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Optimization Model of the Vehicle Routing of Cold Chain Logistics based on Stochastic Demands

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Abstract: With the cold chain logistics and stochastic vehicle routing research advancing the distribution routing problem in the field of cold chain logistics has drawn widespread attention. In this article, the vehicle routing problem, which is resulted from stochastic demand, is researching by the optimized genetic algorithm theory. Initially, the various expenses related to vehicle distribution within the process of cold chain logistics are analyzed; Secondly, a mathematical model involved mixed time window is established. It is able to satisfy diversified customers at different levels of importance. Apart from that, in order to minimize the total costs, another mathematical model based on safe ratio comes out. The innovation of the paper is using a mixed time window model to balance the relationship between services requested by customer and their own levels of importance, adjusting the cooling cost according to temperature differences relied on time and using a safety factor to make balance between the customer demand and the cost in the implementation phase. In addition, the authors took MATLAB as coding platform to simulate and analyze with adaptive genetic algorithm.

Keywords: Cold Chain Logistics; Vehicle Routing Problem; Stochastic Demands; Genetic Algorithm; MATLAB Software

INTRODUCTION

The issue about planning routes for multi-attribute vehicles has been progressing since the development of computer science and communication technology. During the daily operation, there exists the cold chain logistics numerous uncertain factors such as customer requisition adjustment, traffic condition, weather, and the staff individual willingness. Other than that, the cold chain logistics also has its own characteristics, which makes delivery more complicated. In this article, researchers suggest create a model that includes random vehicle routes. By dispatching vehicle rationally, the estimated cost can be controlled and minimized at the end.

COLD CHAIN LOGISTICS AND VEHICLE ROUTING PROBLEM

Generally speaking, the cold chain logistics refers to the system engineering of placing the refrigerated food in specified low-temperature environment in all links before consumption, including the production, storage, transportation and sales, for guaranteeing the food quality and reducing the food consumption, and it is also called the low temperature logistics [Wang Qiang et al., 2007]. Due to insufficient consideration of the particularity of cold chain logistics, the vehicle routing solution to the room temperature logistics is not completely applicable for solving the delivery problem of cold chain logistics, and it usually fails to achieve the optimal route. Compared to the room temperature distribution, the cold chain logistics delivery not only increases some additional fee, but also includes some extra cost, for instance, the cooling cost. Since the delivery time is in positive correlation with the refrigeration cost and cargo damage cost, the timeliness is a significant balance "lever" of the deliver cost of cold chain logistics. Compared with the ordinary logistics, the cold chain logistics requires great pre-stage fixed-cost investment. Generally speaking, vehicle acquisition experience is several or dozen times of the ordinary vehicle acquisition expenses. Seen from the cost-saving analysis of the cold-chain logistics distribution center, the distribution center shall make full use of the transport capacity of each refrigerator car, and reduce the holdings of vehicles on the premise of the fulfillment of tasks. Comprehensively, cold chain distribution cost includes the transportation cost of the room temperature logistics, fixed cost, penalty cost, as well as the energy cost due to the control of vehicle temperature and loss cost in the distribution process, etc.

The stochastic vehicle routing problems are usually the multi-attribute vehicle routing problems, including two broad categories, namely the vehicle routing problem with stochastic demand (VRPSD) and vehicle routing problem with stochastic custom (VRPSC). In VRPSD, assume that the location of all customers and distribution center is known and fixed, and each customer has demands and requirements (the quantity demand of each customer is uncertain, but it is not 0, and it submits to a certain distribution function) moreover, the specific demand of each customer can only be obtained after the vehicle reaches customers. In VRPSC, if the customer has demands or requirements is unknown.

Aiming at the particularity of cold chain logistics and randomness of customer demand, the vehicle routing problems caused by the stochastic customer demand in the cold chain logistics distribution environment are analyzed, for realizing the objective of minimum total cost.

