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Research on the Cold Chain Logistics Distribution System of Agricultural Products

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Abstract. In recent years, with the constant improvement of the people's living standards and quality, people's demand for fresh agricultural products is increasing. The cold chain logistics of agricultural products has become a new field of logistics, which attracts more and more attention from all sectors of society. Distribution of agricultural products is an important part of cold chain logistics of agricultural products. Its research can not only reduce logistics costs and improve economic benefits, but also reduce the loss of agricultural products and improve the freshness of agricultural products. Firstly, this paper analyzes the main distribution modes of cold chain logistics of agricultural products in China, and puts forward some suggestions to improve the existing problems. Secondly, the logistics cost in the distribution process of agricultural products is analyzed and modeled. Finally, an example is given to illustrate the effectiveness of the model.

1. Introduction

As a big country of agricultural products consumption in the world, the research on cold chain logistics of agricultural products has become a research hotspot in the field of logistics. Although China's cold chain logistics has developed rapidly in recent years, compared with western developed countries, China is still in the early stage of development. At present, the cold chain circulation rates of fruits, vegetables, meat and aquatic products in China are 22%, 34% and 41% respectively. The cold chain transportation rates are 35%, 57% and 69% respectively. But the cold chain circulation rate of vegetables and fruits in developed countries such as Japan and the United States has reached more than 95%, and the cold chain circulation rate of meat and poultry is almost 100%[1]. In China people spend 80% of the time distributing and transporting agricultural products from the origin to the hands of consumers. The loss rate is 25% - 30%[2]. Every year the losses only caused by vegetable decay exceed 100 billion , which is enough to meet the demand of hundreds of millions of people for agricultural products. Therefore, the research on cold chain logistics distribution of agricultural products can not only reduce logistics costs and improve the efficiency of distribution, but also maintain the freshness of agricultural products and reduce the loss rate of agricultural products.

2. The distribution mode of agricultural products cold chain logistics

The agricultural products involved in this paper mainly relate to vegetables, fruits, meat, eggs, poultry, aquatic products, flowers and other fresh agricultural products which are difficult to preserve[3]. At present, China's agricultural cold chain logistics distribution model mainly has four modes: self-distribution, outsourcing distribution, joint distribution, mixed distribution.

(1)Self-distribution mode

At present, agricultural products enterprises seldom apply this model because it requires agricultural products enterprises to build their own logistics network for distributing the agricultural products. In general this mode requires more capital and technology investment in the early stage, and is more suitable for enterprises with strong economic strength. By this mode enterprises have greater control over agricultural products and can ensure the accuracy and timely delivery[4].

(2)Outsourcing distribution mode

Outsourcing distribution mode, also known as the third party logistics distribution mode, can reduce the investment and management costs of agricultural products enterprises in cold chain logistics construction, and concentrate more energy on developing their core business. But it can not effectively control the distribution of agricultural products, real-time grasp the temperature of agricultural products, loss and so on. Moreover, the infrastructure of the third-party cold chain logistics in China is poor, and the cold chain technology and cold chain equipment can not meet the distribution requirements of agricultural products, resulting in the loss of agricultural products in the distribution process[5].

(3)Joint distribution mode

Joint distribution mode refers to the agricultural products enterprises finish distributing the products through joint ventures, joint investment, sharing information and joint use of logistics network. It reduces the logistics costs of enterprises, and makes up for the shortage of distribution resources and distribution functions of enterprises. But it requires a higher organization and collaboration capability among enterprises, otherwise the joint distribution will be difficult to carry out.

(4)mixed distribution mode

In the mixed distribution model, we can establish small-scale agricultural product distribution centers in the early stage to provide distribution services for small-scale customers within the city; while for large-scale customers outside the city, we can choose suitable logistics enterprises for outsourcing distribution. On the one hand, enterprises do not need to invest too much capital to ensure the supply of agricultural products; on the other hand, they can also realize the control of agricultural products and adjust the distribution strategies in time according to the real-time market changes.

3. The distribution strategies of agricultural products cold chain logistics

Aiming at the weakness of agricultural cold chain logistics infrastructure, low level of information technology and imperfect industry standards, etc. This paper puts forward the following development strategies of agricultural cold chain logistics distribution.

(1)Speed up the improvement of agricultural products cold chain logistics infrastructure

The loss of agricultural products in transportation is mainly due to the lack of cold chain system support in the distribution process of agricultural products, so it is necessary to increase investment in cold chain infrastructure. We should strengthen the management of refrigerated and insulated vehicles, vigorously promote the use of refrigerated containers, refrigerated van semi-trailers, low-temperature insulated containers and other standard transport units, and improve the supply and demand system of refrigerated containers. Finally we establish a cross-modal refrigerated container cycle sharing system and improve the utilization of refrigerated containers[6].

