Research on Optimization Strategy of Cold-chain Logistics Car Scheduling

Aimin Yang*, Jie Liu and Yue Wang
College of Big Data and Software Engineering, Zhejiang Wanli University, Ningbo, China
Email: yhyang@sina.com

Abstract. In this paper, aiming at the vehicle information supervision problem existing in the transportation process of the third-party small and medium-sized cold chain logistics enterprises, combined with the actual monitoring demand of the vehicle, the cold chain logistics vehicle dynamic monitoring system is designed, and the vehicle scheduling optimization algorithm in the system is carried out. The study. In the aspect of vehicle scheduling in the system, an optimized genetic algorithm is used to find the optimal transportation path and reduce the transportation cost before transportation by planning the transportation sequence and path of the site.

Keywords. Cold Chain Logistics, Real time monitoring, Genetic algorithm, Information management.

1. Introduction

In recent years, with the increase in people’s demand for material and cultural life, people’s consumption concepts have changed a lot. Fresh, healthy, green and natural have become important criteria for consumers to choose products. People’s high-quality demand for perishable products has made cold-chain logistics transportation receive great attention [1]. According to statistics, in 2018, China’s total cold-chain logistics demand reached 180 million tons and the scale of cold-chain logistics market reached RMB 303.5 billion, an increase of 33 million tons and RMB 48.5 billion compared with that in the previous year respectively. By the end of 2018, the total cold storage capacity has reached more than 50 million tons, with an additional capacity of about 5 million tons. In the third quarter of 2018, the holding volume of refrigerated cars in China was 164,200, an increase of 24,000, a very significant increase [2], indicating that China’s cold-chain infrastructure construction has made some achievements. However, the cold-chain industry is still facing many problems to be solved [3].

First, the development of cold-chain logistics is not balanced. Most third-party cold-chain logistics enterprises invest less in the hardware and software of cold-chain transportation, but often choose lower-cost hardware equipment. Meanwhile, the transportation tools are not formal, the staff is not professional, the transportation scope is mostly within small-scale transportation such as within the cities or between adjacent cities, and the existing cars cannot be well scheduled, resulting in the enterprises’ low transportation efficiency, high transportation cost, low service quality and low customer credibility and affected enterprise profitability. Second, cold-chain transportation is also restricted by various human and non-human factors. The human factors include the adjustment of transportation means by managers and carriers to achieve the goal of “low cost”, the change of labor surcharges and other charges, the customized individual needs of customers, and the change of delivery time of sales terminal goods [4]. Third, the degree of specialization, automation and
informatization in each link of cold chain is low, which can neither improve efficiency nor meet the market demand [5]. In the cold storage link, the uneven distribution of cold storage in China is serious, the automation level of cold storage is low, and the utilization rate of cold storage is not high. In the transportation link, due to the lack of standards and necessary supervision, it is common for cold-chain transportation enterprises to adopt informal transportation.

In summary, there are still many problems in the cold-chain logistics transportation and distribution link. Due to the lack of strength of third-party cold-chain logistics enterprises, the transportation scope is mostly within short-distance transportation between cities. Meanwhile, the transportation tools are not formal, and the distribution route arrangement is unreasonable, making the transportation costs high. To save costs, the violations where the refrigeration equipment is turned off temporarily or the cars are not driven according to the specified route during the transportation happen frequently, making it difficult for customers to understand the situation of goods in transit and to trace the source of defective products. Therefore, it is necessary to build a real-time monitoring system for cold-chain logistics and make a reasonable planning of car routing.

2. Application Demand Analysis of Cold-chain Car Scheduling

After investigation, in addition to trunk transportation, the existing cold-chain logistics technology is most widely used in the city distribution system. The structure of this kind of system can be roughly summarized as a Regional Distribution Center (RDC) as the general distribution center. According to the demand intensity of the city, the location planning is carried out and several front warehouses which provide the last kilometer of distribution are established to ensure the cost reduction of bulk goods and flexibly match the different demands of SKU in different regions, and to ensure the distribution time limit of the last kilometer to reduce the time loss of goods. In addition, in the research, it is found that most enterprises adopt the distribution mechanism of: shipment from RDC to front warehouse. If there is a supply-demand difference between the front warehouses in different regions, the distribution mechanism where the goods will be transshipped from closest front warehouse A with surplus stock to the front warehouse B out of stock will be adopted. Based on this kind of setting, demand problems that need to be solved can be divided into three levels:

