The Optimization of Food Distribution Path of Cold Chain in the Beijing-Zhangjiakou Olympic Winter Game

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Abstract. In this paper, we take the winter Olympic Games held in Beijing in 2022 as the research background, mainly in the Olympic Games held during the cold chain food distribution path scheduling optimization problem. The Beijing Olympic Games in 2022 is the first time in the history of China to host the Winter Olympics, and in Beijing, Zhangjiakou two cities together, Beijing will soon become the history of the Olympic Games held the first summer Olympic Games and the Winter Olympic Games city. Therefore, during the Olympic Games held its research on the food supply problems of athletes, but also the issue of cold chain food distribution has become the focus of the study.

Based on the model of vehicle routing problem with time window, we construct a cold chain food distribution model with the aim of minimizing the total cost of distribution. At the same time, in order to respond to the call of green Olympics and green supply chain, we consider energy saving and emission reduction. In the cost calculation, the environmental cost of carbon emission is added. Secondly, the routing of the distribution is optimized by the saving algorithm, and the distribution route is improved by the actual example given. The detailed distribution scheme is given Finally, according to the optimization results, some suggestions are put forward for the cold chain food distribution in the winter Olympic Games.

1. Introduction

1.1. Background

The 24th Olympic Winter Games will be held jointly by Beijing and Zhangjiakou from February 4 to February 20, 2022. Beijing will undertake the opening and closing ceremonies of the Winter Olympics and Paralympics and all ice projects. Yanqing and Zhangjiakou will host all the snow projects. Beijing, Yanqing and Zhangjiakou will each have their own Olympic Village. By then, participants from around the world, athletes and their accompanying staff, reporters, spectators and other participants will gather in Beijing and Zhangjiakou two cities, bringing joy and excitement to the two cities, while also testing its food cold chain logistics The food demand of the Winter Olympic Games has triggered a huge demand for food cold chain logistics and brought instantaneous pressure on the food cold chain logistics system of the host city.

The Olympic food cold chain logistics is an important part of the Olympic logistics, which refers to the frozen food storage in the production, storage, transportation, sales, to the consumer before the link is always in the prescribed low temperature environment, in order to ensure food quality and reduce food A systematic project of loss. The development of cold chain logistics in China is fast, but accompanied by many problems, such as the low degree of specialization, the low efficiency of overall cold chain circulation and the unobstructed information, resulting in a high distribution cost. Therefore, it is necessary for us to conduct an in-depth study of the Olympic Cold Chain Logistics and provide the necessary theoretical support for the successful hosting of the Winter Olympic Games.
Distribution costs are a very important part of the cold chain logistics costs. Cold chain logistics distribution costs include not only transport costs at room temperature logistics, fixed costs, penalties, but also in the distribution process to control the temperature inside the car to increase the cost of energy consumption, the cost of goods, such as loss. In order to ensure the timely delivery and stability, as well as maximize economic efficiency, cold chain logistics companies must take appropriate measures to plan the distribution path. Therefore, the planning of the delivery route has become an important factor affecting the operation of the enterprise.

The main problem studied in this paper is the vehicle path planning problem, which can be described as follows: For a series of loading points and unloading points, organize appropriate driving directions so that vehicles can pass through them in an orderly way and meet certain constraints. The goal and return to the vehicle parking space [1]. This problem was first proposed by Dantzig and Ramser [2] and has become the core issue in transportation and distribution. The path planning of cold chain goods is developed on the basis of this theory.

Under the background of the Winter Olympics, the problem of routing optimization emphasizes timeliness and stability, so the factors to be considered are more complicated. Therefore, how to make a reasonable path planning for the special characteristics of the Olympic Winter Games so as to reduce the distribution distance, reduce the logistics loss, and meet the requirements of the customers for the time window, has become crucial in the food cold chain distribution management of the Winter Olympic Games problem.

1.2. Literature Review

Regarding the optimization of cold chain distribution, Wang Shuyun and Sun Hong studied the path planning problem under the change of demand [3]. Ma Xianguo, Liu Tongjian and Yang Pingzhe analyzed the cold chain logistics vehicle routing optimization model based on stochastic demand [4]. LvJunjie and Sun Shuang pairs of city cold chain logistics to establish a set of fair and effective cost-sharing mechanism [5]. Based on the traditional vehicle routing problem, Zhu Jinfeng analyzed the characteristics of fresh perishable product distribution and studied the vehicle routing model [6]. Yang Zhenhua and Lai Pingzhong developed a hybrid simulated annealing algorithm by constructing a multi-vehicle hybrid delivery dispatching optimization model for refrigerated trucks, and compared and analyzed the differences in delivery costs among different models [7].

