Optimization of Fresh Food Cold Chain Logistics and Distribution Paths

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Abstract. The adoption of the cold chain has led many companies to rely on specialization, identifying the transport of temperature-sensitive products as a niche market with significant macroeconomic implications for countries. This paper first describes the current situation of fresh food distribution route selection in N city and points out the problems. Then several distribution route optimization methods are analyzed and compared. Next, the method of route optimization model building is proposed, and the implementation process of route optimization is described. Finally, the distribution route optimization is summarized through the result analysis based on the saving mileage method.

Keywords: cold chain logistics; distribution path; path optimization

1 INTRODUCTION

With the improvement of people's living standards, the demand for fresh food continues to increase, driving the rapid development of fresh cold chain logistics. However, fresh food must be transported under appropriate temperature and humidity conditions to maintain its freshness and safety[1]. Therefore, optimizing the cold chain logistics distribution path of fresh food has become an urgent problem to be solved.

At present, research on logistics distribution path optimization both domestically and internationally uses methods such as ant colony algorithm[2], simulated annealing algorithm[3], genetic algorithm[4], particle swarm algorithm[5], and mileage saving method for optimization. Compared with other methods, the mileage saving method is relatively simple and feasible, does not require too much initial data, and has a relatively high optimization efficiency[6].Therefore, the main content of this article is to improve the delivery efficiency of fresh food, reduce delivery costs, and improve customer satisfaction by using the mileage saving method to optimize the fresh food delivery path in N cities. Solve the problems in the current fresh food distribution system in N city and provide some reference for relevant enterprises.

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2 CURRENT STATUS OF EXISTING DISTRIBUTION ROUTE OPTIONS FOR FRESH PRODUCE IN N CITY

The fresh food distribution in N city mainly adopts a logistics distribution model that combines self operated logistics and third-party logistics, with self operated logistics as the main mode. The proportion of self operated logistics is about 80%. The supply process of fresh food in N city is shown in Figure 1.

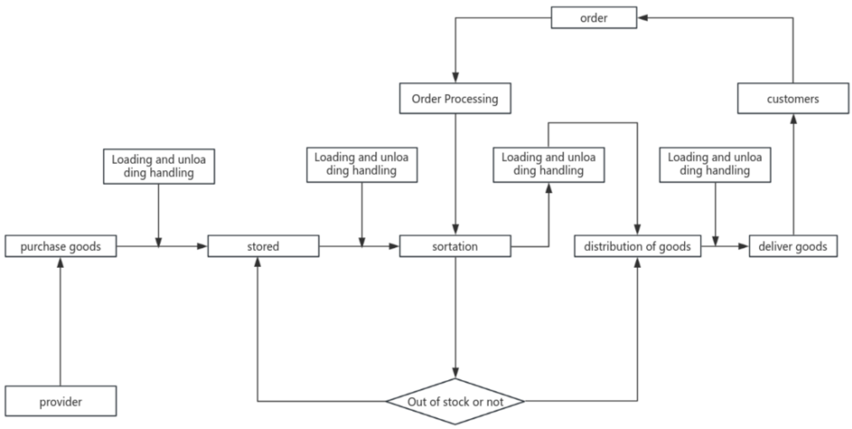

Fig. 1. Flowchart of fresh food supply in N city

At present, N City Fresh is vigorously improving its logistics and distribution capabilities. However, due to the use of a logistics and distribution model that combines self operated and third-party logistics, N City Fresh has strong flexibility in distribution methods and lacks careful and scientific planning of distribution processes and routes. Due to factors such as staff quality and system hardware, the delivery information system in N city is insufficient and information transmission is not smooth, resulting in enterprises not timely obtaining the latest information to adjust delivery routes, delivery vehicles, and delivery times in logistics distribution[7]. Secondly, N city's fresh food only considers the price factors of land or rent when selecting the location of the distribution center, while ignoring the relationship between the distribution center and various stores, which leads to high logistics and distribution costs in the actual distribution process. Secondly, when selecting logistics distribution routes, N city did not consider matching vehicles with suitable cargo carrying capacity. If the carrying capacity is not enough, it cannot deliver all the goods with the minimum number of trips, and cannot choose a reasonable distribution route, which increases logistics costs and also affects distribution efficiency.

