Research on Optimization of Food Cold Chain Logistics Distribution Route Based on Internet of Things

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Abstract. with the Rapid Development of Social Economy and the Continuous Improvement of People's Living Standards, People Pay More and More Attention to the Quality of Life, and Put Forward Higher Requirements for the Quality of Products, Especially the Quality of Cold Chain Products. as a Guarantee of the Quality of Cold Chain Products, Cold Chain Distribution Has Received the Attention of Enterprises. Based on the Technology of Internet of Things, This Paper Establishes a Path Optimization Model for Cold Chain Logistics by Adding Refrigeration Cost and Cargo Loss Cost to the Traditional Path Optimization Model. the Experimental Results Show That the Real-Time Route Optimization Method for Refrigerated Vehicles under the Internet of Things Environment is Effective. the Method Has Practical Significance in Achieving Fine Control of Cold Chain Logistics Distribution Costs and Improving Distribution Service Efficiency.

1. Introduction
With the Rapid Development of Chinese Logistics Industry and the Continuous Improvement of the National Economic Level, the Cold Chain Logistics Industry, an Important Branch of the Logistics Industry, Has Attracted More and More Attention. Relevant Data Show That in the Distribution Process of Chinese Cold Chain Logistics, the Loss of Fruits is 25%, the Loss of Vegetables is 30%, the Loss of Meat and Aquatic Products is 12% and 15%, Ranking First in the World. Its Loss Can Meet the Basic Needs of 200 Million People, Resulting in Economic Losses of 100 Million Yuan Per Year [1]. This Forces the Refrigeration and Preservation Technology to Continuously Improve to Meet People's Needs, Thus Driving the Development of Cold Chain Logistics. for This Reason, the State Has Also Given Policy Support and Financial Support in Cold Chain Logistics in Recent Years. the Ministry of Commerce Has Given Policy Support to Enterprises in Cold Chain Joint Distribution and Energy-Saving Refrigerator. in the Existing Research on the Vehicle Routing Problem of Distribution, the Research on the Special Vehicle Routing Problem of Cold Chain Logistics is Relatively Few. in This Paper, the Multi-Source Mass Information in the Internet of Things is Used to Study the Real-Time Vehicle Routing Optimization Problem of Cold Chain Logistics Distribution.

2. Application Mode of Cold Chain Logistics Distribution in Internet of Things
The internet of things center has a large amount of multi-source information such as traffic information, weather information, road section information, geographic information, etc. using this information, it is established on the internet of things cold chain logistics distribution vehicle route optimization service platform (its architecture diagram is shown in fig. 1). Cold fresh food is treated
after being received, and the content of temperature, humidity, oxygen and the like meet the condition that the food is kept fresh, i.e. the food is always kept in a controllable temperature environment where the food is kept fresh [3]. The quality of cold chain goods can only be guaranteed in a refrigerated or frozen environment, which means that the temperature of goods must be strictly controlled in a series of logistics processes such as procurement, processing, distribution and sales, so as to maintain the quality of goods and reduce logistics losses. Through imitation, crossover and other ways, the correlation solutions of different populations are continuously evolved, and the optimal value is found out, so that the optimal individual is found out. Among them, coding and setting initial population genetic operation are the main contents.

**Figure 1** Based on The Internet of Things Cold Chain Logistics Distribution Vehicle Routing Optimization Architecture Diagram

The bottom resource layer in fig. 1 includes various servers, networks and other hardware equipment, as well as various distributed application resources outside the cold chain logistics system, such as transportation, weather and other systems. Through virtualization technology, storage virtualization, network virtualization and service virtualization form a huge resource pool. Therefore, the distribution center should be a modern circulation facility that can supply or sell at a high level. It should be the material and technical basis for the distribution activities on the e-commerce platform at the present stage, which can not only reduce the circulation links and transaction times of goods, but also, more importantly, generate economies of scale [4]. Users can access the application service layer anytime and anywhere through the network to access the dynamic path optimization service of the cold chain logistics distribution vehicles, and the access service platform can be Web service interface, browser, desktop application program, mobile terminal, etc. Secondly, the random generation of initial population can generate multiple initial populations randomly when optimizing the path. Thirdly, the determination of fitness function. This function can evaluate the advantages and disadvantages of individual solutions and determine the probability of the next generation population. Therefore, the cold chain logistics must be operated in a timely and stable manner, and all logistics links must be closely connected and coordinated with each other with high efficiency, so as to not only save logistics time, but also prevent outside hot air from invading the goods and affecting the quality.