- Batch distribution: RDC will distribute goods to all front warehouses according to the demand of different regions through cars available every day. At this stage, it is necessary to solve the car scheduling problem and reduce the logistics cost with the optimal routing scheme.
- Front warehouse determination: when the system receives an order, it will automatically match and determine the optimal front warehouse from which the goods should be distributed to avoid cost waste caused by cross-regional distribution.
- Last kilometer distribution: when the front warehouse receives the system order, it will integrate the indicators such as user satisfaction and cost, calculate the weight of different indicators through machine learning, and carry out small-scale route planning and order consolidation to maximize the comprehensive efficiency. The process will not be repeated here.

3. Car Path Optimization of RDC-front Warehouse

3.1. Problem Description and Assumptions

The problem of using a cold-chain network for goods scheduling from RDC to a front warehouse in a city can be described as follows: In a car scheduling system, the demand of the front warehouse in each region varies with the region, but the demand of the front warehouse is relatively stable in a certain period of time, and the position is fixed. Now in this system, there is only one RDC in a city, but there are multiple distribution cars with the same maximum load. Considering the driver fatigue and the car fuel consumption/cold-chain facility and equipment loss, each car has a single maximum travel distance. Now, it is necessary to obtain the most reasonable car distribution route. The restrictions are as follows:
• If the total driving route of a car is called a distribution route, the sum of the demand for goods in each front warehouse should not exceed the total load of the car;
• The total driving distance of each distribution route (i.e. the route sum of each front warehouse) should not exceed the maximum driving distance of a car’s single distribution;
• The demand of each front warehouse must be met, and only one car can distribute goods to save resources and reduce transportation costs.

The assumptions are as follows:
• The transportation cost of goods in several SKUs of different front warehouses is calculated by heavy goods, and the facility conditions required for storage and distribution are the same. The SKU whose load capacity meets the conditions and whose volume exceeds the car capacity is ignored when the price is calculated by bulky goods;
• It is assumed that the driving time between different front warehouses is directly proportional to the route distance between different front warehouses, and other situations such as traffic jams/road conditions are not considered.

3.2. Goal Definition
For enterprises using scheduling system, two main factors are considered: distribution time limit and total logistics cost, which are a double goal optimization problem:

Disassembly of total logistics cost structure:
• Warehouse and labor costs: in the design of the above-mentioned scheduling system, he front warehouse and RDC are for the system, so the cost of this part is fixed; because each front warehouse is required every day and only needs to collect goods once, the labor costs are also considered as fixed values;
• Scheduling cost: scheduling cost is only related to the total distribution route.

In view of the particularity of the cold chain, the cost structure is that scheduling costs account for a large proportion, while the warehouse and manpower account for a small proportion; in order to reduce costs on the entire chain, priority is currently given to optimizing scheduling costs; Through comprehensive consideration of the above two points, this model can be simplified to the problem of single-target car routing optimization for one-way distribution, that is, obtaining the minimum value of the total distribution route.

3.3. Model Establishment and Variable Definition
Definition of basic variables:
K: Use K cars to schedule the distribution of the front warehouse.
L: The demand for goods with L front warehouses needs to be met.
X_k: The maximum load capacity of each car is related to the attributes of the car itself, (k = 1, 2, ..., K)
Y_i: The demand of each front warehouse is related to the regional attributes of the front warehouse, (i = 1, 2, ..., L)
C_{ij}: Distance from front warehouse i to j
n_k: Number of front warehouses for distribution of the k_{th} car
r_i: In a distribution route, the front warehouse is arranged in the i_{th} for cars to distribute, (i = 1, 2, ..., n_k), where r_{k0} = 0 is RDC.