Vehicle routing problem solving methods are precise algorithms, heuristic algorithms and intelligent algorithms. In theory, the use of precision algorithms is the best choice. However, precise algorithms are difficult to be implemented due to the rigorous requirements of the solution. Therefore, there are not many applications in the real world. This article focuses on some of the literature on heuristic algorithms and intelligent algorithms.

Heuristic algorithms: Cui Hongzhi and Gong Jiaan improved the saving algorithm, and solved the multi-type vehicle routing problem with time window constraints by using the improved saving algorithm [8]. Zhao Mingli established a vehicle path optimization model with time window constraints and designed a heuristic algorithm based on conservation mileage method to solve the model [9]. Yang Ya-ting studied the problem of vehicle routing with deliverable delivery. This problem allows one task to be accessed multiple times and allows the same vehicle to access the same task more than once, and a three-phase heuristic algorithm is designed [10].

Intelligent algorithms: Cao Gaoli et al. Aiming at vehicle routing optimization with capacity constraints, an efficient hybrid quantum evolutionary algorithm is proposed. Through the comparison of the simulation experiment and the algorithm on the classic test problems of different scales, the validity and robustness of the proposed algorithm are verified [11]. Zhang Youhua, Zhang Cui-jun and Cui Zhong-qiang achieved the effect of complementarity through the use of alternating optimization using ant colony algorithm and genetic algorithm, and exchanging information in time, which enhanced the searching ability of the algorithm [12]. Yang Jin and Ma Liang gave a bee colony algorithm, calculated several benchmark problems, and compared and analyzed the results with other algorithms to verify the effectiveness of the algorithm [13].
2. Model building
In this paper, the goal of minimizing the total cost of distribution is to build a cold chain food distribution path planning model under the background of the Winter Olympics.

2.1. Description of the problem
A distribution center for the Winter Olympics distributes cold-chain food to venues. The distance between venues and the distance between venues and distribution centers is known. The goal of minimizing the total distribution costs is to pre-plan the delivery routes. Delivery vehicles will be in accordance with the scheduled delivery path to complete the delivery task.

2.2. Model assumptions
(1) the geographical location of the delivery demand point, the time window requirement is known;
(2) determine the customer demand; vehicles starting from the distribution center, according to the scheduled route, and finally back to the distribution center;
(3) The vehicles are moving at a constant speed during the delivery, and the traveling speed is constant.
(4) Each customer node cold chain food can only be a one-time delivery of a car to complete;
(5) The quality of the cold-chain product declines with the accumulation of time, which will lead to the corresponding deterioration cost;
(6) does not consider the time when the vehicle is loaded and unloaded at the distribution center.

2.3. Parameter description
\( V = \{0, 1, \ldots, n\} \): Customer node set, where 0 represents distribution center;
\( K = \{1, 2, \ldots, m\} \): The collection of refrigerated trucks
\( f \): The fixed cost of refrigerated trucks;
\( c \): Refrigeration unit for the time driving costs;
\( c_e \): The transport process unit time due to heat transfer inside and outside the refrigerated compartment resulting refrigeration costs;
\( c'_e \): The refrigeration cost per unit time due to heat intrusion during unloading.
\( c_d \): The unit of time during transport led to the quality of cold chain products decline rate;
\( c'_d \): The unloading process unit time lead to the quality of the cold chain product ratio;
\( q_i \): The demand for customer nodes;
\( Q \): the capacity of refrigerated trucks;
\( u_i \): The customer node service at time \( i \);
\( t_{ij} \): The travel time from the node \( i \) to node \( j \) for the refrigerated truck \( k \);
\( t_k \): For refrigerated trucks arrived at the customer node moment;
\([e, l]\): Time window for customer node;
\( a \): The waiting time for refrigerated trucks as early as the unit cost;
\( b \): For the refrigerator car late unit cost of punishment;
\( r_k \): A collection of nodes on the route for the car;
\( o \): For the unit from the carbon emissions on the environment caused by pollution costs;
\( d_{ij} \): Is the distance traveled by the vehicle from node to node;
\( x_{ij} \): As a decision variable, if the car path from the node to the road, take 1, otherwise, take 0;
As a decision variable, if the vehicle path contains nodes, take 1, otherwise, take 0.