The cold chain logistics distribution vehicle route optimization service platform based on the Internet of Things can effectively solve the demand for real-time information in the real-time route optimization of cold chain logistics distribution vehicles. Initialize all parameters in the algorithm; Secondly, all particles in the population are evaluated, and the evaluation process is based on the fitness function set in advance. According to the different situations, there are certain restrictions on the relevant aspects of distribution, which generally include: meeting the requirements of customers on the types and quantities of goods; Providing services within the time range preset by the customer; Considering the actual requirements such as the nature and quantity of goods to be distributed in cold chain logistics, it is very necessary to select a suitable number of refrigerated distribution vehicles and plan a suitable transportation route for efficient distribution [5]. Using the computing resources of the cloud center, the effective real-time optimization path can be quickly calculated in an effective time, so as to improve the logistics service efficiency and make the distribution cost of cold chain logistics achieve fine management.
3. Distribution Vehicle Routing Optimization Model Based on Internet of Things

3.1 Description of Vehicle Distribution Route Problem in Cold Chain Logistics

According to fig. 1, the structure of vehicle routing optimization for cold chain logistics distribution is constructed. The ultimate goal of the optimization model is to optimize the total vehicle travel time and distribution cost. Logistics distribution center is the place where goods are stored, packaged, distributed and distributed. The types of goods stored in the distribution center are not limited, and they can be single types or multiple types. Under certain parameters such as time and cost, the feasible solution relative to the optimal solution is searched out, so the parameter setting has an important influence on the calculation of the algorithm. The total demand of each customer shall not exceed the maximum loading capacity of the vehicle; The total length of each delivery and transportation path cannot exceed the maximum distance traveled by the vehicle at one delivery. It is a tool needed for cold chain logistics goods distribution [6]. In general, when selecting a delivery vehicle, the type of vehicle, the rated load of the vehicle, the volume of the vehicle, the maximum travel distance of the vehicle, the devices equipped with the vehicle, etc. are usually considered. During the delivery process, the temperature and humidity in the compartment must be within a certain range, otherwise the customer's satisfaction with the product will be affected. The carrying capacity of the transport vehicle is required to be able to bear the maximum carrying capacity of the transported goods, and the longest driving distance is the longest distance that the transport vehicle can travel for a delivery of goods. In the cold chain logistics, refrigerated trucks are essential in cold chain distribution. Under normal circumstances, the transport vehicle shall return to the distribution center as required after completing the distribution.

3.2 Vehicle Routing Optimization Model for Cold Chain Logistics Distribution

According to the integrity and variability of logistics information, vehicle routing problem (VRP) is divided into static vehicle routing problem and dynamic vehicle routing problem. Static VRP means that the information required for logistics distribution is known and unchangeable in advance, while dynamic VRP means that the information required for logistics distribution is not completely known in advance, or the information will be updated continuously during the distribution process. The analysis of the route optimization model for refrigerated vehicles includes the analysis of distribution time and cost. In the framework, traffic information cloud is accessed through a unified interface to obtain traffic information of the vehicle location for distribution time analysis. The comprehensive cost analysis of distribution includes the analysis of fixed cost, transportation cost, cargo damage cost, energy cost and penalty cost [7].

3.2.1 Distribution Time Analysis

Through obtaining the real-time traffic information of the road section where the vehicle is traveling from the real-time traffic information of the cloud center, the distribution time is calculated. Average vehicle speed $V_i$, lane width $LR_i$ and tonnage of vehicles allowed to pass at the section where the vehicle is located. In the process of distribution, demand may change dynamically with time. The latter refers to the delivery arrival time agreed in advance between the customer and the delivery party. Generally, there are upper and lower time limits, which reflect the delivery service quality to a certain extent. It can be a specific person, also can be each big shopping mall, supermarket, convenience store, etc. The location of the customer, as well as the customer's demand and the requirements for the delivery time, all affect the formulation of the distribution plan by the distribution center. Only when the lane width $LL_i$ is greater than the vehicle width $L$ and the tonnage $QR_i$ of the passing vehicle is greater than the total tonnage $Q$ of the vehicle, the path $i$ may be selected. Therefore, the total travel time $T$ of the vehicle to complete the distribution is shown in formula (1) [8].

$$ T = \sum_{j=1}^{N} t_{(j,j-1)} $$ (1)
3.2.2 Analysis of Distribution Comprehensive Cost