(2) Accelerate the informatization construction of agricultural products cold chain logistics

With the help of large data platform and information technology, we can improve the information communication of agricultural cold chain logistics and reduce the loss of agricultural products. We should establish the information platform of agricultural cold chain logistics, integrate the cold chain logistics resources, and enhance the informationization level of cold chain logistics business management. We also should promote the application of two-dimensional code, RFID, GPS, GIS and other Internet of Things technology in cold chain logistics distribution of agricultural products, and establish the whole process of cold chain circulation of agricultural products quality and safety system and information traceability system [7].

(3) Establish and improve the cold chain logistics standard system for agricultural products

In order to promote the healthy and rapid development of China's agricultural products cold chain logistics industry, reduce the loss of agricultural products, and ensure the quality of agricultural products. China should regulate the service, technology and energy consumption standards of all aspects of agricultural products cold chain logistics. We should lay down the standards of interconnection and interoperability of cold chain related enterprises, uniform coding rules and middleware interface standards of basic application platform, etc.

In addition, we also should increase the training of agricultural cold chain logistics personnel, accelerate the formulation of relevant laws and regulations on agricultural cold chain logistics. Through the above measures, we will jointly improve the problems faced by the development of cold chain logistics of agricultural products in China.

4.Optimization modeling of agricultural products cold chain logistics distribution path

In the cold chain logistics of agricultural products, the transportation cost is usually as high as 50%. One of the main reasons for the loss of the cold chain logistics of agricultural products is that the transportation and distribution links are not effectively linked up. We research on the distribution route of agricultural cold chain logistics. On the one hand, we can understand the various links of agricultural cold chain logistics distribution; on the other hand, we can also effectively control the distribution cost. Therefore the distribution route optimization modeling of agricultural products cold chain logistics is established in this paper.

4.1 Problem description

In the cold chain logistics of agricultural products the running time of agricultural products distribution vehicles is usually constrained with the perishable characteristics of agricultural products. In this paper, an optimization model of agricultural product transportation route based on time window is established. The time variable is introduced into the objective function. Cost factors are considered in modeling, and time constraints are transformed into cost functions. The model studied in this paper is a multi-demand point model for a single distribution center. The objective function of the model is to minimize the total cost. The total cost includes the fixed cost of the distribution vehicle, the transportation cost of the distribution vehicle, the penalty cost based on time, the cost of agricultural products damage, and the energy cost of refrigeration equipment.

4.2 Problem hypothesis

(1)The demand for agricultural products of each customer, the distance between customers and the distribution center and the distance between customers are known;

(2)Each customer has certain transport time requirements, and transportation must be carried out within the required time range;

(3)Each customer must accept the service of the distribution center, and only accept the service of a refrigerated vehicle;

(4)The agricultural products of the distribution center can meet all the needs of customers, and no shortage is allowed;

(5)The load of refrigerated trucks should not exceed the maximum vehicle load;

(6)The starting point and terminal point of refrigerated trucks are both distribution centers;

4.3 Parameters description

m :The number of refrigerated trucks; n :The number of customer points to be served; C_0 :The fixed costs of every refrigerated vehicle; C :The cost per unit distance of every refrigerated vehicle; d_{ij} :The distance from customer points i to j ; C_1 :The penalty coefficient for vehicle arrival in advance; C_2 :The penalty coefficient for delayed arrival of vehicles; ET_i :The earliest time allowed by customer points i ; LT_i :The latest time allowed by customer points i ; S_i :The arrival time of refrigerated vehicle at customer point i； P:Unit price of agricultural products； a_1:The damage coefficient of agricultural products in transit； a_2:The damage coefficient of agricultural products during loading and unloading； d_{ij}:The distance between customer point i and customer point j ； q_i:The demand for agricultural products at customer point i； δ:The ratio of energy consumption per unit time of refrigeration equipment when the vehicle k is driven from the distribution center to the customer i (/ hour)； ε:The ratio of energy consumption per unit time of refrigeration equipment when the vehicle k is serving the customer i (/ hour)； P_e： The price of energy consumption per unit time (yuan / hour)； v_{ik}:The handling efficiency of the vehicle k at the customer i (ton / hour)； T_k:The departure time of the vehicle k from distribution center； t_{ik}:The time when the vehicle k arrives the customer i； M_k:Maximum load capacity of each vehicle； L_k:Maximum driving distance of each vehicle；

$$X_{ijk} = \begin{cases} 1 & \text{If the refrigerated vehicle k goes from i to j;} \\ 0 & \text{Otherwise;} \end{cases}$$

$$\lambda_{ik} = \begin{cases} 1 & \text{The refrigerated vehicle K delivers to the customer point i;} \\ 0 & \text{Otherwise;} \end{cases}$$

