

Research on Optimizing the Distribution Path of Agricultural Cold Chain Logistics in Green Consumption Era

Li Zhang

Baotou Teachers' College, Baotou, 014030, China

Abstract

In recent years, with the rapid development of China's fresh market, cold chain logistics ushered in a new development opportunity. Because of the late start and slow development of cold chain logistics in China, it is difficult to achieve cross-regional and off-season sales activities, resulting in a situation of high output and small sales volume, which is also an important reason for the high price and poor quality of fresh agricultural products. With the passage of time, the characteristics of cold chain distribution of agricultural products have become an important direction for the future development of logistics industry. In this paper, aiming at the characteristics of agricultural cold chain distribution, the carbon emissions in the process of distribution were quantified as costs and added to the total cost, and an optimization model of agricultural cold chain logistics path with time window considering the minimum total cost as the objective function was constructed. The improved genetic algorithm was used to solve the problem. The simulation results show that the improved genetic algorithm is an effective method to solve the optimization problem of agricultural cold-chain logistics path considering carbon emissions, and has guiding significance for the selection of low-carbon and environmentally friendly distribution routes for agricultural cold-chain logistics distribution enterprises.

Keywords: *Cold Chain Logistics; Fresh Agricultural Products; Distribution Route Optimization; Cost-Saving Method*

1. INTRODUCTION

With the demand of the era of economic globalization, the logistics industry is also developing towards a more scientific and modern direction. As an important part of the logistics industry, the cold chain logistics of agricultural products has become a hot topic. Agricultural cold chain logistics refers to a systematic project in which all links of agricultural products, such as fruits, vegetables and meat, are always under the specified low temperature control to ensure their quality from production to consumption. The innovation of this study is that according to the particularity of cold chain logistics distribution, the factors of time, temperature and cargo damage in the process of cold chain logistics distribution are fully considered. By using cost-saving method and arranging distribution routes reasonably, the distribution time can be shortened and the loss of goods can be reduced. At the same time, the time window requirement of customers can be met, the customer satisfaction and the competitiveness of cold chain logistics enterprises can be improved, which is in line with the future development direction of cold chain logistics market in China.

2. PROBLEMS IN COLD CHAIN LOGISTICS OF AGRICULTURAL PRODUCTS IN CHINA

Compared with developed countries, the overall level of cold chain logistics of agricultural products in China is relatively low, the loss of agricultural production circulation is high, and the cost of logistics remains high [1]. Especially in the west areas where the development is relatively lagging behind, the logistics infrastructure of agricultural products is relatively backward, the circulation efficiency is low, the storage and transportation conditions are backward, and the lack of advanced information network platform leads to serious loss of agricultural products in the circulation process [2]. The backward technology of cold chain logistics in China has led to the decay and fragrance of fresh agricultural products in the transportation process, which can't guarantee the "safety" and

"green" problems of fresh agricultural products in transportation [3]. At the same time, the lack of professionals in cold chain logistics restricts the rapid development of cold chain logistics in China [4].

3. RESEARCH ON OPTIMIZING DISTRIBUTION ROUTE OF COLD CHAIN LOGISTICS

3.1 Problem description and hypothesis

The cold chain logistics transportation model established in this study was based on the service of a cold chain distribution center for multiple customers [5]. Under the constraints of customer demand, vehicle load limitation and customer time window requirement, the minimum total cost of distribution can be achieved by formulating reasonable transportation routes [6]. At the same time, according to the characteristics of cold chain logistics distribution, seven basic assumptions are made as shown in Fig.1: distribution is only a one-way delivery process; the load of refrigerated transport vehicles is determined; all customers' demand for goods must be met and only one refrigerated truck can distribute the goods required by each customer; the starting point and ending point of vehicles must be the same distribution center; the geographical location of each customer and the demand for goods are known; to determine the service time specified by the customer, delivery must be carried out within the specified time period, and the arrival of vehicles within the customer satisfaction time window will not be punished; if the vehicle arrives beyond the customer satisfaction time window, there will be a certain time penalty, and the penalty cost is related to the arrival time of vehicles; the optimal distribution routes between distribution centers and customers, as well as between two customers, are known; products need a certain temperature to maintain their quality and value. Combining with the actual distribution process, in this experiment, the cost of time, temperature and goods loss in the process of cold chain logistics distribution was deeply studied. Taking the minimum total cost of distribution as the objective function, the basic model of cold chain logistics distribution problem was established to reduce the energy consumption cost of logistics distribution activities, ensure the quality of products and reduce the loss in circulation [7].

