coefficient when the time that the cold chain car arrives at the customer is later than the time window agreed by the customer
x_{ijm}	0-1 variable, the vehicle m drives directly from the customer i to j, otherwise it is 0
y_{im}	0-1 variable, the vehicle m meets the distribution demand of the customer for chilled aquatic products, otherwise it is 0

1.2.2 Cost function analysis

(1) Fixed cost

The fixed cost can be expressed by the following formula:

$$C_1 = \sum_{m=1}^{M}\sum_{j=1}^{N} f_m x_{ojm}$$

(2)Fuel consumption cost

The fuel consumption per unit distance can be expressed by the following formula:

$$\rho(M) = \rho_0 + \frac{\rho_* - \rho_0}{Q} M$$

Where Q is the maximum bearing weight of the cold chain car.Then, the fuel consumption can be expressed by the following formula:

$$\rho(Q_{ij})d_{ij}$$

$\rho(Q_{ij})$ refers to the fuel consumption per unit distance when the cold chain vehicle carries seafood with weight of qij from customer i to j.It can be expressed by the following formula:

$$fuel = \sum_{m=1}^{M}\sum_{i=0}^{N}\sum_{j=0}^{N}\rho(Q_{ij})d_{ij}x_{ojm}$$

If c is the current oil price, the fuel consumption cost in the whole distribution process can be expressed by the following formula:

$$C_2 = cfuel$$

(3)Environmental costs

The environmental cost in the whole process of distribution and transportation can be expressed by the following formula:

$$C_3 = vwfuel$$

(4)Refrigeration cost

The cooling cost in the whole distribution process of the cold chain car can be expressed by the following formula:

$$C_4 = \sum_{m=1}^{M}\sum_{i=0}^{N}\sum_{j=0}^{N}\left(at_{ij}^{m}x_{ijm} + bT_i y_{im}\right)$$

(5)Damage cost

The activity decline function of fresh products can be expressed by the following formula：

$$\theta(t) = \theta_0 e^{-\alpha t}$$

During the distribution of marine products by cold chain trucks, the cost of cargo damage can be expressed by the following formula:

$$C_{51} = \sum_{m=1}^{M}\sum_{i=0}^{N} y_{im}q_i\left(1 - e^{-\alpha_1\left(t_i^m - t_0^m\right)}\right)P$$

$$C_{52} = \sum_{m=1}^{M}\sum_{i=0}^{N} y_{im}Q_{im}\left(1 - e^{-\alpha_{2T_i}}\right)P$$

$$C_5 = C_{51+}C_{52}$$

$$= \sum_{m=1}^{M}\sum_{i=0}^{N} y_{im}\left[q_i\left(1 - e^{-\alpha_1\left(t_i^m - t_0^m\right)}\right) + Q_{im}(1 - e^{-\alpha_{2T_i}})\right]P$$

(6)Penalty cost

The penalty cost in the whole distribution process can be expressed by the following formula:

$$C_6 = e_1\sum_{i=1}^{N} max\{E_i - t_i,\ 0\} + e_2\sum_{i=1}^{N} max\{t_i - L_i,\ 0\}$$

To sum up, the construction of marine products cold chain distribution model and its constraints are shown in the following formula:

$$minZ = C_1 + C_2 + C_3 + C_4 + C_5 + C_6$$

$$= \sum_{m=1}^{M}\sum_{j=1}^{N} f_m x_{ojm} + cfuel + vwfuel + \sum_{m=1}^{M}\sum_{i=0}^{N}\sum_{j=0}^{N}\left(at_{ij}^{m}x_{ijm} + bT_i y_{im}\right)$$

$$+ \sum_{m=1}^{M}\sum_{i=0}^{N} y_{im}\left[q_i\left(1 - e^{-\alpha_1\left(t_i^m - t_0^m\right)}\right) + Q_{im}(1 - e^{-\alpha_{2T_i}})\right]P$$

$$+ e_1\sum_{i=1}^{N} max\{E_i - t_i,\ 0\} + e_2\sum_{i=1}^{N} max\{t_i - L_i,\ 0\}$$

