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Optimization and Application of Urban Terminal B2B Distribution Route with Time Windows for Cold Chain Logistics

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Abstract: This paper mainly studies the B2B distribution routing optimization of fresh perishable goods cold chain logistics with time windows. First, we introduce the background of the research and the progress of vehicle routing optimization with time windows at home and abroad. Secondly, the existing problems of B2B distribution at the end of the city are analyzed, and the design idea of the model is put forward. Then, the shortest optimization model with time windows and distribution routes is established. Finally, the feasibility of the model is verified by the actual example of XM company. The results show that the genetic algorithm can solve the B2B distribution routing optimization problem with time window at the end of cold chain logistics city, which can meet the requirements of different customers for different distribution time, shorten the distribution time and reduce the operation cost of enterprises.

Keywords: Time window; Cold chain logistics; B2B distribution; Path optimization

1. Introduction

1.1. Background

In recent years, China's logistics industry has entered a rapid development stage, especially the cold chain logistics. The national demand for refrigerated food (fruits and vegetables, eggs, dairy products, etc.), frozen agricultural products (meat, ice cream, etc.) and pharmaceutical special products (including blood products, drugs and vaccines) has gradually increased. According to incomplete statistics, China's frozen and refrigerated products annual growth rate is about 10%, there is a better market demand[1]. However, more than 80% of the time is spent in the process of the transfer of fresh perishable products from producers to terminal retail and commercial supermarkets. China's cold chain technology as a whole lags behind the developed countries. The phenomenon of "broken chain" often occurs in the circulation process, resulting in serious losses of fresh perishable products in China[2]. Compared with cold chain trunk logistics, terminal distribution has many factors, such as many links, wide range of services, complex distribution routes, and has more stringent requirements for storage conditions and transportation temperature. Enterprises unreasonable planning and design of urban terminal B2B logistics distribution scheme will seriously restrict the efficient operation of the entire logistics system. Therefore, cold chain logistics terminal B2B distribution is a crucial link in the whole logistics distribution network.

1.2. Research status at home and abroad

Vehicle routing problem with time windows(VRPTW)is one of the classic problems of vehicle routing problem(VRP)[3]. VRPTW problem is more practical than traditional VRP problem in logistics management and transportation organization optimization, so it has been widely concerned and explored by scholars. Similar to the VRP problem, the VRPTW problem can be solved by exact algorithm and heuristic algorithm. The precise algorithm has high precision, but its computational difficulty and amount increase exponentially with the increase of the number of nodes, so the efficiency of the solution is difficult to guarantee. In contrast, the heuristic algorithm has the characteristics of strong global search ability, high efficiency and stronger practicability. Therefore, most researchers focus on how to construct high-quality heuristic algorithms, such as genetic algorithm[4], ant colony algorithm[5], simulated annealing[6], particle swarm optimization[7] and bat algorithm[8]. After years of research, scholars have achieved some results by using heuristic algorithm to solve VRPTW.

Milagros and others proposed that in order to ensure the quality of products, meet the customer needs and service time constraints in cold chain transportation, time windows and control temperatures were considered as constraints of vehicle routing problem, and a cost minimization model was established[9]. Dabbing and others provide distribution services to merchant customers at the right time to achieve the goal of reducing distribution time and cost[10]. Marie and others fuse security factors, the order of merchants and merchants' customer distribution, and the time constraints of the distribution process into the vehicle routing model, design an improved tabu

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search algorithm, and use examples to prove its effectiveness[11]. Zhu Jinfeng studied the optimization of logistics distribution routing in urban cold chain, put forward the optimization method of VRPTW problem, and finally found that the cost-saving method can not only find the optimal distribution routing quickly, but also meet the time window requirements of merchants and customers, which can effectively reduce the cost of logistics distribution[12]. Luo Yong and other improved genetic algorithms have better global optimization ability in solving the problem of logistics path optimization[13]. Liu Wusheng and others established a vehicle routing model with uncertain customer demand, and added penalty cost and order information to obtain the optimal route planning[14].