Establishing Stochastic Customer Vehicle Routing Problem Model

Problem Description

The distribution does not merely mean the delivery of commodities to the demanders [Zhao Jiajun et al., 2004]at the right time, in the appropriate place and at the proper cost, and instead, it shall deliver optimal service to the demander .The delivery of products from the distribution center to the ultimate customer may go through three stages, including the loading process at the distribution center, transportation process and unload process after the vehicle arrives at the customer's site. As for the vehicle routing problem, it can assume that vehicles can be sent out from the distribution center and will start performing the distribution task. In this paper, costs incurred in the entire process after the vehicle leaves the distribution center till it finishes offering services to the customers are considered (the loading cost incurred in the distribution center is neglected).

In this paper, the random vehicle routing problem of the cold-chain logistics studied can be described as: the system comprises a distribution center and several different clients. The geographic positions of all individuals are known, but different clients have different requirements on the distribution time, and products must be distributed within accepted periods. As a result, vehicle distribution routing shall be arranged reasonably to minimize the total cost, and it shall satisfy the following conditions: (1) All distribution vehicles shall belong to the distribution center, and they must set off from the distribution center and finally return to the distribution center; (2) The distribution center has fixed number of distribution vehicles, with known and the same maximum loading; (3) Symmetrical network, and the customer spatial distance satisfies the triangle inequality: dij≤dik+dkj; (4) The demand of each customer is no-negative and less than or equal to the maximum load of the vehicle; (5) Demands of all customers must be satisfied, and the distribution service for customers at one time shall not accomplished by different vehicles; (6) Demands are separable, namely when the residual goods cannot satisfy the demand of current customers, residual goods on the vehicle shall be delivered to the customer at first, and then, the vehicle shall go back to the distribution center, be reloaded and return to the customer for finishing the residual distribution task; (7) Uncertain factors, such as the traffic jam, temporary traffic control, etc. in the driving process will not be considered, namely, vehicles will drive at a constant speed; (8) The loading of vehicle shall not exceed the rated loading at each time; (9) The distribution center has enough commodities that can satisfy the demand of customers, and there won't be out-of-stock; (10) There is no midway assignment, namely the number of customers is certain, and there won't be temporary increase of customers after the vehicles leaves the distribution center; (11) The refrigerated vehicles can always keep the needed storage temperature in the distribution process, and variations of the in-vehicle temperature will not be considered; (12) The loading time in the distribution center will not be considered, but the unloading time can be considered and the service time is directly related to the demand of customers; (13) Pure delivery condition is considered, and there is no pickup task.

Establishing Model

a) parameter setting

According to the demand of model establishment, the following parameters are set: K: the number of refrigerated vehicles in the distribution center; N: maximum allowed loading of the refrigerated vehicles; M: the number of customers in need of services from the distribution center; P: price of unit mass of the refrigerating fluid; P1: price of products of unit mass; Q1: thermal load incurred in unit time and in unit temperature difference when the door is closed; Q2: thermal load incurred in unit time and in unit temperature difference when the door is open; η: cost factor of the unit demand about unit time in advance; β: cost factor of unit demand in delayed unit time; θ_1: quantity of damaged cargo in unit time in the distribution process; θ_2 : quantity of damaged cargo in unit time of the service process; D_i: demand distribution of customer i and the demand distribution complies with the normal distribution, $D_\mathrm{i} \sim \mathrm{N}(\mu_\mathrm{i},\ \sigma_i^2)$; T: time consumed for unloading commodities of unit mass; T_i : time spent in serving customer i, or $\mathrm{T}_i = \mathrm{D}_\mathrm{i} t$; V: the vehicle is in fixed running speed in the distribution process; C1: fixed cost consumed by each refrigerated vehicle every day; C2: transportation cost incurred in driving unit mileage; C3: extra cost paid to the customer after each failure of routing; R_{ki}: time spend for vehicle k in arriving at the customer i; L_{ki}: time for vehicle k to drive away from customer i; α: safety factor (in order to decline the times of routing failure).

b) cost analysis

In this paper, the objective function of minimum cost is established for analyzing the vehicle routing problem based on the cold-chain logistics. At first, it mainly analyzes the total cost in the distribution process formed by various costs.