$$s.t. \sum_{i=1}^{N} q_i y_{im} \leq Q_m, \quad \forall i$$

$$\sum_{m=1}^{M}\sum_{j=0}^{N} x_{ojm} = \sum_{m=1}^{M}\sum_{j=0}^{N} x_{jom}$$

$$\sum_{m=1}^{M} y_{im} = 1, \quad \forall i$$

$$\sum_{i=0}^{N} x_{ijm} = 1, \quad \forall i, j, m$$

$$\sum_{i=0}^{N}\sum_{j=0}^{N} x_{ij} = N$$

$$\sum_{i, j\in S\times S}^{j} x_{ijm} \leq |S| - 1, \quad S \subseteq \{1,2, \ldots, N\}$$

$$x_{ijm}, y_{im} = 0 \; or \; 1, \quad \forall m, i, j$$

$$t_j = t_i + T_i + t_{ij}, \quad \forall i, j$$

2. Solution model based on ant colony algorithm

The transfer probability of distribution points can be determined. The transfer probability can be expressed by the following formula:

$$P_{ij}^{k}(t)\begin{cases}\dfrac{[\tau_{ij}(t)]^{\alpha}[\eta_{ij}(t)]^{\beta}}{\sum_{s\subset alloed_k}[\tau_{is}(t)]^{\alpha}[\eta_{is}(t)]^{\beta}} \\ 0, \quad Otherwise\end{cases}$$

To update the pheromone ,it can be expressed by the following formula:

$$\Delta\tau_{ij}(t) = \begin{cases}Q/L_k(t) & The\ kth\ ant\ passes\ through\ this\ cycle\ (i, j) \\ & 0, \quad Otherwise\end{cases}$$

$$\Delta\tau_{ij}(t) = \sum_{k}^{K} \tau_{ij}^{k}(t)$$

The above formula is the pheromone increment of the k_{th} ant on the path (i, j) after this traversal; L_K is the total length of the path traveled by the k_{th} ant in this traversal; Q is the pheromone intensity coefficient, usually a normal number; ρ is pheromone volatilization factor. The pheromone update expression on each path can be expressed by the following formula:

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

Suppose that the number of customers that the distribution center needs to provide services is represented by n, and the number of ants is represented by m. N_f refers to the number of node iteration cycles, and N_{max} refers to the maximum number of iteration cycles.

3. Example analysis

The coordinates of customers and their specific demand information are shown in Table 2.

Table 2 seafood demand information of each customer

No	X	Y	Requirement（kg）	Earliest delivery time	Latest delivery time	Service time（min）
0	30.54	30.12				
1	45.9	38.48	400	1	2	4
2	45.41	50.96	300	1.3	1.8	3
3	42.19	16.24	1000	1.6	2	10
4	42.98	38.86	500	1.5	1.5	5
5	42.96	25.47	400	1	2.1	4
6	40.57	49.5	520	1	2.3	5
7	40.94	66.54	800	0.9	2	8
8	38.11	38.47	700	0.8	3	7
9	38.38	50.24	500	1	2.6	5
10	35.59	46.59	300	1.7	2.7	3
11	35.2	29.61	400	1.9	2.8	4
12	25.72	45.78	850	1.4	2.5	12
13	22.67	65.11	300	1.3	2	3
14	22.57	85.63	800	1.1	2.1	8
15	20.38	10.31	500	1.2	3	5
16	20.91	45.21	900	0.8	2.8	9
17	18.54	30.32	300	0.9	2.9	3
18	15.95	65.17	560	1.9	2.5	6
19	15.51	80.81	540	1.1	2	5
20	30.69	50.32	300	1.4	3	3

Other relevant parameter information settings are shown in Table 3:

Table 3 relevant parameter information settings

Symbol	description	Value
M	Total number of cold chain cars owned by the distribution center	5
N	Total number of customers to be delivered by the distribution center	20
Q	Rated maximum load capacity of cold chain car	4.7t
f_m	Fixed cost required for deployment and use of unit cold chain car	600
a	Refrigerant loss coefficient of unit cold chain car during transportation	6￥/h
b	Refrigerant loss coefficient of unit cold chain truck during loading, unloading and	15￥/h
v	Carbon tax rate	30￥/t
w	Carbon emission coefficient	1
P	Unit price of chilled aquatic products	50
c	Unit fuel price	8.06￥/L
e_1	Penalty coefficient when the time that the cold chain car arrives at the customer is earlier than the time window agreed by the customer	0.03
e_2	Penalty coefficient when the time that the cold chain car arrives at the customer is later than the time window agreed by the customer	0.06