2.4. Mathematical model
In the case of known customer demand, the distribution cost of cold chain products with time windows is mainly composed of five parts: fixed cost, driving cost, cooling cost, deterioration cost and penalty cost. In response to the environmental theme of “Green Olympics”, this paper increases the environmental pollution cost of the carbon emissions of refrigerated vehicles during their operation. The fixed cost is the fixed cost of assigning each refrigerated truck, including the fixed loss of the refrigerated truck, the driver’s salary, etc. Assuming that the fixed cost of each refrigerated truck is $f$ and there are a total of $m$ distribution routes, the fixed cost is:

$$C_1 = mf$$

This paper assumes that the refrigerated truck travels at a constant speed and considers that the driving cost is proportional to the travel time of the refrigerated truck. The driving cost per unit time of the refrigerated truck is $c$, and the driving time of the refrigerated truck $k$ from the customer node $i$ to the customer node $j$ is $t_{ij}^k$, and the driving cost of the delivery vehicle is:

$$C_2 = c \sum_{k \in K} \sum_{i \in V} \sum_{j \in V} t_{ij}^k x_{ij}^k$$

The cost of cooling is the cost incurred to maintain the temperature defined by the cold chain in the refrigerated compartment. It can be divided into two parts: the cooling cost caused by the heat conduction inside and outside the refrigerated compartment during the running of the refrigerated truck, and the refrigerated truck required by the customer. Reaching before the time window, waiting for the cooling cost caused by heat conduction inside and outside the refrigerated compartment; the cooling cost caused by the thermal intrusion of the refrigerated door during unloading. The cooling cost of the delivery vehicle is:

$$C_3 = \sum_{k \in K} \sum_{i \in V} \sum_{j \in V} \sum_{\theta_{ij}^k} x_{ij}^k c_{ij}^k$$

Among them, $t_{ij}^k = t_{ij}^k + \max\{e_j - t_{ij}^k, 0\}$, $\max\{e_j - t_{ij}^k, 0\}$ is the waiting time of the refrigerated truck. The cost of deterioration is caused by the decrease in the quality of the cold chain during the distribution process, including the deterioration cost caused by the transportation process and the unloading process. The deterioration cost of the cold chain product is:

$$C_4 = \sum_{k \in K} \sum_{i \in V} \sum_{j \in V} \sum_{\theta_i^k} q_{ij}^k$$

$$\theta_i^k = c_d \sum_{v_i \in V} t_{i(v_i)}^k + c_d \sum_{v_i \in V} u_i (v_i \in v_i)$$

The penalty cost is caused by the arrival of the delivery vehicle before or after the customer node time window, and the penalty cost during the delivery process is:

$$C_5 = \sum_{k \in K} \sum_{i \in V} (a \max\{e_j - t_{ij}^k, 0\} + b \max\{t_{ij}^k - l_j, 0\})$$

In response to the call for the Green Olympics, consider the carbon emission costs of refrigerated vehicles, calculated as follows:

$$C_6 = \sum_{i \in V} \sum_{j \in V} \sum_{k \in K} \rho d_{ij} x_{ij}^k$$

In summary, the objective function is:

$$\min C = C_1 + C_2 + C_3 + C_4 + C_5 + C_6$$

S.T.

$$\sum_{k \in K} \sum_{i \in V} x_{ij}^k = 1, j \in V$$
\[
\sum_{j \in V} x^k_{ij} = \sum_{j \in V} x^k_{ji}, \ i \in V, k \in K
\]
\[
\sum_{i \in V \setminus \{0\}} x^k_{0i} = \sum_{i \in V \setminus \{0\}} x^k_{0i}, k \in K
\]
\[
(\max\{t^k_i + e_i, t_{ij}^k + u_i\} = t^k_j, i, j \in V, k \in K
\]
\[
\sum_{i \in V} q_i y^k_i \leq Q \forall k
\]
\[
x^k_{ij} \in \{0,1\}, i, j \in V, k \in K
\]
\[
y^k_i \in \{0,1\}, i \in V, k \in K
\]

Equation (1) is the objective function and consists of five parts: fixed cost, driving cost, cooling cost, deterioration cost, and penalty cost. Equations (2) and (3) ensure that each customer node has one and only one vehicle for it; (4) ensures that the vehicle is returned by the distribution center and ultimately returns to the distribution center; (5) defines the vehicle's arrival time. Equation (6) is the refrigerated truck capacity limit; Equations (7) and (8) indicate that the decision variable is a 0-1 variable.

3. Algorithm design
Qi Xiaohong et al. compared the route planning obtained by scanning method, recent insertion method and saving algorithm through simulation test[14]. The results show that the vehicle routing arrangement obtained by the saving algorithm can not only meet the demand service level of the network. And can effectively improve the utilization rate of vehicles. To this end, this paper will use the saving algorithm to optimize the distribution route.

The basic idea of the saving algorithm is: first connect each delivery point with the distribution center to form a delivery line with only one delivery point, and calculate the total cost; then calculate the connection point of the two delivery points on one line. The cost savings value, the greater the savings, the more the total distance connecting the two delivery points is reduced until the savings value is zero.

