Research on Location of Cold Chain Logistics Distribution Center with Low Carbon in Beijing-Tianjin-Hebei Area on the Basis of RNA-Artificial Fish Swarm Algorithm

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Abstract. In order to improve the existing problems of the artificial fish swarm algorithm, the fish swarm algorithm is improved by using the characteristics of RNA computing, and the RNA-artificial fish swarm algorithm is proposed. Since cold-chain food has the characteristics of perishable quality and can generate a large number of carbon emissions during its transportation, this paper establishes a model for optimizing cold chain low carbon logistics location in the Beijing-Tianjin-Hebei area, including factors such as food spoilage, refrigeration and carbon emissions. The logistics location optimization model is solved 30 times with the basic fish swarm algorithm and the RNA-artificial fish swarm algorithm respectively. The simulation results prove the effectiveness of the RNA-artificial fish swarm algorithm.

1. Introduction

Artificial Fish Swarm Algorithm (AFSA) is a search algorithm based on swarm intelligence proposed by Li Xiaolei et al. [1]. The basic artificial fish swarm algorithm includes foraging, clustering, following and other behaviors. Artificial fish can use these behaviors to find the place with the highest food concentration in the environment so as to realize global optimization. The algorithm performs good optimization effect in the initial stage, but in the late stage of the algorithm, the algorithm is prone to oscillation, which slows down the optimization speed and worsens the accuracy. In view of the shortcomings of fish swarm algorithm, scholars have put forward many improved methods. Based on the analysis of parameters, Lu Fengyi et al. [2] established a model in which the field of view and step length inversely, and utilized the advantages of the differential evolution algorithm’s mutation behavior to interfere with the artificial fish, thereby speeding up the optimization speed. He Li et al. [3] introduced the judge criterion and simulation operator in the simulated annealing algorithm into the fish swarm algorithm and used the improved fish swarm algorithm (SA_AFSA) in the micro-grid optimal dispatching problem. The results showed that SA_AFSA has better results in economy and environmental protection.

RNA computing is an algorithm on the basis of molecular biology. The full name for RNA is ribonucleic acid, and it carries essential genetic material. The four nitrogenous bases, including adenine (A), uracil (U), cytosine (C) and guanine (G), determine the difference of RNA molecules [4]. RNA computing includes transposition, replacement and recombination [5].

(1) Transposition operation: The two fragments in an RNA molecule are transposed, namely
In this paper, an RNA-artificial fish swarm algorithm is proposed based on RNA computing. The basic idea of the modified algorithm is that introduce transposition, replacement and recombination operations in RNA computing into the basic fish swarm algorithm to enrich the diversity of the fish school and enhance the degree of information exchange so as to better jump out of the local extreme value and improve the search level of the algorithm and convergence efficiency.

2. Model

The reasonable selection of distribution centers is of vital importance to the improvement of the logistics system. Duan Guanhua et al. [6] integrated hesitation tendency into the intuitionistic fuzzy clustering class method to determine the logistics center’s optimal location. Chen Gang et al. [7] established a pure integer linear programming model with the goal of total mileage, and studied the location of UAV distribution centers in the context of military-civilian integration. Lai Zhizhu et al. [8] established an emergency facility location model aiming at the shortest time and the lowest cost to deal with emergencies more effectively. Liu Jing [9] improved the simulated annealing algorithm by using particle swarm optimization algorithm, and applied the improved simulated annealing algorithm to optimize the shipping logistics distribution center’s location.

In the process of cold chain logistics, it is necessary to keep temperature at a lower level, a large amount of energy consumption and carbon dioxide can be generated. Therefore, the location about cold chain low carbon logistics distribution center needs to consider the economic cost and environment in the process of logistics distribution. This paper builds a cold chain low carbon logistics distribution center location model, which includes \( I \) providers, \( J \) distribution centers to be selected and \( M \) demanders. Total cost includes fixed cost, transportation cost, cargo damage cost, refrigeration cost, carbon emission cost and penalty cost. The model is described as follows:

\[
\min \text{Cost} = \sum_{j=1}^{J} \alpha_j c_j + \sum_{i=1}^{I} \sum_{j=1}^{J} \alpha_j \left( q_{ij} p_i d_{ij} + h_j + p_{ij} t_{ij} + p_e \left( E_i d_{ij} + E_i t_{ij} \right) \right) \\
+ \sum_{j=1}^{J} \sum_{m=1}^{M} \alpha_{jm} \left( q_{jm} p_j d_{jm} + \left( h_{jm} + H_m \right) + \left( p_{jm} t_{jm} + p_{jm} T_m \right) + p_e \left( E_j d_{jm} + E_j t_{jm} \right) \right) + C_6
\]

\[
h_j = p_j q_j \left( 1 - e^{-R_0} \right)
\]

\[
h_{jm} = p_j q_{jm} \left( 1 - e^{-R_{tm}} \right)
\]

\[
H_m = p_j q_{jm} \left( 1 - e^{-R_{tm}} \right)
\]

\[
C_6 = \sum_{m=1}^{M} \left( p_{61} \max \left( E T_m - t_m, 0 \right) + p_{62} \max \left( t_m - L T_m, 0 \right) \right)
\]