(1) Fixed cost

Vehicle fixed cost refers to the fixed cost of purchasing vehicles of the distribution center, daily maintenance, repair and depreciation of vehicles, as well as the human cost, including the driver and other employees, etc. The fixed cost of the distribution center is in positive correlation with the number of refrigerated vehicles. Assume that the distribution center has K refrigerated vehicles, and the fixed cost of each vehicle is C1, and then, the fixed cost of the distribution center is: $TC1 = K * C_1$

(2) Cooling cost / energy cost

Perishability is one of the features of the cold chain logistics, and it requires that products are always in low-temperature environment in each link of the logistics for guaranteeing the quality of products [He Jing et al., 2012]. In the distribution process, it must consume energy uninterruptedly to keep the temperature invariant, and the cost increased due to the refrigeration is called the cooling cost or energy cost. The cooling cost is mainly formed by the refrigerant consumed in the cooling process.

Generally, the thermal load is mainly from the solar radiation, radiant heat, as well as the heat carried by the external air and water vapor/ In the cold-chain logistics distribution process, the thermal conduction caused by the temperature difference is the most closely related to the temperature control of the vehicle. Consequently, the cooling cost incurred in the entire distribution process is divided into two parts: the energy cost proceeded in the running process of vehicles and the cooling cost produced in the process of serving the customers, namely the cooling cost produced in the process of opening the door. When the door is closed, assume that the external temperature and in-vehicle temperature keep invariant, the thermal load incurred in unit time must be fixed; when the door is open, it is also assumed that the thermal load is a constant value.

The total cooling cost of all vehicles in the distribution process is: $P * Q_1 \sum_{k=1}^{K} \sum_{i=0}^{M} \sum_{j=0}^{M} d_{kij} X_{kij} / v * \Delta T$

After the back door is open in the service process, the total cooling cost incurred in serving the customers of all vehicles is: $PtQ_2 \sum_{i=1}^{M} D_i * \Delta T$

The total cooling cost of all vehicles incurred from leaving the distribution center to returning to the distribution center is:

$$TC2 = P * \Delta T * \left(Q_1 \sum_{k=1}^{K} \sum_{i=0}^{M} \sum_{j=0}^{M} d_{kij} X_{kij} / v + Q_2 t \sum_{i=1}^{M} D_i \right)$$

(3) Cargo damage cost

The refrigerated goods have perishability, and the product quality may be impacted easily by the temperature, humidity, oxygen concentration, and moisture content, etc. With the time extension and temperature variations, the quality of perishable products may decline gradually, and even loses the use value. When the product quality declines to a certain degree, there may be cargo damage cost. During the cold-chain logistics distribution, residual cargo in the refrigerated vehicle is closely related to the demand of customers, as well as the wastage quantity. Figure 1 and Figure 2 is the residual cargo in the service process when the cargo damage cost is not considered and is considered respectively.