In this study, there is no significant improvement or innovation in the solution method, and the path adjustment method based on genetic algorithm is still used to improve the convergence speed of the algorithm. But it is worth mentioning that the introduction of a hard time window penalty costs to ensure that the merchant customers to meet the timeliness of distribution requirements and reduce fresh perishable goods in transit damage costs. The model considers the timeliness and corruption of fresh and perishable products in order to shorten the distribution path in the overall goal and meet the customer time window requirements. The model data comes from the actual city terminal B2B distribution operation of XM company, so the solution results have more reliability and reference value.

2. Problem Analysis and Design Ideas

Compared with cold chain trunk logistics, terminal distribution has many factors, such as many links, wide range of services, complex distribution lines and so on, and has more stringent requirements for storage conditions and transportation temperature, which makes the city terminal logistics distribution capacity insufficient, seriously restricting the efficient operation of the entire logistics system. Distribution network at the end of the city is mainly in the form of B2B. The cooperative enterprises generally have five categories: distributors, supermarkets (KA), catering chain, industry, fresh e-commerce and so on. In distribution, merchants have different requirements for distribution time. If the distribution route and order cannot be rationally arranged, it will increase the rate of loss and cost of distribution, premature or late distribution will lead to increased costs, affecting the quality of distribution services.

It is difficult for a single distribution center in a city to satisfy the distribution of long-distance merchants in a short time. To a certain extent, it increases the return empty load rate, increases the distribution cost, and leads to a decline in response speed. In order to adapt to this situation, most logistics companies in the same city generally set up multiple distribution centers. Therefore, when distributing fresh perishable goods, we should not only consider the difference of distribution routes and time, but also consider the timeliness and cost of damage.

3. Model Construction and Hypothesis

This model has no great improvement or innovation in solving methods, and still adopts the path adjustment method based on genetic algorithm to improve the convergence speed of the algorithm. Taking the shortest distribution route as the objective, the penalty cost with time window and hard time window is introduced to ensure the timeliness of distribution and reduce the in-transit damage cost of fresh perishable goods. By reasonably arranging the distribution routes, shortening the distribution time, reducing the loss of goods, while meeting the merchant customer time window requirements, improve customer satisfaction.

3.1. Model hypothesis

(1)Distribution task is to dispatch from the regional central cold storage to the distribution center cold storage. Distribution center distributes to the merchant customers. Each merchant customer is served only once. After the vehicle completes the task, it returns to the distribution cold storage and waits for the next task.

(2)There are enough vehicles to meet the needs of transportation tasks.

(3)Because of the distribution in the city, the maximum distance of transport vehicles is not considered.

(4)Taking the mileage of all vehicles as a measure of transportation costs, and considering the most cost savings by reducing one transport vehicle.

(5)The volume of goods in the distribution center can meet the needs of business customers.

(6)Each distribution vehicle must not exceed its rated load.

3.2. Model establishment

(1) Objective function

$$MinZ = \sum_{h=1}^{H} d_{CV_k} + \sum_{h=1}^{H} \sum_{k=1}^{K_h} \left[\sum_{i=1}^{n_{hk}} d_{r_{hk(i-1)} r_{hki}} + d_{r_{hkn} r_{hko}} .sign(n_{hk}) \right] + \sum_{i=1}^{M} P(t_1) \quad (1)$$

Among $p(t)$ is the penalty cost under hard time windows.

M :

$$p(t) = \begin{cases} M, \ t_i < E' \\ 0, \ ET \le t_i \le LT \\ M, \ t_i > LT \end{cases} \quad (2)$$

(2) Constraint condition

$$\sum_{i=1}^{n_{hk}} q_{hr_{hki}} \le Q \quad (3)$$

$$\sum_{i=1}^{n_{hk}}\sum_{i=1}^{n_{hk}} d_{r_{hk(i-1)}r_{hki}} + d_{r_{hkn_{hk}}r_{hko}} * sign(n_{hk}) \le D \quad (4)$$

$$O \le n_{hk} \le L_h \quad (5)$$

$$\sum_{k=1}^{k_h} n_{hk} = L_h \quad (6)$$

$$\sum_{h=1}^{H} L_h = M \quad (7)$$

$$R_{nk} = \{r_{nki} / r_{nki} \in \{1,2,...,n_{hk}\}, i = 1,2,...,n_{hk}\} \quad (8)$$

$$R_{hk1} \cap R_{hk_2} = \phi, \forall hk_1 \ne hk_2 \quad (9)$$

$$ET_i \le t_i \le LT_P i = 1,2,...,M \quad (10)$$

$$sign(n_{kk}) = \begin{cases} 1, & n_{kk} \ge 1 \\ 0, & other \end{cases} \quad (11)$$