S.T.

\[
\alpha_j = \begin{cases} 1, & \text{distribution center } j \text{ is selected} \\ 0, & \text{distribution center } j \text{ is not selected} \end{cases}
\]

\[
\alpha_{jm} = \begin{cases} 1, & \text{the distribution center } j \text{ delivers food to the demand point } m \\ 0, & \text{the distribution center } j \text{ delivers food to the demand point } m \end{cases}
\]

\[
\sum_{j=1}^{J} \alpha_j \leq N
\]
\[ \sum_{j=1}^{M} \alpha_{jm} = 1, m \in M \]  \hspace{1cm} (10)

\[ \sum_{i=1}^{N} \sum_{j=1}^{M} q_{ij} = 0 \]  \hspace{1cm} (11)

\[ \sum_{j=1}^{M} q_{jm} \geq \sum_{m=1}^{M} q_m \]  \hspace{1cm} (12)

\[ EET_m \leq t_m \leq LLT_m \]  \hspace{1cm} (13)

In the formula, Cost represents the total cost; \( c_j \) is the fixed cost of the distribution center \( j \); \( p_2 \) is the unit distance transportation cost per unit of food; \( d_{ij} \) and \( q_{ij} \) are the distance and transportation volume from provider \( i \) to distribution center \( j \); \( d_{jm} \) and \( q_{jm} \) are the distance and transportation volume from distribution center \( j \) to demander \( m \); \( h_{ij} \) and \( h_{jm} \) respectively represent the cost of cargo damage caused by the transportation of food from provider \( i \) to distribution center \( j \) and distribution center \( j \) to demander \( m \); \( H_m \) represents the cost of cargo damage caused by unloading at the demanders; \( p_3 \) is the unit price of food; \( \beta_1 \) and \( \beta_2 \) are respectively the deterioration rate of food during transportation and unloading; \( t_{ij} \) and \( t_{jm} \) are the transportation time of vehicles from provider \( i \) to distribution center \( j \) and from distribution center \( j \) to demander \( m \) respectively; \( T_m \) is the time taken to unload vehicles at demander \( m \); \( p_{41} \) and \( p_{42} \) are the refrigeration cost generated in the process of transportation and unloading per unit time respectively; \( E_1 \) is the fuel consumption per unit distance traveled by refrigerated vehicles; \( E_2 \) is the energy consumption per unit time of refrigeration equipment; \( e \) is the carbon dioxide emission coefficient; \( p_c \) is unit carbon tax price; \( P_{e1} \) and \( P_{e2} \) are the waiting cost and lateness cost generated per unit time of the vehicle respectively. \( t_m \) is the time of the vehicle arriving at \( m \); \( (EET_m, LT_m) \) is the expected time window of \( m \), \( (EET_m, LT_m) \) is the acceptable time window of \( m \).

Formulas (7)-(8) are related definitions; Equation (9) means that at most \( N \) distribution centers can be built, \( n = 1,2, \cdots, N \); Equation (11) means that only one distribution center can provide distribution service for a demander; Equation (12) indicates that the total amount of transportation from the distribution center to the demander is not less than the total demand of the demander; Equation (13) indicates that the time when the vehicle arrives at the demander must be within the acceptable time range.

3. Example simulation

This article takes the Beijing-Tianjin-Hebei area as an example, regards Binhai New Area (117.68, 39.03) as the provider, and chooses 5 out of 13 municipal administrative units in the metropolitan area (Beijing, Tianjin, Shijiazhuang, Chengde, Zhangjiakou, Qinhuangdao, Langfang, Tangshan, Baoding, Cangzhou, Hengshui, Xingtai, Handan) as distribution centers to distribute food to 26 demanders. The basic artificial fish swarm algorithm and RNA-artificial fish swarm algorithm are used to solve this cold chain location problem independently for 30 times, there are 30 artificial fish, the maximum number of trial is 5, the crowding factor is 0.618, and the perceived distance is 65, the step size is 20, the maximum number of iterations is 100, the probability of RNA transposition is 0.5, the probability of RNA replacement is 0.3, and the probability of RNA recombination is 0.01. Table 1 shows the relevant data of 13 alternative distribution centers, and Table 2 shows the relevant data of demanders.