4.4 Model establishment

（1）Fixed Cost

The fixed cost of distribution optimization of agricultural products cold chain logistics mainly includes the fixed loss of vehicles, the fixed loss of refrigeration equipment on vehicles, the driver's salary and so on.

$$FC = \sum_{k=1}^{m} \sum_{i=1}^{n} \sum_{j=1}^{n} C_0 X_{ijk} \qquad (1)$$

(2)Transportation Cost

The transportation cost of distribution optimization of agricultural products cold chain logistics refers to the cost incurred by refrigerated vehicles when they serve the customers due to fuel consumption and maintenance, which is closely related to the driving distance, speed and time of the vehicles.

$$TC = \sum_{k=1}^{m} \sum_{i=1}^{n} \sum_{j=1}^{n} C d_{ij} X_{ijk} \qquad (2)$$

(3)Penalty Cost

In this paper, we adopt the soft time window restriction rule, that is, if the refrigerated truck does not deliver the agricultural products to the customer within the specified time period, it will need to pay a certain penalty fee to make up for the loss of customers used for sales or inventory.

$$PC = C_1 \sum_{i=1}^{n} \max(ET_i - S_i, 0) + C_2 \sum_{i=1}^{n} \max(S_i - LT_i, 0) \qquad (3)$$

(4)Cargo Damage Cost

Agricultural products in the transport process have a extremely high requirement in temperature and environment because temperature rise and environmental changes will cause a certain degree of damage. The loss cost of distribution optimization of agricultural products cold chain logistics comes from two parts, one is the damage, which agricultural products decay and quality declines as the transportation time accumulates; the other is the loading and unloading cargo damage when the vehicles service the customers, which also includes the cargo damage, which the temperature rises when we frequently open the carriage door, resulting in the inflow of external hot air[8].

$$DC = P\sum_{k=1}^{m}\sum_{i=1}^{n}\lambda_{ik}\left(a_1 d_{ij} + a_2 q_i\right) \quad (4)$$

(5)Energy Resource Cost

In order to keep agricultural products in suitable temperature during transportation and service, we need energy consumption for refrigeration. The energy cost of agricultural products cold chain logistics includes two parts.The first part is the energy cost of refrigerated vehicles transportation from distribution center to customer point. The second part is the energy cost of loading and unloading goods to maintain the goods in a certain environment when they serve customers[9] .

$$EC = \sum_{k=1}^{m}\sum_{i=1}^{n}\lambda_{ik}P_e\left[\delta\left(t_{ik} - T_k\right) + \varepsilon\left(\frac{q_i}{v_{ik}}\right)\right] \quad (5)$$

The optimization model of agricultural products cold chain logistics distribution path based on Internet of things is as follows:

$$\min F = FC + TC + PC + DC + EC = \sum_{k=1}^{m}\sum_{i=1}^{n}\sum_{j=1}^{n}C_0X_{ijk} + \sum_{k=1}^{m}\sum_{i=1}^{n}\sum_{j=1}^{n}Cd_{ij}X_{ijk} + C_1\sum_{i=1}^{n}\max(ET_i - S_i, 0)$$

$$+C_2\sum_{i=1}^{n}\max\left(S_i - LT_i, 0\right) + P\sum_{k=1}^{m}\sum_{i=1}^{n}\lambda_{ik}\left(a_1d_{ij} + a_2q_i\right) + \sum_{k=1}^{m}\sum_{i=1}^{n}\lambda_{ik}P_e\left[\delta\left(t_{ik} - T_k\right) + \varepsilon\left(\frac{q_i}{v_{ik}}\right)\right] \quad (6)$$