3.3. Model description

The cold chain logistics company transfers goods from O to H distribution centers from the radiation regional center cold storage. The first h distribution center i, the demand of merchants and merchants is q_{hi} , time window is $[ET_I, LT_i]$. Each distribution center has more than one vehicle available. The rated load of the vehicle is Q. Each day, the cold storage distribution center carries out distribution tasks to some goods demand points according to the needs of the customers. Quantity required for each demand point q_{hi} $(q_{hi} \prec Q)$,And known: distance from each demand point $d_{I,j}$.The distance between distribution centers and demand points. Requirements: ① Determine the number of vehicles needed in each area; ② . Assign tasks for each cold chain transport vehicle and determine the optimal route; ③ . Minimum total transport costs.

In the above model, Eq. (1) is the objective function, which requires the shortest total one-way distribution (i.e. the sum of the lengths of each distribution route); Eq. (3) guarantees that the sum of the goods demanded by each merchant customer on each route does not exceed the vehicle's load; Eq. (4) guarantees that the length of each distribution route does not exceed the maximum one-time distribution of the vehicle. Formula (5) indicates that the number of merchant customers on each route of a distribution area does not exceed the total number of merchant customers in that area; Formula (6) indicates that the sum of the number of merchant customers on each distribution route of a distribution area is equal to the total number of merchant customers in that area; Formula (7) indicates that each merchant customer has received distribution services; Formula (8) denotes the composition of merchant customers on each route; Formula (9) limits each merchant customer to one vehicle for delivery; Formula (10) is the time window constraint for merchant customers to load and unload goods; Eq. (11) indicates that the trolley participates in the distribution when the number of business customers serving the k_{th} vehicle in area h is greater than or equal to 1, so $sign(n_{ck}) = 1$.When the number of merchant customers of the K vehicle service is less than 1, it means that the vehicle is not used. so $sign(n_{ck}) = 0$. The specific symbols in the model are shown in Table 1.

Table 1. Symbol Table

Symbol	Explain
H	The number of distribution centers
M	Number of business customers required
L_h	The number of merchant customers required to distribute h distribution centers
K_h	The number of distribution vehicles owned by the H distribution center
Q	Rated load of vehicles
D	Maximum distance traveled by vehicle at one time
q_{hi}	No. h distribution center i business customers' demand
d_{CVk}	The linear distance between the H distribution center and the warehouse.
n_{ck}	The number of merchant customers in vehicle distribution h K distribution center （$n_{ck} = 0$Indicated not enabled）
$d_{i,j}$	The line distance of i merchant customers to j merchant customers
R_{ck}	Path K in area H
r_{hi}	On the route K of the H distribution area, the order is i merchant customers. （r_{hk0} Express distribution center）

3.4. Model solution

In this scheme, a hybrid genetic algorithm is adopted. Firstly, the above model problem is transformed into H single distribution center vehicle scheduling problem by scanning method. Then the improved genetic algorithm is used to optimize the route of each single distribution center problem.

3.4.1. Partitioned distribution algorithm

The partitioning method uses a scanning method, and the scanning method is a heuristic algorithm for solving the VSP in which the number of vehicles is not limited. The solution process involves the steps:

① Establish a polar coordinate system with the starting point (distribution center) as the origin;

② Start a group with two merchant customers from the smallest perspective;

③ The merchant customers are added to the group one by one in the counterclockwise direction according to the morning time and the afternoon time until the total amount of the merchant customer's demand exceeds the vehicle's load quota;

④ Create a new group and continue the process until all merchant customers are added to the group.