The fixed cost $C_1$ of transportation vehicles includes the wages of drivers and supercargos and the cost of vehicle wear and tear, and $C_1=\text{f}$ is constant. This kind of problem is quite complicated. It covers three factors at the same time: dynamic changes in demand, time window constraints and time dependence. The three factors influence each other. The closer to the reality, the more difficult it is to solve. For example, the customer's demand for delivery time, the customer's demand for type and quantity of goods, the customer's location, the customer's demand, the number of vehicles served by the customer, as well as the traffic flow on some traffic routes and the requirements for the quantity of vehicles carried, etc. The transportation cost $C_2$ of the vehicle includes the fuel consumption, repair and maintenance cost of the vehicle, which is directly proportional to the mileage traveled by the vehicle, as shown in formula (2).

$$c_2 = \sum_{i=0}^{k} \sum_{j=0}^{k} c_{ij} x_{ij}$$ (2)

$c_{ij}$ is the transportation cost of the refrigerated truck on the section $(i, j)$, and $c_{ij} = c_{ji}$, where $x_{ij}$ is represented by 0,1, $x_{ij} = 1$ means that the refrigerated truck has passed the section $(i, j)$, otherwise $x_{ij} = 0$.

The damage cost of the cold collection includes three cases: first, the cargo damage due to the length of the transportation time and the unloading time; the second is a discrete time-varying model, which is suitable for the case where the variable in the system is a discrete distribution function of time. Generally, the difference equation To describe; the third is the combination of the first two, continuous-discrete time-varying hybrid model, according to the actual situation, the first two methods are combined. The transportation network is composed of the connection between the distribution center and the customer, and between the customer and the customer. Some transportation networks, especially the road transportation network, will limit the weight of the transportation line transport vehicles, which also affects the distribution center's formulation of the distribution plan. The elements of. The vehicle runs at a uniform speed $v$; the demand and location of each customer are known, and only one vehicle can complete the distribution demand, and all customers are served; due to the road condition, the cold storage is damaged. The damage cost of the cold storage is represented by $C_3$, as shown in formula (3).

$$C_3 r \sum_{i=0}^{k} \lambda_j (\alpha_1 t_{ij} + \alpha_2 \beta_j + \alpha_3 s_{ij})$$ (3)

Among them, $r$ represents the unit price of the product, $\lambda_j$ is 0, 1 variable, $\lambda_j = 1$ indicates that the refrigerated truck serves customer $j$, otherwise $\lambda_j = 0$; $\alpha_1$ is the percentage of damage during the product transportation process; $t_{ij}$ indicates the customer from $i$ to customer $j$. Time; $\alpha_2$ indicates the proportion of products damaged during the door opening and loading / unloading process; $\beta_j$ is the quantity of goods of customer $j$; $\alpha_3$ is the proportion of product damage caused during the transportation of the vehicle; $s_{ij}$ is the mileage between customer $i$ and customer $j$.

The basic indexes of reliability include reliability, failure rate, failure rate, repair rate, average life, etc. Reliability is a mathematical measure of reliability, a quantitative form and a probability value. Reliability is a distribution function of time, generally expressed by $R(t)$, if the specified time limit is $t$, the reliability can be expressed as [9]:

$$0 \leq R(t) \leq 1.$$ (4)

General cold chain logistics distribution system will have one or more distribution centers. Only one cold chain logistics distribution center is called single distribution center, and the number of distribution centers used by the distribution system is only one. If the distribution system uses more
than one distribution center, it is called multiple distribution centers. Because in real life, the number of direct denial of service customers is still relatively small. If you want to improve the reliability of delivery service arrival time, you can achieve it by increasing the penalty fee agreed by both parties.

The energy cost of refrigerated trucks is mainly the cost of consuming refrigerant. Refrigerant consumption is related to the heat transfer coefficient of the carriage, the temperature inside the carriage, the area inside and outside the carriage, and the temperature outside. The calculation formula of refrigerant consumption is shown in formula (5).

\[ G = a \times b \times S \times \Delta t \]  

(5)

Where \( G \) is the refrigerant consumption, \( a \) is a constant, \( b \) is the heat transfer coefficient, \( S \) is the average surface area inside and outside the vehicle, and \( \Delta t \) is the temperature difference between the inside and outside of the vehicle. The ideal solution, looking for the solution closest to the ideal point, can be seen as a method of target search based on the distance function. Since ideal points are usually not available, compromise must be made. The compromise method is to minimize the distance function. The number of vehicles distributed by the distribution center is more than one, the weight of the goods loaded by the distribution vehicle is greater than the vehicle's load capacity, and the vehicle is in a fully loaded state during operation, but cannot exceed the specified full load percentage. Then the cooling cost of the vehicle in operation is expressed by \( G_i \), as shown in equation (5).

\[ G_i = \sum_{j=1}^{n} r_{ij} \times G \times t_{ij} \times x_{ij} \]  

(6)

Where \( r_{ij} \) is the price of the refrigerant, \( t_{ij} \) is the time from customer \( i \) to customer \( j \), and \( x_{ij} \) is a variable of 0,1.