3 DELIVERY ROUTE OPTIMIZATION

3.1 Route Optimization Modeling

(1) Problem Description: Vehicles departing from the fresh food distribution center P in N city deliver fresh food to the stores on various routes. In order to minimize vehicle scheduling, each store on the route is delivered by a insulated refrigerated truck, and the delivery volume of each store should be less than the capacity of the delivery vehicle. The goal of optimizing delivery routes is to find the optimal vehicle delivery route on the basis of completing delivery tasks, so as to minimize the delivery vehicles and total delivery mileage S.

(2) Symbol Description：

P: N City Fresh Food Distribution Center;

n: indicates the number of stores;

T: indicates the company's rated loading capacity per vehicle;

L: denotes the total mileage traveled by the vehicle each time it departs from the distribution center;；

m: denotes the number of distribution vehicles that can be dispatched;

Q_i: denotes the order demand of store store (i=1,2$\cdots n$);

d_{ij}: denotes the distance from store i to store j ((i,j=N1,N2$\cdots N$22), where i or j is equal to 0, the point is the fresh food distribution center of city N.

n_s: indicates the number of store outlets that the distribution center's distribution vehicle needs to reach for this distribution (s=1， 2$\cdots n$ when n=0, it means that the vehicle is not involved in the distribution);

x_{ij}: i has a value of 0 or 1, with 1 indicating that the delivery vehicle travels from store i to store j and 0 indicating that the delivery vehicle travels from store j to store i;

y_{is}: The value of y is either 0 or 1, with 1 indicating that the delivery of goods in store i is completed by s and 0 indicating that the delivery of goods in store i is not completed by s.

x_{ijs}: The value of i is 0 or 1, where 1 indicates that the delivery vehicle is traveling from store i to store j, and 0 indicates that the delivery vehicle is traveling from store j to store i.

(3) Modeling Constraints.

Fresh food in N city is mainly distributed from the distribution center to each store, and to achieve the minimum total mileage (S), according to the above conditional variables, to establish the model of distribution route optimization:

$$\sum_{s=1}^{m} y_t = \{ \begin{matrix} 1 & i = 1,2,3 \cdots n \\ m & i = 0 \end{matrix} \tag{1}$$

$$\sum_{s=1}^{n} y_t = \{ \begin{matrix} 1 & i = 1,2,3 \cdots n \\ m & i = 0 \end{matrix} \tag{2}$$

$$\sum_{i=0}^{n} \sum_{j=0}^{n} di_j x_{ij} \leq L \tag{3}$$

$$\sum_{i=1}^{n} x_{ij} = y_{jj}; j = 0,1,2..n \tag{4}$$

$$\sum_{j=1}^{n} x_{ijs} = y_{is} \tag{5}$$

$$minS = \sum_{i=0}^{n} \sum_{j=0}^{n} \sum_{j=0}^{m} d_j^m x_{ij} \tag{6}$$

In the above model for distribution route optimization:

Equation (1) indicates that the vehicles required for distribution are m vehicles and each store on the distribution route can only be completed by one of the m vehicles;

Equation (2) indicates that for each distribution route, the total demand cannot exceed the vehicle loading capacity;

Eq. (3) The total number of distribution miles for each distribution route cannot exceed the total number of miles the vehicle can travel;

Eq. (4) A store can only be delivered by one vehicle during each delivery operation;

Equation (5) indicates that only one vehicle leaves each store in a single delivery;

Equation (6) represents the objective function of the minimum mileage value sought.