3.4.2. Genetic algorithm

The genetic algorithm constructed in this scheme is improved on the basis of the algorithm in order to facilitate computer processing. The genetic coding is based on natural number coding. The solution vector of the model can be programmed into a chromosome coding length n+M+1.

such as (0, $i_1, i_2, ..., i_e$, 0, $i_f, ..., i_k, o, ..., o, i_p, ...i_q$, , 0) , i_j represents the j warehouse on a certain line.0 Show the yard. The number is m+1, and the chromosome structure can be understood as vehicle starting from the 0 car field. Afte r $i_1, i_2, ..., i_e$ back to the garage 0,Sub-path 1,The second vehicle is also departing from the yard, afte r $i_1, i_2, ..., i_e$ back to the garage 0,Sub-path 2.This is repeated until all the warehouses have been visited. In this way, the chromosome has the characteristics that the interior of the sub-path is ordered, and the sub-paths are disordered.

4. Example Application

According to the conditions provided by XM Company, Shanghai WJ Refrigerator and Shanghai SJ Refrigerator are two distribution centers, and 22 demand points covered by two distribution centers are selected. The fresh demand of each demand point is 4 T and below. Each distribution center has 4 vehicles, 9.6 m vehicle type, 13.3 t load, 7.6 m vehicle type and 8 T load. The running speed is 30km/h. The location coordinates of the distribution center and 22 merchant customers as well as the cargo demand of each demand point are obtained through Baidu map. The coordinates of the two distribution centers are: WJ cold storage distribution center A (1215.37km, 3460.45km), SJ cold storage distribution center B (1195.15km, 3457.89km).The coordinates of 22 business customers and their fresh demand (as shown in table 2, merchant customer demand information sheet).

It is necessary to arrange the distribution routes reasonably and make the total mileage of distribution vehicles the shortest. For simplicity, it is assumed that the distance between each demand point and the distribution center and the demand point is a linear distance, which can be calculated from the coordinates of the merchant customer and the distribution center. The penalty function is a hard time window, M=1000000. By scanning method, the following results are calculated by the algorithm program:

(1)WJ Distribution Center A serves 9 merchants, with the numbers 11, 12, 13, 14, 22, 21, 8, 9 and 10 respectively.

(2)SJ Distribution Center B serves 13 merchant customers, numbered 1, 2, 3, 4, 5, 6, 7, 16, 17, 18, 19, 20 respectively.

Table 2. Merchant Customer Demand Information Table

Distributor	number	Abscissa/km	Ordinate/km	Requirement/t	ET	LT
Text road 176 fresh supermarket	1	1187.33	3459.07	0.9	14:00	15:00
Hui Kang Garden Fresh Supermarket	2	1189.86	3457.90	0.7	14:00	15:30
Vegetable and beauty are fresh and convenient.	3	1191.23	3456.99	1.3	14:05	15:30
Loyalty fruits and vegetables	4	1191.54	3460.33	1.5	13:40	15:00
E fresh fruit and vegetable supermarket	5	1191.98	3460.81	2.2	13:40	
Name wins fresh convenience store	6	1192.84	3455.80	0.6	14:10	16:00
One cent profit fresh supermarket	7	1192.37	3459.07	1.3	11:10	14:00
Fresh fresh supermarket everyday	8	1205.18	3458.30	1.1	8:20	9:00
Lian Jie fresh supermarket	9	1209.90	34580.75	2.1	8:30	11:00
Lian Jie fresh supermarket	10	1210.56	3455.81	1.4	8:45	12:00
M8 fresh house	11	1221.05	3462.36	1.3	9:00	10:45
Fresh housekeeper talks about shop	12	1220.57	3463.62	1.5	9:10	10:45
Cheung Yi fresh Pujiang shop	13	1217.47	3464.53	1.6	9:15	13:10
Love home supermarket	14	1216.66	3466.78	0.9	9:20	11:15
Like the sea fresh life square	15	1196.15	3463.13	1.9	13:30	14:30
Fat cat Restaurant	16	1189.81	3458.75	2.1	11:00	13:30
70 after dinner bar	17	1190.52	3458.52	3.5	11:00	11:30
Farm vegetable	18	1194.52	3458.71	2.9	11:15	14:20
Farm house	19	1194.79	3456.77	1.5	14:10	16:30
Kentucky Fried Chicken	20	1188.96	3459.67	1.7	13:50	15:30
Wu Ling's Restaurant	21	1214.35	3461.03	1.2	8:00	8:30
Old Beijing mutton Restaurant	22	1208.80	3464.46	0.8	8:10	8:40

Based on genetic algorithm, Mat R2014a is used to solve the problem by coding, and the scanned service area is planned reasonably. It is found that the distribution does not exceed the time window, so there is no penalty cost.