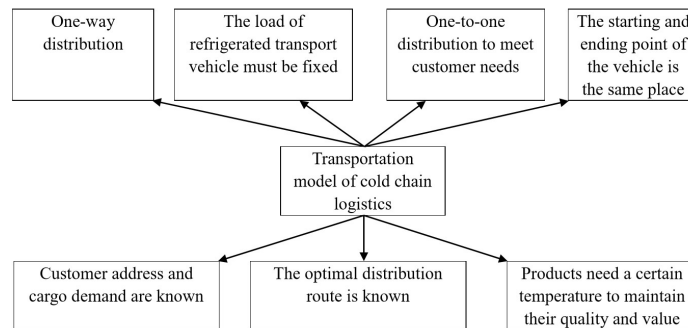


FIG. 1 BASIC ASSUMPTIONS FOR ESTABLISHING A COLD CHAIN LOGISTICS TRANSPORT MODEL

3.2 Definition of cold chain logistics distribution cost

According to the decision goal, the objective function of cold chain logistics distribution model is the lowest total cost [8]. According to the characteristics of cold chain logistics, the cost of cold chain logistics distribution can be divided into three parts: time cost, temperature cost and cargo loss cost [9]. Among them, time cost includes vehicle transportation cost and customer time window cost; temperature cost includes refrigeration cost in transportation process and additional energy consumption cost caused by temperature difference change in unloading process; cargo loss cost includes product loss cost and cargo loss cost caused by temperature difference change in loading and unloading process [10].

Transportation is an important part of the distribution process, and it also takes the longest time. Therefore, transportation cost is an important part of time cost, and the transportation cost of distribution vehicles is positively correlated with the number of mileage and time of vehicles [11]. For the transportation cost of distribution vehicles, the following formula is used to calculate:

$$C_{11} = \sum_{i=0}^n \sum_{j=0}^n \sum_{k=1}^m x_{ij}^k c_{ij}^k \quad (1)$$

In formula: c_{ij}^k represents the transportation cost of the k vehicle from customer i to customer j ; x_{ij}^k is a variable of 0 and 1, if the k vehicle completes the distribution of customer i to customer j , $x_{ij}^k = 1$, otherwise, $x_{ij}^k = 0$.

In order to obtain more efficient and high-quality services, customers will require merchants to deliver goods within the prescribed time. However, in reality, due to inappropriate distribution routes, customers can't receive goods within the prescribed time. This kind of cost caused by time window is an implicit cost. Compared with the three explicit costs of transportation cost, temperature cost and cargo loss cost, although it can't substantially change the cost of distribution process, it will affect customer satisfaction and service experience, and there is a risk of quality decline and loss of customers. If implicit time window cost is expressed explicitly by mathematical model, it can be used as an important index to measure the efficiency and cost of logistics distribution. Therefore, time window cost should be an important part of logistics distribution cost. The cost of time window is as follows:

$$C_{12} = \sum_{j=1}^n p q_j F_j(s_j) \max\{(E_j - s_j), (s_j - L_j), 0\} \quad (2)$$

In formula: P denotes the unit price of the product; q_j denotes the demand of customer j ; s_j denotes the time to reach customer j ; E_j or L_j denotes the earliest or latest delivery time required by customer j ; $F_j(s_j)$ denotes the loss cost coefficient function caused by violating customer time window.

$$F_j(s_j) = \begin{cases} \infty & s_j < e_j \text{ or } s_j > l_j \\ \alpha & e_j \leq s_j < E_j \\ 0 & E_j \leq s_j \leq L_j \\ \beta & L_j < s_j \leq l_j \end{cases} \quad (3)$$

In formula: e_j or l_j denotes the earliest or latest delivery time acceptable to j customers; α and β denote the loss cost factor caused by violation of customer time windows ($\alpha < \beta$).