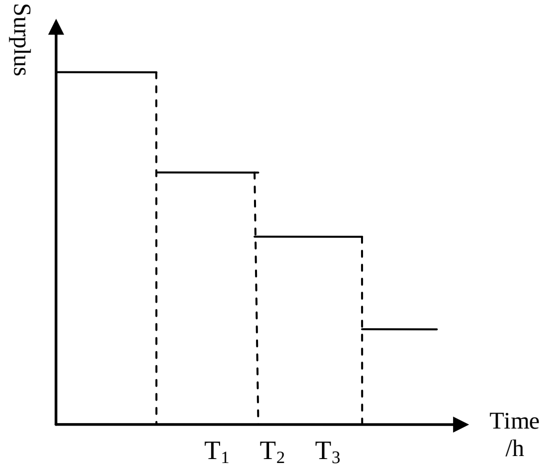

Figure 1. Leave out the cargo damage cost

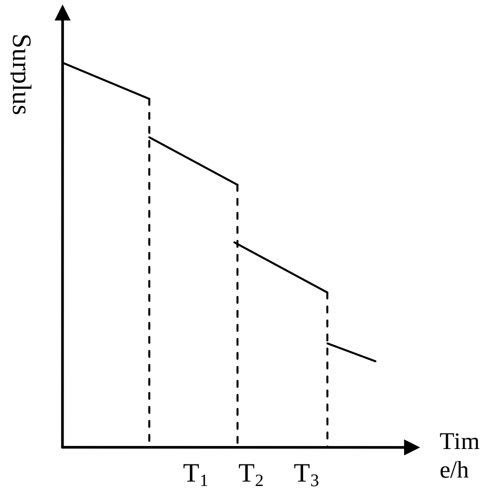

Figure 2. Consider the cargo damage cost

The door of the vehicle is shut down in the distribution process, and at this moment, it can reduce air circulation between the vehicle and external atmosphere effectively. However, when it serves the customers, the door opening accelerates the air circulation speed, which may increase the temperature in the carriage, and the quality of fresh goods declines rapidly, which may result in the higher cargo damage cost incurred in the service process. According to the above analysis, the cargo damage cost in the distribution process can be divided into two parts: the cumulative cargo damage caused in the driving process, and the accelerating wastage of products near the door due to the opening of door. When the demand is separable, there are no products in the refrigerated vehicle in the returning process in case of routing failure, and there will not be the cargo damage cost;

The cargo damage cost incurred in running process:

$$P_1\theta_1\sum_{k=1}^{K}\sum_{i=0}^{M}\sum_{j=0}^{M} d_{kij}X_{kij}/v$$

The cargo damage cost incurred in offering service:

$$P_1\theta_2 t\sum_{i=1}^{M} D_i$$

Total cargo damage cost incurred by all vehicles:

$$TC3 = P_1\left(\theta_1\sum_{k=1}^{K}\sum_{i=0}^{M}\sum_{j=0}^{M} d_{kij}X_{kij}/v + \theta_2 t\sum_{i=1}^{M} D_i\right)$$

(4) Transport cost

The transport cost may impact the variant cost, including the labor, fuel and maintenance, etc. The major factor impacting the transport cost is the transport distance, and the two are in positive correlation. In this paper, the transport cost is divided into the direct transport cost and indirect transport cost.

The transport cost incurred according to the pre-designed distribution routing is the direct transport cost:

$$C_2\sum_{k=1}^{K}\sum_{i=0}^{M}\sum_{j=0}^{M} d_{kij}X_{kij}$$

In the VRPSD problem, there may be the routing failure in the predicted distribution route due to the random demands, namely, the residual cargo of the vehicle may not satisfy the demand of the customer, and it may not be able to finish the pre-optimized distribution route. After the routing failure, extra running distance and delivery time may be increased. The transport cost incurred is called the indirect transport cost:

$$\sum_{k=1}^{K} 2C_2 d_{kro}X_{kro}Z_k$$

The transport cost incurred in the distribution process is:

$$TC4 = C_2\left(\sum_{k=1}^{K}\sum_{i=0}^{M}\sum_{j=0}^{M} d_{kij}X_{kij} + \sum_{k=1}^{K} 2d_{kro}X_{kro}Z_k\right)$$

(5) Extra payment cost

Due to the uncertain demands, the pre-designed routing may encounter routing failure. When it meets the routing failure, in order to reduce the extra cost incurred for satisfying the customers' demand, including the extra damage cargo cost and extra cooling cost, the extra cost, namely the compensation in time of routing failure is specified. When it encounters the routing failure at customer r, the increased extra cost is:

$$TC5 = \sum_{k=1}^{K} d_{kro}X_{kro}Z_k\left(P*Q_1/v + P_1*\theta_1/v\right) + C_3\sum_{k=1}^{K} Z_k$$

(6) Penalty cost (VRP with time window restriction)

The arriving constraint within the required time range will be added on the basis of VRP, forming the VRP with time windows [Zhou Gengui, 2012]. The postal delivery problem in real lives, scheduling problem of trains or buses, etc. can be summarized as VRPTW. According to the restrictions on the time window, the time window can be divided into the hard time window and soft time window [Zhao Yanwei et al., 2014].