Objective function
\[ W = \min \sum_{k=1}^{K} \left( \sum_{i=1}^{L} C_{r_i r_{i(k-1)}} + C_{r_{k0} r_{k(k-1)}} \cdot \text{sign}(n_k - 1) \right) \]  \hspace{1cm} (1)

Constraints and interpretation
\[ \sum_{i=1}^{n} Y_{n_i} \leq X_k, k = 1,2,\ldots, K \]  \hspace{1cm} (2)

\[ 0 \leq n_k \leq L, k = 1,2,\ldots, K \]  \hspace{1cm} (3)

\[ \sum_{k=1}^{K} n_k = L \]  \hspace{1cm} (4)

\[ \text{sign} \ (n_k - 1) = \begin{cases} 1, & n_k \geq 1 \\ 0, & \text{other} \end{cases} \]  \hspace{1cm} (5)

\[ \sum_{i=1}^{K} n_i = 1 \]  \hspace{1cm} (6)

3.4. Optimized Genetic Algorithm for Car Routing Problem

The disadvantage of the simulated annealing method is that the convergence speed is relatively slow and the execution time is relatively long. The performance of the algorithm is related to the initial value. At the same time, the parameters are relatively sensitive and the reproducibility is poor. However, the ant colony algorithm is more likely to fall into the local optimal solution, so we use an optimized genetic algorithm to solve the scheduling problem here.

Genetic algorithm is a kind of search algorithm, which can solve the optimization problem. The search algorithm is the evolutionary algorithm which first refers to Darwin’s theory of biological evolutionism and Mendel’s theory of hybrid genetics, and evolves according to the phenomenon of biological evolution, including genetic phenomenon of gene, mutation of gene, natural random selection and hybrid phenomenon. Genetic algorithm is to simulate the relevant theory of biological evolution put forward by Darwin in nature to derive the method of global random search and optimization. The essence of genetic algorithm is an efficient, parallel and global search method, which can automatically acquire and accumulate knowledge about search space in the search process and adaptively control the search process to calculate the global optimal solution [6]. Genetic algorithm is operated by the law of survival of the fittest, that is, select the optimal individuals from each generation of the existing population, and then generate a new approximately optimal individual, i.e. approximately optimal solution, according to the methods such as individual’s heredity and mutation and to their fitness value to the problem domain. This process can cause the continuous evolution of individual in the whole population, so as to get a new individual. It can be called a natural selection if the fitness of the new individual to the natural environment is higher than that of the original individual.
3.4.1. Execution Flow Chart of Genetic Algorithm. The execution flow chart of genetic algorithm is shown in figure 1.

![Execution Flow Chart](image)

**Figure 1.** General algorithm execution flow chart.

3.4.2. Genetic Algorithm Composition Structure and Basic Interpretation. Basic structure of output strategy-chromosome coding. In this problem, in order to solve the car route optimization problem, the format of the output strategy (i.e., the optimal solution within the computable range) needs to be defined. Here, the order Li of the front warehouse is directly adopted as the composition of the output strategy; For example: if there are 10 front warehouses and 3 available distribution cars, the code of the front warehouse is marked as 1:10. If a strategy is output, K=1: (10, 2, 8, 7); K=2: (4, 5, 1, 9); K=3: (3, 6). The output strategy represents the distribution route of three cars; When genetic algorithm is used to solve the problem, we regard the output strategy as chromosome coding, i.e. a certain distribution method; the information represented by the coding of each chromosome is as follows: which car is responsible for the distribution of the front warehouse and in the current car distribution route, the order of this front warehouse is arranged in which place;

3.4.3. Strategy Evaluation Function-Fitness Calculation. For the strategy of algorithm output, it is necessary to find a reasonable way to evaluate its feasibility, and evaluate its advantages and disadvantages to ensure that it is available in the actual situation and can achieve the effect of cost minimization.

- Feasibility guarantee. Due to the constraints of the model constraints, all strategies of the population output by each iteration can already guarantee: The total demand of the front warehouse on each route does not exceed the maximum load of the cars on the distribution route; The total driving distance of each route does not exceed the longest single driving distance of the cars on the distribution route; However, it cannot be guaranteed that: One car will be scheduled to each front warehouse to avoid waste of resources.