In the process of vehicle routing problem development, combined with the actual distribution situation, there will be a situation that some customers request service time, that is, the constraint of service time window appears in the vehicle routing problem. The model aims at minimizing the total cost of the logistics system, which includes transportation cost, refrigeration cost and penalty cost caused by exceeding the customer's demand time. Cold chain logistics distribution products require low temperature refrigeration all the time during the distribution process, resulting in refrigeration costs. The refrigeration cost includes the transportation refrigeration cost and the loading and unloading refrigeration cost. When the car door is opened, the outside air directly convects with the air in the refrigerated car, resulting in the alternation of cold and heat. Therefore, to calculate the refrigeration cost of opening the car door, only the cost of refrigerant consumed by the heat exchange of the car door needs to be calculated, which is expressed by \( C_{s} \), as shown in equation (7).

\[ C_{s} = \sum_{i=1}^{n} r_{i} \times a \times S \times \Delta t \times t_{i} \]  

(7)

Where \( t_{i} \) is the time the vehicle stays and waits at customer \( i \), and \( S \) is the area of the door.

In the vehicle routing problem with time windows, according to the actual situation, if there are some unexpected situations in the vehicle distribution process, the vehicle may not be able to deliver the goods within the specified time. In strict accordance with the time requirements, the customer satisfaction is high, but the distributor needs to pay a great price and the distribution cost will increase a lot. During the distribution process of frozen and refrigerated products, many uncontrollable factors such as temperature will lead to product damage, thus resulting in the cost of goods damage. The cost of goods damage is mainly caused by the following two situations: one is that the cumulative delivery time causes the products to be damaged; Another situation is that loading and unloading goods and opening the refrigerated doors lead to the destruction of products, thus resulting in the cost of goods damage. After receiving orders from each point of sale, the distribution center needs to make the optimal distribution plan as soon as possible to meet the needs of all customer points within the effective time limit. If the goods are delivered to the customer in other time periods, it will bring unnecessary troubles to the customer. If the goods are delivered in non-agreed time periods, it will
indirectly lead to the decrease of customer satisfaction. If the goods fail to arrive on time, a certain fine will be imposed on the logistics distribution enterprise. Then the penalty cost due to not delivering the product to the customer point within the time window is expressed by $C_6$, as shown in formula (8) [10].

$$C_6 = \omega_1 \sum_{j=1}^{\infty} \max[(a_j - s_j - t_j), 0] + \omega_2 \sum_{j=1}^{\infty} \max[(s_j - b_j), 0]$$

Among them, $\omega_1$ and $\omega_2$ respectively represent the cost of loss caused by refrigerated vehicles unloading the cargo earlier and later than the time window. $s_j$ is the time when the vehicle arrives at customer $j$, and $t_j$ is the time the vehicle waits at customer $j$.

From different levels of customer value, the beneficiaries are different. First of all, from the enterprise level, customer value is the economic and social benefits brought to the enterprise by the customer's purchase of certain goods or services of the enterprise, and is the value brought to the enterprise by the customer's behavior. Goods required by customers on the same route can only be delivered by the same vehicle. The transportation vehicle used for distribution is the same vehicle with refrigeration function. The distribution process is at a constant low temperature, the type of goods to be distributed is single, and the requirements for refrigeration temperature are consistent. If the delivery vehicle is delayed and the customer refuses to accept the service, there will be significant losses such as cargo damage and transportation, and the customer's satisfaction with the service will be zero. The mathematical meaning is that it is not solvable within the specified time window and the design of the corresponding distribution route is not feasible. In the process of distribution of refrigerated goods, other expenses will be incurred under time constraints, such as high-speed charging costs incurred by driving on expressways. Expressed as $C_7$, as shown in equation (9).

$$C_7 = \sum_{i=1}^{m} g, m \leq n, \text{ Among them } m \leq n$$

In summary, the real-time route optimization model of a multi-objective cold chain logistics distribution vehicle is constructed as follows:

$$\text{Min } [W, B + W, C] \quad (10)$$

Among them

$$B = \sum_{j=1}^{\infty} t_{(j-1)} + \sum_{j=1}^{\infty} t_j \quad (11)$$

$$C = C_1 + C_2 + C_3 + C_4 + C_5 + C_6 + C_7 \quad (12)$$

Among them, equation (10) regards time and cost as optimization objective functions, and gives certain weights $W1$ and $W2$ when solving the model according to its importance in actual cold chain logistics.