The hard time window (the traditional time window) refers that customers have strict requirements on the delivery time [Jiang Changbing et al., 2011], namely the distribution vehicle must finish the distribution of cargo within the specified time range, or the customer may reject this batch of cargo. Therefore, the vehicle must arrive on time or in advance (wait till it reaches the earliest service time required by the customer), or the loss may be enormous. For instance, in Just in time system, the delay of cargo may result in the delay or idle condition of the entire production line. The soft time window refers that if the cargo is not delivered within the expected time range, certain amount of penalty cost can be paid within the acceptable range, but the customer may reject the cargo if it exceeds the acceptable range [Wu Neng, 2012].

Figure 3 and Figure 4 stand for the hard time window and soft time window respectively, in which (E, F) is the time window that can be accepted by the customer, while (e, f) is the time window required by the customer.

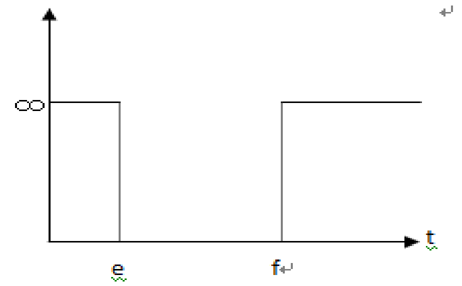

Figure 3. Hard time window

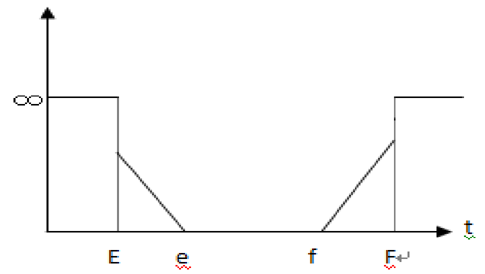

Figure 4. Soft time window

With hard time window, the penalty cost of customer i can be represented as:

$$H_i = \begin{cases} \infty, R_{ki} < e \\ 0, e \le R_{ki} \le f, \quad i = 1,2,\ldots,M \\ \infty, \ R_{ki} > f \end{cases}$$

Since the running speed may be impacted by the traffic condition and many uncertainties, and the cargo may not arrive within the specified time. Practically, customers may receive the cargo, but it would lower the satisfaction degree. Consequently, the hard time window may not reflect the practical problems well, while the soft time window is more ordinary, and it can improve the punctuality and reflect the relation between the operating cost of distribution center, scale and service level by setting relatively high penalty cost. In the studies on the cold chain logistics, the urban traffic jam grows severer and severer, which brings a great problem for the logistics distribution, and the vehicle routing problems with time window is usually based on the restrictions of the soft time window.

Aiming at the room temperature VRPTW, customers would be waited for if the vehicle arrives in advance (namely it starts serving the customer after it reaches the confinement time), for it will not generate the penalty cost or other cost due to the violation of time window. In the cold chain logistics distribution process, the cooling cost and cargo damage cost may increase with the total distribution time, while the shortening of product use time declines the probability of product sales. Consequently, the cost incurred in the waiting process is called the opportunity cost. Therefore, it is assumed that in the cold chain logistics distribution process, in order to avoid the opportunity cost incurred in the waiting process, it is stipulated that the vehicle pays the penalty cost and then serve the customer immediately after arriving in advance.

1) Penalty cost incurred due to the arrival in advance:

$$P_1 D_i (e - R_{ki})\eta, \quad E \le R_{Ai} < e$$

2) Penalty cost incurred due to the delay of arrival:

$$P_1 D_i (R_{ki} - f)\beta, \quad f \le R_{ki} < F$$

Therefore, the punishment of customer i in soft time window is:

$$H_i = \begin{cases} \infty, R_{ki} < E, \\ P_1 D_i (e - R_{ki})\eta, \quad E \le R_{Ai} < e \\ 0, e \le R_{ki} \le f \\ P_1 D_i (R_{ki} - f)\beta, \quad f \le R_{ki} < F \\ \infty, \quad R_{ki} > F \end{cases}, \quad i = 1,2,\ldots,M$$