Generally, the transport objects of cold chain logistics are perishable products. The quality and value of products are often affected by temperature, humidity, time and other factors. In the process of distribution, in order to reduce the deterioration of products and ensure their quality, low-temperature transportation is usually used. However, low-temperature transportation is only a means to control and slow down product decay, which can't completely block the occurrence of this phenomenon, so that the cost of goods damage caused by product damage in cold chain logistics distribution process must also be considered. There are many factors affecting the decay of cold chain distribution products: Assuming that other factors are not taken into account in the transportation process, if the product is transported only at constant temperature, the decay of the product is only related to the distribution time; during the loading and unloading process, air convection is formed due to the temperature difference between the inside and outside of the vehicle, which results in the temperature change in the carriage, thus accelerating the loss of the product. The loss cost of these two parts can be expressed by the following formula:

$$C_2 = p \sum_{k=1}^m \sum_{j=1}^n x_j^k q_j (\theta_1 t_{0j}^k + \theta_2 t_j^k) \quad (4)$$

In formula: x_j^k is a variable of 0 and 1, if the k vehicle completes the delivery of customer j , $x_j^k = 1$, otherwise, $x_j^k = 0$; t_{0j}^k represents the travel time of the k vehicle from the distribution center to customer j vehicle; t_j^k represents the loading and unloading time of the k vehicle at customer j ; θ_1 and θ_2 represent the product cargo damage coefficient.

Temperature is the decisive condition for maintaining refrigerated products. It is important for cold chain logistics to reduce or slow down the decay rate of products at appropriate temperature. The deterioration of fresh agricultural products is mainly caused by microorganisms, enzymes, oxidation, respiration and mechanical damage. Temperature plays an important role in the above five deterioration factors. Thus, temperature control can effectively reduce the deterioration. In the process of cold chain distribution, the cost of temperature is mainly caused by the refrigeration energy consumption of refrigeration trucks. Therefore, ignoring other factors in the study, the temperature cost of

fresh products was divided into two parts: First, with the change of temperature in the process of vehicle transportation, the energy cost of refrigerators also changes, and the formula is as follows:

$$C_{31} = \sum_{i=0}^n \sum_{j=1}^n \sum_{k=1}^m x_{ij}^k \theta_3 t_{ij}^k T \quad (5)$$

In formula: t_{ij}^k denotes the driving time of the k vehicle from customer i to customer j ; θ_3 denotes the product refrigeration cost coefficient; and T denotes the temperature inside the vehicle. Secondly, in the process of loading and unloading fresh products, air convection (ΔT) is formed due to the temperature difference between inside and outside of the vehicle, which leads to drastic changes in the temperature in the carriage, thus increasing the energy consumption cost of the refrigerator. The formula is:

$$C_{32} = \sum_{i=0}^n \sum_{j=1}^n \sum_{k=1}^m x_{ij}^k \theta_4 t_{ij}^k \Delta T \quad (6)$$

In formula: θ_4 represents the product refrigeration cost coefficient.

3.3 Model establishment

To sum up, the cold chain logistics distribution optimization model is constructed as follows:

$$\begin{aligned} \min z &= C_{11} + C_{12} + C_2 + C_{31} + C_{32} \\ &= \sum_{i=0}^n \sum_{j=0}^n \sum_{k=1}^m x_{ij}^k c_{ij}^k + \sum_{j=1}^n p q_j F_j(s_j) \max\{(E_j - s_j), (s_j - L_j), 0\} \\ &\quad + p \sum_{k=1}^m \sum_{j=1}^n x_j^k q_j (\theta_1 t_{0j}^k + \theta_2 t_j^k) + \sum_{i=0}^n \sum_{j=1}^n \sum_{k=1}^m x_{ij}^k \theta_3 t_{ij}^k T + \sum_{i=0}^n \sum_{j=1}^n \sum_{k=1}^m x_{ij}^k \theta_4 t_{ij}^k \Delta T \end{aligned} \quad (7)$$