Suppose that the vehicle starts from the distribution center at 5:00, and the unloading time at the distribution centers and demanders is proportional to the unloading quantity, with a ratio coefficient of
The waiting cost and lateness cost per unit time of the vehicle are 10 yuan and 20 yuan respectively. Food’s price is 5000 yuan/t, vehicle speed is 60km/h, deterioration rate in transportation is 0.02, deterioration rate in unloading is 0.04, the transportation cost is 0.3 yuan/t·km. In unit time, the refrigeration cost generated by transporting food is 15 yuan, the refrigeration cost of unloading food is 20 yuan, the vehicle’s fuel consumption is 0.225L/km, the refrigeration equipment’s energy consumption is 0.0025L/t·km, the carbon tax price is 20 yuan/kg, and carbon dioxide emission coefficient is 2.66kg/L [10].

Table 1. Data related to alternative distribution centers.

| Distribution center       | Longitude and latitude | Capacity | Fixed cost |
|---------------------------|------------------------|----------|------------|
| Beijing City              | (116.42, 39.92)        | 16       | 7000       |
| Tianjin City              | (117.20, 39.13)        | 18       | 6500       |
| Shijiazhuang City         | (114.30, 38.02)        | 22       | 6000       |
| Chengde City              | (117.57, 40.59)        | 24       | 4500       |
| Zhangjiakou City          | (114.53, 40.48)        | 20       | 5000       |
| Qinhuangdao City          | (119.35, 39.55)        | 18       | 4000       |
| Langfang City             | (116.70, 39.52)        | 20       | 3500       |
| Tangshan City             | (118.11, 39.36)        | 20       | 4500       |
| Baoding City              | (115.30, 38.51)        | 22       | 5000       |
| Cangzhou City             | (116.52, 38.18)        | 22       | 4000       |
| Hengshui City             | (115.42, 37.44)        | 24       | 4000       |
| Xingtai City              | (114.30, 37.04)        | 24       | 5500       |
| Handan City               | (114.28, 36.36)        | 22       | 5000       |

Table 2. Data related to the demanders.

| No. | Demander                      | Longitude and latitude | Quantity | Expected time window | Acceptable time window |
|-----|-------------------------------|------------------------|----------|----------------------|------------------------|
| 1   | Huairou District, Beijing     | (116.63, 40.32)        | 5        | 5:30-8:30           | 5:15-9:00             |
| 2   | Fangshan District, Beijing   | (116.13, 39.75)        | 4        | 5:15-9:10           | 5:00-9:40             |
| 3   | Jinghai District, Tianjin     | (116.92, 38.93)        | 2.5      | 5:20-9:15           | 5:10-9:40             |
| 4   | Ninghe County, Tianjin       | (117.82, 39.33)        | 4        | 5:20-9:30           | 5:00-9:50             |
| 5   | Pingshan County, Shijiazhuang City, Xinji City | (114.20, 38.25) | 3.5 | 5:30-8:15 | 5:20-8:40 |
| 6   | Shijiazhuang City, Fengning County, Chengde City | (115.22, 37.92) | 4 | 5:45-7:45 | 5:30-8:10 |
| 7   | Longhua County, Chengde City | (116.65, 41.20)        | 2        | 6:30-9:10           | 6:00-9:50             |
| 8   | Chongli County, Zhangjiakou City, Huaian County, Zhangjiakou City | (117.72, 41.32) | 3.5 | 5:15-9:30 | 5:00-10:00 |
| 9   | Huaian County, Zhangjiakou City, Changli County, Qinhuangdao City | (115.27, 40.97) | 3 | 5:40-9:20 | 5:10-9:50 |
| 10  | Zhangjiakou City, Changli County, Qinhuangdao City | (114.42, 40.67) | 4 | 5:30-9:30 | 5:00-10:00 |
| 11  | Changli County, Qinhuangdao City, Handan | (119.17, 39.70) | 4 | 5:20-9:10 | 5:00-9:40 |
| 12  | Qinhuangdao City, Qinhuangdao City | (118.95, 40.40) | 2 | 5:40-8:20 | 5:15-9:00 |


The solution results of the two algorithms for 30 times are shown in Table 3.