In real lives, there are some VIP customers in enterprises, and they are usually provided with some special service for improving the customer satisfaction and loyalty, for instance, the bank may set VIP window for reducing the waiting time of VIP and offering priority service. The priority level may be classified according to the degree of importance, and it is stipulated that the delivery time for customers with higher priority has rigidity, namely the hard time window. The delivery time of other customers can be a little earlier or later in a certain range, namely the soft time window. Aiming at the importance of different customers in real lives, the combined time window can be constructed, and it mainly combines the hard time window and soft time window. Different time window restrictions can be employed for different customers.

cooling cost modification

In the distribution process, the running speed on a certain road is impacted by the weather, traffic condition and other uncertainties. Therefore, the running time of the vehicle on different roads may be stochastic, and the arrival time may also be stochastic. The climate of different regions in different seasons may not be the same, and the temperature of the same place at different moments is also different, for instance, the temperature in the morning and at night is relatively low, while the temperature at noon is the highest in a day. The variation of temperature with time is shown in Figure 5:

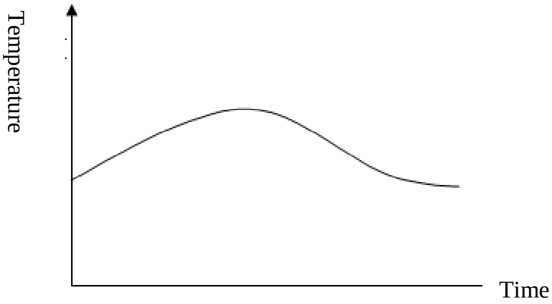

Figure 5. Temperature variation chart in a day

It can be seen from the figure that the temperature in gradual change, but the amplitude of variation within a certain period of time is quite small. The cooling cost is impacted by the temperature difference, and the two are in positive correlation. When the change of temperature with time is considered, the temperature difference may also change with time, and there is the functional relationship between the thermal load and temperature difference in unit time. Assume that the variation function of temperature with time is H (T), the temperature difference is ΔH (T).

The cooling cost of vehicle k driving from customer i to customer j:

$$\int_{L_{ki}}^{R_{kj}} Q_1 * P * \Delta H(T) dT$$

Consequently, the total cooling cost of vehicle k in the distribution process is:

$$\sum_{k=1}^{K} \sum_{\substack{i,j=0 \\ i \neq j}}^{M} \int_{L_{ki}}^{R_{kj}} Q_1 * P * \Delta H(T) dT$$

The cooling cost of serving all customers is:

$$\int_{R_{ki}}^{R_{ki}+T_i} Q_2 * P * \Delta H(T) dT$$

Therefore, the modified cooling cost is:

$$TC2' = \sum_{k=1}^{K} \sum_{\substack{i,j=0 \\ i \neq j}}^{M} \int_{L_{ki}}^{R_{kj}} Q_1 * P * \Delta H(T) dT + \int_{R_{ki}}^{R_{ki}+T_i} Q_2 * P * \Delta H(T) dT$$

Establishing mathematical modeling

On the premise of satisfying the constraint condition, the objective function of the minimum cost is established as follows:

$$\text{Min} Z = TC1 + TC2' + TC3 + TC4 + TC5 + \sum_{i=1}^{M} H_i$$

S.t:

$$\sum_{k=1}^{K} Y_{ki} = 1, \quad i = 1,2,\ldots, M \tag{1}$$

$$Y_{ki}=\begin{cases}0, & \text{Customer i is not served by the}k^{th}\text{ vehicle}\\ 1, & \text{Customer i is served by the}k^{th}\text{ vehicle}\end{cases},\quad i=1,2,\ldots,\ M \tag{2}$$