4. CASE STUDY OF COLD CHAIN LOGISTICS DISTRIBUTION ROUTE OPTIMIZATION BASED ON COST-SAVING METHOD

Cost-saving method forms the idea of radiation lines with only one origin by connecting individual points with source points, thus calculating the maximum savings between points. On this basis, an improved cost-saving method was proposed to solve the problem by adding constraints such as time window and temperature control and combining the characteristics of cost-saving method. The characteristics of this algorithm are as follows: it belongs to the successive approximation method, with the advantages of simple technical steps, easy to understand, fast calculation speed and easy to consider various practical problems, having its own advantages in solving small-scale vehicle distribution routing problems such as vehicle distribution routing for small and medium-sized enterprises. At present, the bottleneck of the development of cold chain logistics lies in the high cost of distribution, one of the important aspects of which is the requirement of distribution time. The addition of improved time window saving method will require cold chain enterprises to make the best choice of distribution route under time constraints. Therefore, the saving method with time and temperature constraints is more suitable for the actual vehicle distribution situation of cold chain logistics enterprises. According to the formula of cold chain logistics distribution model (7), the total cost of objective function is minimized by considering the constraints of time, temperature and loss cost in the process of cold chain logistics distribution. In this study, when using cost-saving method to optimize the distribution route of cold-chain logistics vehicles, relevant factors included saved transportation costs, saved damage costs, saved refrigeration costs and penalty costs. Under the constraints of time window and vehicle load, considering the feasibility of the distribution route, the maximum savings among the points can be found, and the transportation route with the most savings can be calculated. The solving steps are summarized as follows: (1) sorting according to the order of the customer's receiving time; (2) taking the customer with the earliest time window as the first distribution point, determining the next distribution point according to the customer with the greatest total cost savings, and so on until the vehicle load and time window limit are reached; (3) deleting the selected customer and repeating the above steps until all customers' distribution tasks are completed.

5. CONCLUSION

In this study, firstly, the cold chain logistics of fresh agricultural products in our country was summarized. According to its particularity, taking cold chain logistics distribution as the starting point, the influence of time, temperature and cargo loss cost on distribution cost was analyzed separately in the process of distribution, so as to construct the objective function with the aim of minimizing total cost. And an improved cost-saving method based on time window was proposed to improve the performance and efficiency of the algorithm. It is hoped that this study can provide reference for the optimization of agricultural cold-chain logistics distribution path in the era of green consumption.

REFERENCES

- [1] YuanHuiqun, Yang Jiaqi. Obstacles and Reflections on the Development of Cold Chain Logistics of Agricultural Products in Low Carbon Era. *Development and Research*, 2012, 05:56-59.
- [2] Pang Biao. Upgrading of cold chain logistics. *China Logistics and Procurement*, 2018, 09:44-45.
- [3] Hong Li. Development status and Countermeasures of cold chain logistics under the background of fresh e-commerce. *Journal of Anhui Radio and Television University*, 2018, 02:28-31.
- [4] Ai Xiaoling. Research on the Development Strategy of Agricultural Cold Chain Logistics in Jiangsu Province Based on Supply-side Reform. *Logistics Science and Technology*, 2018, 4106:69-71+78.
- [5] Hongtao. Innovation of cold-chain logistics model of agricultural products in China. *China Market*, 2018, 27:1-4.
- [6] Du Tiantian, Li Xuecheng. Reflections on the structural reform of agricultural cold chain logistics supply side. *Taiwan Agricultural Exploration*, 2018, 04:82-85.
- [7] Shen Qian. Research on the Development of Fruit and Vegetable Cold Chain Logistics in Jiangsu Province Based on Green Supply Chain. *Logistics Technology*, 2018, 3711:102-105.
- [8] Chang Lina, Han Xing. Current situation and development proposals of fruit and vegetable cold chain logistics in China. *Chinese fruit and vegetable*, 2015, 3502:5-10.
- [9] Kang Kaijie. Restrictive factors and Countermeasures for the development of cold chain logistics of Gansu characteristic agricultural products. *Journal of Northwest Adult Education College*, 2016, 06:97-100.
- [10] Li Yaohua. Study on the Evaluation of Agricultural Cold Chain Logistics Efficiency from the Perspective of Eco-economy. *Commercial Economic Research*, 2015, 36:31-32.
- [11] Huang Tao. Exploration and Analysis on the development of cold chain logistics industry of agricultural products in Xinjiang. *Xinjiang Finance and Economics*, 2016, 02:54-59.