Set information heuristic factor α=1. Expected heuristic factor β= 4. Pheromone volatilization factor ρ= 0.75, ant colony number m=100, pheromone strength coefficient q=3, nf=1, N_{max}=400. The optimal distribution path strategy obtained by using MATLAB software is shown in Figure 1:

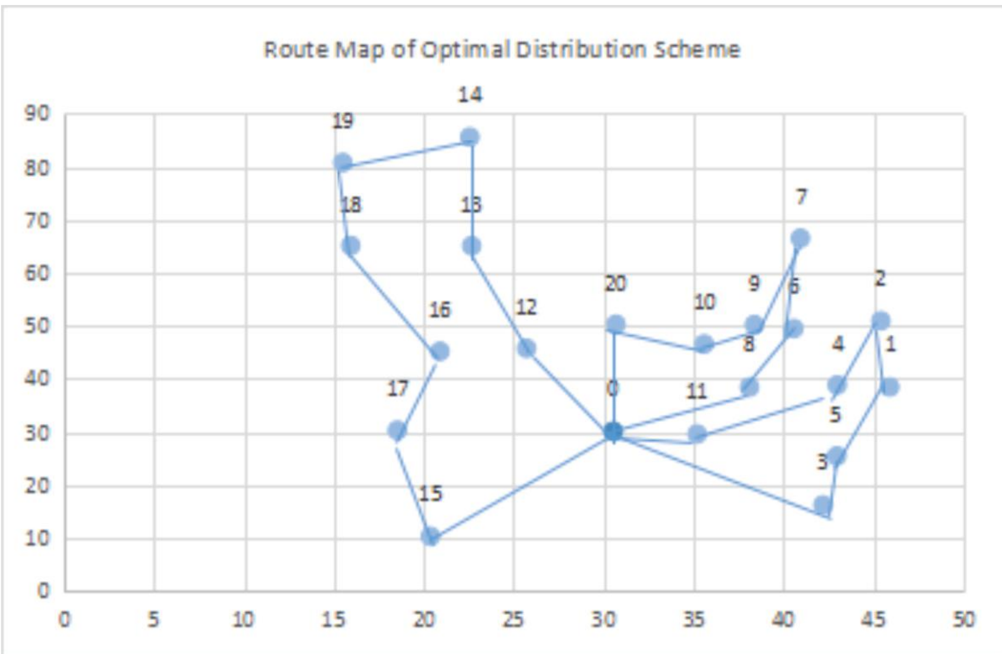

Fig1 Route map of optimal distribution scheme

The trend chart of minimum cost of each generation can be shown in Figure 2:

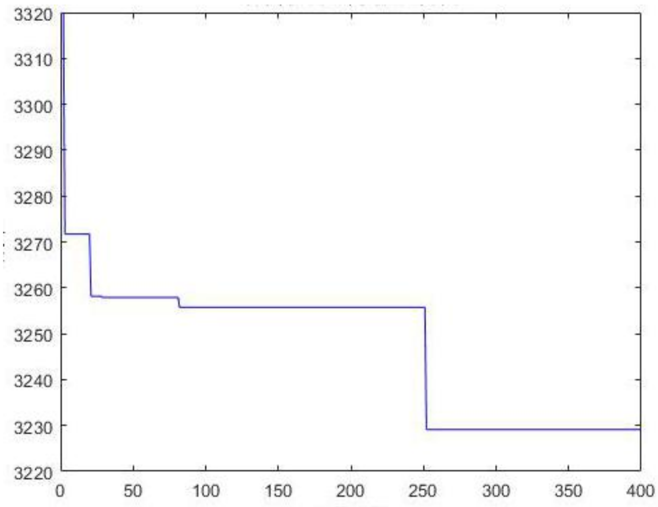

Fig2 Trend chart of minimum cost of each generation

It can be seen from Figure 2 that the number of iterations of this algorithm is 400 and the value of the objective function is stable at 3230 when it is near the 250th.

4. Epilogue

This paper summarizes the problems of seafood distribution in the cold chain according to the characteristics of seafood. Combined with the problems in the distribution of seafood,the cold chain distribution path model pf seafood is constructed.In order to verify the effectiveness of the model, through MATLAB software, the ant colony algorithm is used to optimize the distribution case objective function, and the marine cold chain distribution path map is obtained. This can provide method support for seafood cold chain distribution enterprises to develop low-carbon cold chain distribution in the future.

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