- Chromosome advantages and disadvantages. If the chromosome can minimize the objective function, it is regarded as the optimal solution in the current evolution algebra. Based on the above two considerations, it is necessary to set a fitness calculation function in the genetic algorithm to evaluate whether each chromosome can be inherited or output as the final result. Therefore, it is defined that: $\beta$ is the punishment weight of infeasible distribution route. Take a larger positive route which is preferably far greater than the objective function.

$$M = \begin{cases} 
1, & \text{need of some storehouse can't be met} \\
0, & \text{need of all storehouse can be met}
\end{cases}$$

(7)
If the demand of the front warehouse cannot be met, the parameter of the distribution route strategy is $M=1$, and the punishment should be added to make the algorithm recognize it as infeasible.

$$f = \frac{1}{W + M - \beta}$$

(8)

The fitness calculation formula unifies the strategy feasibility and the effect advantages and disadvantages into a single value as the ranking index.

3.4.4. Other Parameters Execution Process Settings. In summary, the research on the optimization strategy of cold-chain logistics car scheduling can effectively reduce the loss in the transportation process, save the transportation cost, ensure the quality and safety of perishable products, and effectively prevent and trace a series of problems affecting the safety of perishable products such as chain break and temperature fluctuation in the cold-chain transportation process to ensure the safety of products. This strategy is of great significance for the efficient management and security of small-and medium-sized third-party cold-chain logistics enterprises.

- Initial population $M$. In the initial case, $M$ chromosomes are generated as the initial population, that is, each chromosome represents a distribution method, $M$ distribution methods are initially generated as the basic candidate pool, and the coding of each chromosome is different;
- Maximum evolution (iteration) number $N$. The termination condition of the algorithm iteration is that when the number of iterations reaches $N$, stop evolution, and output the chromosome with the highest fitness (the best effect) at this time as the current optimal solution of the shortest route problem of the car;
- Crossover probability. In this algorithm, the probability set to 0.8 is used as the crossover probability. In each generation of chromosome population generated, the chromosomes are crossed and recombinated with a certain crossover probability. However, in this problem, because the total number of front warehouse is small, there are not many cases falling into local optimum to make the population continue to evolve and iterate;
- Probability of mutation. In this algorithm, the probability set to 0.01 is used as the mutation probability. The chromosome genes in different positions are mutated;
- Natural selection strategy. In the population results of each generation, the fitness of individual is calculated. The best individuals are selected to enter the next generation and rank them as the first. The other chromosomes of the population in the next generation are produced and formed into the new species group by using the roulette wheel selection according to the fitness of other individuals of the population in the previous generation.

4. Conclusion
As people’s material and cultural life is getting richer and richer, people’s quality requirements for perishable products are constantly improving, which has led to the rapid development of cold-chain logistics. In this paper, aiming at the problems of high transportation cost and inadequate supervision in the transportation process of small- and medium-sized cold-chain logistics enterprises, combined with the actual monitoring and scheduling demands of enterprises for cars, a car scheduling model with the minimum total route is built, the genetic algorithm is selected and improved, and the car scheduling optimization strategy is proposed, which provides a theoretical research basis for the practical scheduling of the cold-chain car transportation from the urban center warehouse to the front warehouse, provides the basis for the optimization algorithm in the design of the dynamic monitoring system for the cold-chain logistics car, and provides a reference for the car scheduling of small- and medium-sized third-party cold-chain logistics enterprise.
5. References

[1] Liu X L 2017 Research on the joint distribution mode of cold-chain logistics under fresh e-commerce environment *Hebei Enterprise* **10** 76-77

[2] Xie R H, Zou Y F and Liu G H 2013 *Principle and Method of Cold-chain Transportation* (Beijing: Chemical Industry Press) 54-57

[3] Cui Zh F 2018 China cold-chain logistics review and 2019 trend outlook *Logistics & Material Handling* **2019** (S1) 14-16

[4] Yang S H 2018 Problems and countermeasures of cold-chain logistics in China *China Circulation Economy* **04** 18-20

[5] Ning X L 2010 Cold-chain logistics mode of food in china *China Logistics and Purchasing* **20** 68-69

[6] Li R P 2014 *Research on Heuristic Optimization Algorithm and Its Application* (Shenyang: Northeastern University) 14-16