Subject to :

$$\sum_{i=1}^{n}\sum_{k=1}^{m}\lambda_{ik}q_i \le M_k \quad (7) \qquad \sum_{i=1}^{n}\sum_{j=1}^{n}X_{ijk}d_{ij} \le L_k \qquad k = 1,2.......m \quad (8)$$

$$ET_i \le S_i \le LT_i \quad i = 1,2,3......n \quad (9) \qquad \sum_{k=1}^{m}\lambda_{ik} = 1 \quad i = 1,2,3......n \quad (10)$$

$$\sum_{i=1}^{n}X_{ijk} = \lambda_{jk} \qquad j = 1,2......n \qquad k = 1,2.......m \quad (11)$$

$$\sum_{j=1}^{n}X_{ijk} = \lambda_{ik} \qquad j = 1,2......n \qquad k = 1,2.......m \quad (12)$$

$$X_{ijk} = \begin{cases} 1 & \text{If the refrigerated vehicle k goes from i to j;} \\ 0 & \text{Otherwise;} \end{cases} \quad i, j = 1,2......n \quad k = 1,2.......m \quad (13)$$

$$\lambda_{ik} = \begin{cases} 1 & \text{The refrigerated vehicle K delivers to the customer point i;} \\ 0 & \text{Otherwise;} \end{cases} \quad i = 1,2......n \quad k = 1,2.......m \quad (14)$$

In this model, the objective(6) is to minimize the operation costs including the fixed cost, transportation cost, penalty cost, damage cost and energy cost of refrigerated vehicles; Constrain(7)indicates that the total demand on each distribution route can not exceed the maximum load capacity of each vehicle; Constrain（8）shows the distance traveled by refrigerated vehicles should not exceed their own distance constraints; Constrain（9）indicates that refrigerated trucks deliver within the specified time window; Constrain（10）、（11）、（12）make sure that each customer can only accept one refrigerated delivery vehicle and that the refrigerated vehicle entering and leaving a certain customer point is the same vehicle.; Constrain（13）、（14）are the values of the variables X_{ijk} and λ_{ik} .

4.5 Example analysis

To verify the effectiveness of the algorithm, a vegetable distribution center A in Shouguang, Shandong Province, was taken as an example. It distributes radishes to seven customers around it. The maximum transport capacity of refrigerated distribution vehicle is $M_k = 7t$. The maximum running distance is $L_k = 500km$. The fixed cost of starting each refrigerator vehicle is $C_0 = 80$yuan . The unit distance cost per refrigerated vehicle is $C = 3yuan/km$. The penalty coefficient for early arrival of vehicles is

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$C_1 = 2\text{yuan}/\min$. The penalty coefficient for late arrival of vehicles is $C_2 = 3\text{yuan}/\min$. The loss coefficient in transit is $a_1 = 0.02$. The cargo loss coefficient during loading and unloading is $a_2 = 0.03$. The price of radishes is $P = 200\text{yuan/t}$. The energy consumption cost per unit time is $P_e = 4\text{yuan/hour}$. The handling efficiency of refrigerated vehicles is $V_{ik} = 4t/\text{hour}$. When refrigerated vehicles run from distribution centers to customers, the proportion of energy consumption of refrigerating equipment per unit time is $\delta = 5/\text{hour}$. The proportion of energy consumption of refrigeration equipment per unit time when refrigerated vehicles start serving customers' points is $\varepsilon = 8/\text{hour}$. The distance between distribution center A and each customer point and the demand of each customer point are shown in Table 1. The time window of each customer point limits the service time as shown in Table 2.

Table 1.The distribution distance and the demand of each customer point

Demand point	0	1	2	3	4	5	6	7	Requirements
0	0	8	14	15	10	9	11	19	
1	8	0	7	12	12	15	12	15	0. 5
2	14	7	0	18	13	14	13	10	0. 65
3	15	12	18	0	9	8	10	11	0. 3
4	10	12	13	9	0	13	7	13	0. 25
5	9	15	14	8	13	0	14	12	0. 5
6	11	12	13	10	7	14	0	15	0. 55
7	19	15	10	11	13	12	15	0	0. 4

The total cost of the optimal solution is 5432.3 yuan and the optimal distribution path is 0-1-2-0; 0-5-4-6-3-7-0 by using LINGO 14 in the running environment of Intel(R) Core(TM) 2Duo 3.3GHz,4GB.

Table 2. The time window constraints and service time of each customer point

Distribution point	Time window constraints	Service hours / hours
1	04:00-05:00	0. 15
2	04:00-05:00	0. 2
3	06:00-07:00	0. 1
4	05:00-06:00	0. 08
5	05:00-06:00	0. 1
6	05:00-07:00	0. 2
7	07:00-08:00	0. 15

5.Conclusion

This paper studies the main distribution mode of agricultural products cold chain logistics, and puts forward improvement measures for the distribution problem. This paper focuses on the optimization of agricultural product distribution routing problem, and establishes an agricultural product transportation routing optimization model with time window, and verifies the feasibility of the model with an

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example. The research content of this paper has important guiding significance for cold chain logistics distribution of agricultural products.

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