$$\sum_{k=1}^{K}\sum_{i=1}^{M}Y_{ki}=M \tag{3}$$

$$\sum_{i}X_{kij}=Y_{jk},\quad j=1,2,\ldots,M;\forall k \tag{4}$$

$$\sum_{j}X_{kij}=Y_{ik},\quad j=1,2,\ldots,M;\forall k \tag{5}$$

$$\sum_{i=1}^{M}Y_{ki}D_i+\left(\sum_{i=0}^{M}\sum_{j=0}^{M}d_{kij}X_{kij}/v+tD_i\right)*\theta_2\le N(1-\alpha),\quad k=1,2,\ldots,K \tag{6}$$

$$X_{kij}=\begin{cases}0, & \text{The }k^{th}\text{ vehicle does not pass the section from client i to client j}\\ 1, & \text{The }k^{th}\text{ vehicle passes the section from client i to client j}\end{cases} \tag{7}$$

$$Z_k=\begin{cases}0, & \text{Vehicle k does not encounter the routing failure}\\ 1, & \text{Vehicle k encounters the routing failure}\end{cases},k=1,2,\ldots,K \tag{8}$$

$$X=(x_{kij})\in S,\quad S=\left\{(X_{kij})\middle|\sum_{i\in R}\sum_{j\in R}X_{kij}\le|R|-1,\ R\in\{1,2,\ldots,\ M\}\right\},\ \forall k \tag{9}$$

$$\sum_{i=0}^{M}X_{kij}-\sum_{i=0}^{M}X_{kji}=0,\quad j=1,2,\ldots,M;k=1,2,\ldots,\ K \tag{10}$$

$$E\le T_{ki}\le F \tag{11}$$

(1)(2) guarantee that each customer is only served by the same vehicle; (3) guarantees that the demands of each customer can be satisfied; (4) and (5) stand for the relation between Xkij and Yjk, in order to reach the only constraint of a certain customer; (6) arranges the routing so that the load of each vehicle will not exceed the maximum capacity; (7) 0-1 variables mean that customer i is served by vehicle k; (8) 0-1 variables mean if there is routing failure in the distribution process of vehicle k; (9) mainly removes the constraint for the by-pass, for avoiding that vehicles are appointed to the routing circulation avoiding the distribution center; (10) the vehicle arrives at the customer and leaves the customer shall be the same; (11) The time window restriction of customer.

Instance simulation verification and result analysis

Instance description and sample data

In this paper, the distribution data sample of a certain distribution center is taken as the example. The distribution center is responsible for delivering a certain fresh product, and it mainly serves 10 customers, whose demand is greater than 0. The distribution center has 5 t refrigerated vehicles, and the fixed cost of vehicles mainly includes the depreciation cost, wage of drivers, vehicle maintenance, etc. Different vehicles have distinct fixed cost. The unit driving cost of vehicles is related to the load of vehicles. The distribution center takes the customers with huge demand as the key customers, and the delivery will be carried according to the delivery time strictly. Consequently, hard time window restraint is employed for customer 2 and 4, while the soft time window restraint is employed for the rest customers.

The demand for products and requirements on the delivery time is shown in table 1. The distance between the distribution center and customers is shown in table 2, and other parameters involved in the model are shown in table 3.

Table 1. Requirements of customers on demands

Customer	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Mean demand value μ	1.5	2.4	1.7	2.2	1.7	1.5	1.4	1.2	1.8	1.5
Demand variance δ2	1	1	1	1	1	1	1	1	1	1
ET (acceptable)	7:30	7:30	7:00	8:00	7:30	7:00	7:30	8:00	7:00	7:30
ET (agreed)	8:00	7:30	7:30	8:00	8:00	7:30	8:00	8:30	7:30	8:00
ET (agreed)	10:00	10:30	9:30	10:30	10:30	10:00	10:00	10:30	9:30	10:30
LT (acceptable)	11:30	10:30	11:00	10:30	11:30	11:00	11:30	12:00	11:00	11:30