3.2 Implementation of Route Optimization Based on Mileage Saving Method

When collecting data, it was found that the location of fresh food distribution centers in many regions is not scientific, only considering factors such as land price or rent, while ignoring whether the distance between the distribution center and each store is reasonable. The location of the fresh food distribution center in N city is more reasonable compared to distribution centers in other regions[8]. Therefore, choose the following fresh produce from N cities as an example. A data survey conducted on N city revealed that there are 20 distribution outlets in N city area. The distribution data of 10 representative fresh stores in N city were selected as the research basis to verify the effectiveness of the model. It is known that the logistics distribution center P and 10 stores adopt a one-on-one round-trip delivery mode from the logistics distribution center to the supermarket. 10 stores will be numbered from A to J, and the shortest delivery distance between distribution center P and each store, as well as the delivery distance between stores, will be determined. Based on the location of the stores, a simplified route map will be drawn between distribution center P and the 10 stores. It is known that the fresh food distribution center in N city has spare 2-ton and 4-ton insulated refrigerated trucks. Due to customer time requirements and logistics costs, the cold chain distribution vehicles cannot travel more than 45km in one round trip. The distance between the distribution center P and each store, as well as the distance between each store, are shown in Figure 2. The number next to the connection line represents the kilometer of the shortest route between the two demand points.

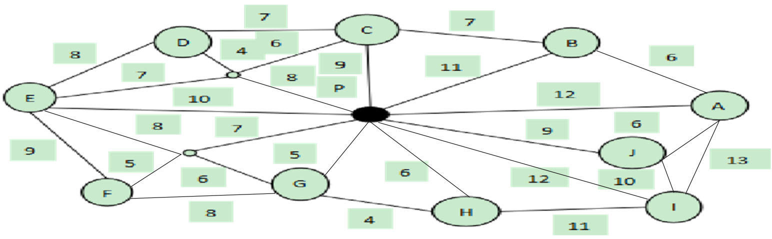

Fig. 2. Schematic of the Mileage Savings Method

Mileage Savings Method Calculation Formula:

$$D(i,j)=A_{pi}+A_{pj}-A_{ij} \tag{7}$$

where A pi denotes the distance from distribution center P to store i, Apj denotes the distance from distribution center P to store j, and A ij denotes the distance from store i directly to store[9].

Total Miles Traveled Calculation Formula:

$$\text{Total mileage}-\sum_{k=1}^{n} A_{pk} \tag{8}$$

where n denotes the number of distribution points and A_{pk} denotes the distance from distribution center P to the kth distribution point.

Based on the actual shortest distance traveled from point P to each demand point, the shortest path between each demand point is calculated. Using the formula of the mileage saving method D(i,j)=A pi+Apj − A ij(i=A, B,..., J; j=A, B,..., J) can be used to calculate the corresponding mileage saving for the distribution center P for any two of the 10 stores A, B, C, D, E, F, G, H, I, and J, respectively, as shown in figure 2.

The leftmost column represents the demand of each store. First of all, we need to calculate the mileage savings between each demand point according to the mileage savings formula and sort them in descending order, and finally find out the largest mileage savings of 17, connect AB, at this time, the row where J is there is a 15 at the intersection of A and B, so J and A are connected. At this time, the row where C is located has a 15 at the intersection of B and C, implying that B and C are connected, and finally construct the first loop: P-J-A-B-C-P. Getting its distribution mileage is 37km, less than 45km, and the sum of demand (2.0+1.8+3.5+2.2=9.5) is less than the carrying capacity of 10t.

Table 1. Mileage Savings

Demand （economics）	P										
1.8		A									
3.5		17	B								
2.2		8	13	C							
0.9		4	9	14	D						
2.8		0	0	6	14	E					
3.0		0	0	0	7	13	F				
1.3		0	0	0	0	1	9	G			
2.4		0	0	0	0	0	6	7	H		
2.2		9	3	2	0	0	1	2	7	I	
2.0		15	8	0	0	0	0	0	0	11	J

As shown in table 1, since the vehicle capacity has not yet reached the upper limit, this loop can be combined with one more point, but since the demand of the other stores is all greater than 0.5 t, it will not be added again. At this point the first optimized distribution route is obtained: P-J-A-B-C-P.

The four demand points J, A, B and C, which have already formed a loop, are eliminated, and then the same steps are combined with the weight limit of the vehicle and the round-trip mileage restriction, and the mileage-saving method is used to further optimize the distribution routes to obtain the optimal distribution route scheme, and so on, until the completion of the distribution task.