4. Experimental Simulation

According to the model established by using real-time traffic information, the processing process in the cold chain logistics distribution vehicle route optimization service platform of the internet of things is shown in fig. 2. From the customer level, customer value is the product or service provided by the enterprise, from which the customer obtains benefits or value, which is the value that the customer obtains from the enterprise. Traffic congestion index, or traffic index for short, is a conceptual value that focuses on the spatial range, duration and severity of traffic congestion. The refrigeration cost incurred by vehicles is mainly the fuel consumption and maintenance cost generated by the power provided by refrigerators, which is 100 yuan per hour. The penalty cost for deterioration is 1500 yuan per hour. The locations between customers are shown in Table 1 and the required service time range is shown in Table 1. The maximum load capacity of the distribution vehicle is 4.5t, and the vehicle starts from the distribution center, assuming that the fixed cost $f = 1,000$, the unit transportation cost $c_0 = 4$, and...
the temperature inside the vehicle is -10 ℃, the temperature outside the vehicle is 30 ℃, and the vehicle uses liquid nitrogen as refrigerant. From the perspective of the enterprise, the customer value is defined as: the customer value is the profit that the customer brings to the enterprise, and it is the profit that the enterprise obtains from the customers with whom it has good and stable cooperation. This profit is not only limited to the explicit profit, that is, it is obtained through the trading relationship, but also the implicit profit that the customer brings to the enterprise through recommendation and dissemination.

Figure 2 Working Principle Diagram of Model Simulation

Table 1 Customer Time Window Range and Demand

| Distribution point | Service time window | Service time | Demand/t |
|--------------------|---------------------|--------------|----------|
| 0                  | (5-10)              | -            | -        |
| 1                  | (7-9)               | 25           | 0.66     |
| 2                  | (7-8)               | 20           | 0.5      |
| 3                  | (8-11)              | 30           | 0.22     |
| 4                  | (7-10)              | 35           | 0.56     |

Table 2 Comparison of Execution Time of Different Number of Processors

| Number of processors | Execution time/s | Speed-up ratio | Efficiency |
|----------------------|------------------|----------------|------------|
| 2                    | 17.36            | -              | -          |
| 2                    | 12.24            | 1.36           | 0.77       |
| 3                    | 8.36             | 2.5            | 0.8        |
| 4                    | 5.23             | 3.38           | 0.41       |

In order to increase the one-time carrying capacity and reduce the unit distribution cost, large vehicles should be selected as far as possible to complete the distribution task under good road conditions. When measuring the customer value, we should not only consider how much profit the customer brings to the enterprise at present, but also analyze the potential value of the customer. With the development of the customer, we should consider the profit that the customer may bring to the enterprise in the future. In real life, the driving speed of vehicles will vary due to the influence of weather, rush hour, special festivals, traffic control and other factors. In the shortest possible time period, the speed will converge, and the calculation method will be closer to reality, but at the same time it means the calculation process is complicated and complicated. The calculation results all get the optimal path within the effective time range. At the same time, the time and cost of the calculation results are different according to the different attention to the vehicle distribution cost and time. At the same time, when W1=0 and W2=1, different numbers of processors are used, and the execution time of the algorithm is also different. To a certain extent, the more processors, the shorter the calculation time. As shown in table 2. Some potential customers will choose to cooperate with the enterprise because of their good evaluation of the enterprise. Then, the enterprise will bring economic benefits because of these good recommendations, which will help the enterprise to expand the market and achieve longer-term development.

5. Conclusions

Cold chain distribution cost is the key part of cold chain logistics cost. How to reduce the cost of cold chain distribution is an important breakthrough for the above problems. Cold chain goods are generally fresh and perishable, and the delivery time directly affects the quality of goods and service level. It is also particularly important to improve the time reliability of cold chain delivery. This paper introduces the particularity of cold chain logistics compared with normal temperature logistics, and
analyzes the significance of using Internet of Things to optimize the real-time route of refrigerated vehicles. The characteristics of cold chain logistics and distribution route optimization are discussed. On the basis of comprehensive analysis of the current research situation of cold chain logistics, this paper introduces the relevant contents of the path optimization of cold chain logistics, such as the concept and characteristics of cold chain logistics and its differences from traditional logistics, and on the other hand, combs the definition and components of path optimization. According to the fact that parallel computing is the key technology to realize the application of the Internet of Things, this paper uses coarse-grained parallel genetic algorithm to solve the model. The simulation results verify the effectiveness of the cold chain logistics vehicle routing optimization method based on the Internet of Things and improve the efficiency of distribution services.

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