|   | Average value | Optimal value | Worst value | Standard deviation | Average convergence algebra |
|---|---------------|---------------|-------------|--------------------|-----------------------------|
| 13 | Gu’an County, Langfang City | (116.30, 39.43) | 1 | 5: 10-9: 20 | 5: 00-9: 50 |
| 14 | Xianghe County, Langfang City | (117.00, 39.77) | 4.5 | 5: 20-8: 30 | 5: 00-9: 10 |
| 15 | Zunhua County, Tangshan City | (117.95, 40.18) | 2.5 | 5: 30-9: 10 | 5: 10-9: 40 |
| 16 | Tanghai County, Tangshan City | (118.45, 39.27) | 1 | 5: 15-9: 30 | 5: 00-10: 00 |
| 17 | Laisyuan County, Baoding City | (114.68, 39.35) | 4 | 5: 10-9: 45 | 5: 00-10: 10 |
| 18 | Shunping County, Baoding City | (115.13, 38.83) | 4.5 | 5: 05-8: 40 | 5: 00-9: 20 |
| 19 | Renqiu City, Cangzhou City | (116.10, 38.72) | 4 | 5: 20-9: 10 | 5: 00-9: 40 |
| 20 | Haixing County, Cangzhou City | (117.48, 38.13) | 3 | 5: 50-9: 30 | 5: 30-10: 00 |
| 21 | Fucheng County, Hengshui City | (116.15, 37.87) | 3 | 5: 40-8: 15 | 5: 15-8: 50 |
| 22 | Guicheng County, Hengshui City | (115.97, 37.35) | 3.5 | 5: 30-9: 20 | 5: 20-9: 40 |
| 23 | Lincheng County, Xingtai City | (114.50, 37.43) | 4.5 | 5: 30-8: 30 | 5: 00-10: 00 |
| 24 | Guangzhong County, Xingtai City | (115.15, 37.07) | 4 | 5: 50-9: 00 | 5: 15-9: 40 |
| 25 | Shexian County, Handan City | (113.67, 36.57) | 5 | 5: 30-9: 20 | 5: 10-10: 00 |
| 26 | Wei County, Handan City | (114.93, 36.37) | 4.5 | 5: 30-9: 30 | 5: 00-9: 50 |

The solution results of the two algorithms for 30 times are shown in Table 3.

As can be seen from Table 3, in terms of total cost, the average value, optimal value and worst value of RNA-artificial fish swarm algorithm (RNA-AFSA) are reduced by 13524.95, 13426.99 and 15044.35, respectively, compared with the basic artificial fish swarm algorithm (AFSA), indicating that RNA-AFSA can get a lower cost when solving the model. In terms of standard deviation, the standard deviation of AFSA is greater than that of RNA-AFSA, indicating that the stability of AFSA is worse than that of RNA-AFSA. In the aspect of convergence algebra, the RNA-AFSA’s average convergence algebra is smaller, suggesting that it has a faster convergence rate.

The schematic diagram of the optimal location solved by the basic artificial fish swarm algorithm and the RNA-artificial fish swarm algorithm is shown in Figure 1-2. Figure 1 shows that the optimal site selection scheme obtained by the basic artificial fish swarm algorithm is as follows: First of all, cold chain food are transported from the provider, Binhai New Area, to 5 distribution centers: Tianjin, Tangshan, Baoding, Zhangjiakou and Langfang; Then, the food is transported by the distribution centers to demanders: (1) demanders delivered by Tianjin: 1, 2, 5, 7; (2) demanders delivered by Tangshan: 8, 13, 15, 16, 20, 22, 26; (3) demanders delivered by Baoding: 3, 9, 10, 18, 21, 23; (4) demanders delivered by Zhangjiakou: 4, 12, 19, 24, 25; (5) demanders delivered by Langfang: 6, 11,
As can be seen from Figure 2, the optimal location scheme solved by RNA-artificial fish swarm algorithm is as follows: First, cold chain food are transported from the provider, Binhai New Area, to five distribution centers: Tangshan, Qinhuangdao, Baoding, Cangzhou and Langfang. Then, the food is transported by the distribution centers to demanders: (1) demanders delivered by Tangshan: 4, 11, 15, 24, 25; (2) demanders delivered by Qinhuangdao: 1, 17, 19; (3) demanders delivered by Baoding: 5, 7, 13, 14, 18, 21; (4) demanders delivered by Cangzhou: 8, 9, 12, 16, 20, 22, 26; (5) demanders delivered by Langfang: 2, 3, 6, 10, 23.
The comparison of the optimization curves of the two algorithms is shown in Figure 3. As can be seen from Figure 3, the RNA-artificial fish swarm algorithm has faster convergence speed and higher optimization accuracy.

![Optimization Curves](image)

Figure 3. Comparison of the two algorithms’ optimization curves.

4. Conclusion
This paper introduces transposition, replacement and recombination operations in RNA computing into the basic artificial fish swarm algorithm, and then proposes the RNA-artificial fish swarm algorithm. By comprehensively considering various influencing factors in cold chain food’s transportation process, the total cost includes six kinds of costs, including fixed cost, transportation cost, cargo damage cost, refrigeration cost, carbon emission cost and penalty cost, and location model of cold chain low carbon logistics distribution center with the goal of minimizing the total cost is established. At the same time, RNA-artificial fish swarm algorithm is applied to the location model of cold chain low carbon logistics distribution center in the Beijing-Tianjin-Hebei area. The results of the example show that the RNA-artificial fish swarm algorithm has lower total cost, stronger stability and faster speed in solving the model.

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