Table 2. Distance between customers

Customer / Distance	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
0	0	5	7	3	6	9	2	1	4	5	8
1	5	0	4	6	8	7	4	5	5	7	6
2	7	4	0	8	9	5	3	7	4	6	2
3	3	6	8	0	5	6	4	3	5	7	6
4	6	8	9	5	0	7	5	6	3	5	9
5	9	7	5	6	7	0	8	9	6	6	3
6	2	4	3	4	5	8	0	2	2	5	7
7	1	5	7	3	6	9	2	0	4	5	8
8	4	5	4	5	3	6	2	4	0	3	5
9	5	7	6	7	5	6	5	5	3	0	6
10	8	6	2	6	9	3	7	8	5	6	0

Table 3. Parameters

P_1	**1000 Yuan /t**	**θ_1**	**0.3%**
K	5	θ_2	0.5%
Q_1	48 kCal/h	η	0.5%
Q_2	60 kCal/h	β	1%
v	4	P	0.2 Yuan/kCal
t	0.2 h/t	C_1	200
N	5t	C_3	100
C_2	3	ΔT	25℃

Result analysis

At first, arrangements of the designated routing are made according to the mean customer demand. Due to the uncertainties of customer demand, there may be routing failure in the distribution process, and all costs and extra cost shall be calculated when the distribution task is fulfilled. With MATLAB coding platform, the self-adaption genetic algorithm is applied to work out and analyze the mathematical model. In this paper, different safety coefficients are set, namely 0, 0.01, and 0.05 respectively. Aiming at different safety coefficients, the calculation result is obtained, as shown in table 4.

It can be learnt from the running result that with the increase of routing failure, the total cost of finishing the distribution may be on the rise. Due to the demand randomness, the routing failure may be unavoidable, and it shall avoid or reduce the times of routing failure on the premise of satisfying the constraint, so that the sum of predicted running distance and extra running distance is the minimum, for realizing the cost minimization. If the safety coefficient is too small, it may not alleviate the demand fluctuation, but if it is too big, the cost of appointing stage may increase constantly. Therefore, safety coefficients can be set reasonably to realize the purpose of declining the total distribution cost.

Table 4. Running results

α	0	0.01	0.05
Distribution routing	0-9-7-0; 0-3-5-10-0 0-2-1-0; 0-6-8-4-0	0-2-1-0; 0-3-5-10-0 0-4-9-0; 0-8-6-7-0;	0-3-4-0; 0-9-8-10-0 0-2-5-0; 0-1-6-7-0
Arrival moment	7-8.25-9.86-10.39 7-7.75-9.59-10.68-12.98 7-8.75-10.23-11.78 7-7.5-8.3-9.29-9.73	7-8.75-10.23-11.78 7-7.5-9.59-10.68-12.98 7-8.5-10.19-11.8 7-8-8.74-9.54-10.07	7-7.75-9.34-11.28 7-8.25-9.36-10.85-11.15 7-8.75-10.48-13.07 7-8.25-9.55-10.35-10.88
Total cost	5581.5	5207.9	5342.4
Pre-assigned cost	4323.3	4583.55	4718
Extra charges	1258.2	624.4	624.4
Fixed cost	800	800	800
Penalty cost	3.9	18.12	10.15
Transportation cost	180	183	204
Damage cost	45.4	48.4	49.9
Cooling cost	3294	3534	3654

CONCLUSION

This article investigates the delivery route optimization under cold chain logistics issue. It illustrates the basic approach to solve VRPSD by presenting alternative schemes after failure of the original project. Meanwhile, setting up mathematical model consists every detailed expenditures optimize the total costs. During the feasibility study, the safe ratio is also brought into the research as result of the further practices in the condition of daily business. The model presented in this article is quite functional and innovative. To be more specific:

1) The model combines hard time windows and soft time windows and categorizes the customers by level of importance. Then, the penalty cost is proposed after mixed time window theory comes out.

2) According to a feature that temperature difference is relied on the time, the costs of refrigerating can be adjusted by users.

3）Through the setting up of safety coefficient, this paper tries to reduce the probability of path failure, control the balance between the decrease of customers' demand fluctuation and the increase of cost in assignment, in order to search the goal of total cost's minimization.

In this paper, it mainly works out and analyzes the model with the genetic algorithm with Matlab software as the platform.

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