The final optimization path is shown in Figure 1-1WJ Distribution Center A's path optimization diagram for 9 merchants and Figure1-2SJ Distribution Center B's path optimization diagram for 12 merchants.

Through the path optimization diagram of WJ Distribution Center A serving 9 merchants and SJ Distribution Center B serving 12 merchants, the final B2B path optimization solution can be obtained. The specific results are shown in Table 3 model optimal solution.

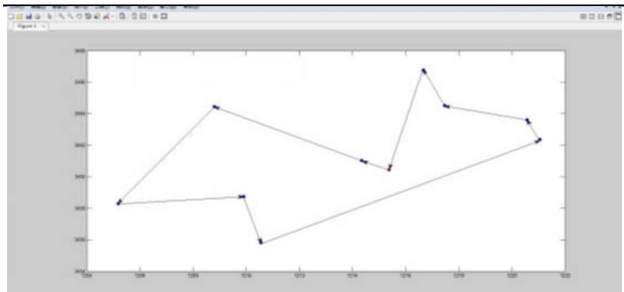

Figure 1. Path optimization map of WJ distribution center A for 9 business customers

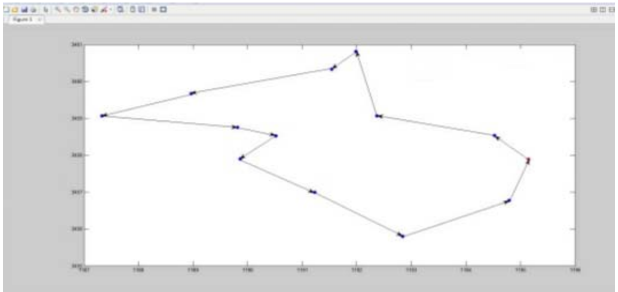

Figure 2. Path optimization map of SJ distribution center B for 12 business customers

Table 3. Optimal Solution of Model

	WJDistribution Centre	SJDistribution Centre
Distribution line	21-22-8-9-10-11-12-13-14	18-7-5-4-20-1-16-17-2-3-6-19
Distribution mileage (km)	47.934	31.954
Distribution quantity (t)	19.2	11.9
Distribution vehicle (Car)	2(Load capacity 13.3t and load capacity 8t)	1(Load capacity 13.3t)
Vehicle rate	73.75%	89.47%

In order to see the effect before and after the model optimization more directly, this paper compares the optimal solution with the sub-optimal solution (see Table 4). It can be seen that the genetic algorithm is used to solve the B2B distribution routing optimization problem with time window at the end of cold chain logistics city, which can satisfy the distribution time difference between different merchants and customers. Different requirements shorten the delivery time and reduce the operation cost of enterprises.

Table 4 .Comparison Table of Optimization Results

	Pre optimization	After optimization	Result contrast
Distribution mileage (km)	92	80	Save mileage 13%
Distribution time (h)	3.1	2.7	Save time 0.4

5. Summary

This paper mainly studies the B2B distribution routing optimization of fresh perishable goods cold chain logistics with time windows. The results of a specific example show that the genetic algorithm can solve the B2B distribution routing optimization problem with time window at the end of cold chain logistics city, which can meet the different requirements of different merchant customers on the distribution time, shorten the distribution time and reduce the operation cost of enterprises.

However, there are still some shortcomings to be improved. First, the genetic algorithm may not be the best and most advanced algorithm, and it can be compared with other heuristic algorithms such as ant colony algorithm, simulated annealing, particle swarm optimization, bat algorithm and so on. Secondly, the time window is known and fixed, but the change of customer time window will interfere with the logistics distribution routing optimization scheme. That is to say, how to deal with the optimization of time window under dynamic changes is an important direction of my future research.

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