Before the optimization of distribution routes, the N City Fresh Food Distribution Center to stores basically used a one-to-one approach, or according to the order volume of each store to take a carpooling approach, and did not take into account the problem of planning routes.

4 ANALYSIS OF THE RESULTS OF DISTRIBUTION ROUTE OPTIMIZATION BASED ON THE MILEAGE SAVING METHOD

By analyzing the data of the company's existing distribution routes and the order quantity of each supermarket, based on the company's existing vehicles, the number of vehicles needed to complete the distribution quantity of supermarkets in each region in the initial route is calculated. Through the statistics of each data. Comparison before and after optimization from four aspects, respectively, the total mileage, the load capacity of the vehicle, the number of vehicles needed, the average loading rate for comparison of data before and after optimization. The analysis of the effect of the company's distribution plan before optimization is shown in Table 2, and the effect of the company's distribution plan after optimization is shown in Table3.

Table 2. Distribution effect analysis before optimization

serial number	Distribution routes	mileage	dead weight	Number of vehicles required	loading factor
Route 1	P-A-B-C-D-P	18.9km	1.24t	1 vehicle with a capacity of 1.5 tons	82.6%
Route 2	P-E-F-G-P	32.1km km	2.34t	1 vehicle with a capacity of 2.5 tons	93.6%
Thread 3	P-H-I-J-P	24.6km	1.81t	1 vehicle with a capacity of 2.5 tons	72.4%

Table 3. Analysis of distribution effect after optimization

serial number	Optimization of routes	mileage	dead weight	Number of vehicles required	loading factor
Route 1	P-E-A-B-D-C-F-P	36.5km	2.5t	1 x 2.5 ton vehicle	100%
Route 2	P-H-G-J-I-P	28.4km	2.44t	1 x 2.5 ton vehicle	97.6%

By comparing the optimized effect with the initial delivery effect of the company, the delivery distance has increased from the initial 75.6km to 64.9km, a decrease of 8.7 kilometers; The average loading rate increased from the initial 87.06% to 92.44%, an increase of 5.38%. By re planning the delivery route, the utilization rate of vehicles and delivery efficiency have been improved.

5 ALGORITHMIC IMPROVEMENTS

In the face of greater demand, more distribution stores, and more complex constraints, simply using mileage savings to optimize distribution routes is a huge amount of data and high complexity. In this case, tools can be used to program the data and monitor the real-time location of the vehicles, so that an alert is sent to the distribution center when the vehicles do not follow the established routes, and penalties are imposed on the drivers in time to ensure that the produce arrives at the stores in a fresh condition[10]. For the delivery time problem can be added to the time window and time penalty cost, so that the driver in strict accordance with the prescribed route and speed driving, not in accordance with the prescribed time to arrive at the store driver, according to the delay time for the appropriate penalties.

6 CONCLUSION

In this paper, the current situation and problems of fresh food cold chain logistics and distribution are studied, and a distribution path optimization method based on mileage saving method is proposed. The optimization model based on the number of distribution target points and the location of distribution center is established by collecting and organizing the data of fresh food distribution center and each store in N city. Through the optimization model, the optimal distribution path scheme was obtained, and the distribution effect before and after optimization was compared. Through the analysis of the results, the following conclusions were drawn: the optimized distribution path can improve the utilization rate of vehicles, reduce the distribution cost, and save the company's resources. At the same time, the optimization of the distribution path can improve the distribution efficiency, shorten the distribution time, and improve the customer satisfaction. In addition, this study proposes improvements to the algorithm to ensure that the goods are delivered to the stores in a fresh state by monitoring the vehicle's location and travel route in real time and penalizing violations in a timely manner. The results of this study are of great significance to the subsequent research and practice, which can provide scientific reference for the inventory preparation of enterprises, and provide a reference for improving the efficiency of logistics and distribution and reducing costs.At present, the cold chain logistics industry lacks unified standards and norms, resulting in market chaos and unfair competition. In order to regulate the market and promote the healthy development of the industry, it is necessary to formulate and improve cold chain logistics related standards and norms, and strengthen supervision and law enforcement.

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