The cost savings value \( S(i, j) = c_{0i} + c_{0j} - c_{ij} \) after the connection is denoted by \( S(i, j) \), and the delay amount (or advance amount) of the time when the vehicle arrives at the customer \( e_{ij} \) after the connection between the customer \( i \) and the customer \( j \) is reached, compared with the time when the vehicle arrives at the customer \( j \) on the original route. \( e_{ij} \) can be derived from:\[ e_{ij} = S_i + t_i + t_j - S_j. \]

In order to discuss the convenience of the time window constraint problem, two more important parameters need to be defined:

\( \Delta_j^- \) indicates the maximum advance amount of the arrival time of the \( j \) point that does not need to wait for each task behind the \( j \) point on the line on the vehicle line; \( \Delta_j^+ \) indicates that the tasks behind the \( j \) point on the vehicle line do not violate the time window constraint and reach the maximum point \( j \) allow for a delay.

4. Case analysis
This article refers to the position of the cold chain distribution center of the 2008 Beijing Olympic Games, given an Olympic distribution center, and distributes the cold chain of dairy products to 12 venues in Beijing. The distance from the distribution center to each node and the distance between any two nodes are known. The service time window \([e_i, l_i]\) and the time window of each venue (at 4
o'clock in the morning) are known, and the demand for each venue is known. Each refrigerated truck can carry up to 3 tons of dairy products at a speed of 30 km/h, and the price per unit of dairy products is 100 yuan/piece. The fixed cost of the refrigerated truck is 120 yuan, and the driving cost per unit time is 35 yuan. The cooling cost per unit time during the driving process and unloading process is 15 yuan/h, 20 yuan/h, and the waiting cost and penalty cost per unit time are 90 yuan, loading and unloading rate is 6 tons/h. The ratio of the quality of the cold chain products during the transportation and during the unloading process was 0.5% and 1%, respectively. The optimization results are shown in Table 1.

| Path   | Departure time |
|--------|----------------|
| 0-1-7-8-6-5-0 | 4:00          |
| 0-3-4-9-0     | 4:40          |
| 0-10-2-0      | 5:00          |
| 0-11-12-0     | 4:20          |

5. Conclusion and suggestion

This paper studies the planning and selection of the distribution path of cold chain food in the Winter Olympic Games, and uses the saving algorithm to optimize the distribution route, and validates it with examples, and provides relevant suggestions for the selection of distribution routes, in order to be able to provide for the winter of 2022 in China. It will provide theoretical guidance and basis for the distribution of cold chain logistics.

Due to the perishable and temperature-sensitive characteristics of cold chain foods, the distribution cost is much higher than that of normal temperature goods. Therefore, reducing the distribution cost on the basis of ensuring the quality of cold chain products has become the focus of cold chain logistics enterprises. According to the above analysis, the Winter Olympic Games can select the corresponding distribution route planning mode according to the actual situation. This paper puts forward the following suggestions:

(1) Strengthen demand information sharing and establish strategic cooperative relationship

If the information between cold chain distribution and upstream and downstream cannot be shared, a large number of information islands will be generated, resulting in a double waste of resources and funds. When distributing cold chain food, it is necessary to share information dynamically and cooperate closely with customers to achieve high degree of information sharing, ensure the accuracy and real-time of information, timely understand the dynamic and logistics service process, and improve the accuracy, pertinence, efficiency and integrity of cold chain logistics distribution.

(2) Use demand forecasting method to grasp the changing trend of customers' demand

The demand for cold-chain food is the result of many factors such as climate and market. The organizers of the Winter Olympic Games can forecast the future demand by using historical data, combining market conditions, using data mining technology, time series analysis and other scientific methods, so as to provide a basis for the formulation of distribution plan and control decision-making.

(3) Using Electronic Information Technology to Construct Cold Chain Logistics Information Platform

Cold chain logistics has higher requirements for time and temperature control in distribution. Informatization is a powerful means to achieve real-time control. Using modern RFID and Internet of Things technology, the cold chain logistics information platform is constructed. Through the management of the whole process of cold chain logistics distribution, the two purposes of reducing costs and improving service level are realized. Firstly, the visualization of distribution process is realized through the cold chain logistics information platform, so as to timely and accurate dispatch of cold chain goods transportation vehicles, thereby improving transportation efficiency and avoiding invalid transportation. Secondly, the distribution vehicles of cold chain products are brought into the Internet of Things. The temperature monitoring can be provided by using the RFID temperature tag,
which can realize the dynamic perception of the cold chain products on the vehicle and dynamically monitor the quality and safety of the cold chain food on the way.

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