STUDY ON VEHICLE ROUTING OPTIMIZATION OF COLD CHAIN LOGISTICS WITH SOFT TIME WINDOW UNDER STOCHASTIC DEMAND

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In the paper, we proposed a vehicle routing model with soft time window. The objective function of the model is to minimize the total cost including fixed cost, transportation cost, refrigeration cost, damage cost, penalty cost and shortage cost. We introduce customers' satisfaction rate into the constraints of the model. According to the characteristics of the model, we design a hybrid algorithm which combines Monte Carlo with Periodic Evolutionary Genetic Algorithm. Through practical numerical case, we discussed the relationship between customers' satisfaction rate and total cost, and the influence of customers' demand maximum deviation value on cost. The results show that the model and algorithm can effectively and feasibly solve the vehicle routing problem of stochastic demand in cold chain distribution system, which can provide scientific decision-making reference for the distribution of cold chain logistics enterprises.

Keyword: Cold chain logistics; Vehicle routing; Periodic Evolutionary Genetic Algorithm; Monte Carlo

1. Introduction

In recent years, with the continuous improvement of people's living standard in China. Consumers put forward higher requirements for food safety, freshness and convenience, as well as diversity of food categories. The food is not limited in original production and consumption field, which promotes the rapid development of the cold chain logistics industry. Cold chain logistics means that frozen foods, special logistics to ensure food quality, is always in a prescribed low temperature environment in the production, storage, transportation, sales and other links [1]. The particularity of cold chain logistics is mainly due to the perishable of the products and the high requirement of timeliness. The value of the products will gradually decrease with the passage of time, which increases the cost of

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distribution. This requires the distribution enterprises to formulate reasonable distribution routes, improving the efficiency of distribution.

Vehicle Routing Problem (VRP) is the key to the total cost reduce of cold chain logistics distribution. VRP and its variants have been researched in previous work. The Vehicle Routing Problem of cold chain logistics were researched and reported in literature [2-13]. Literature [14-20] investigated and reported the normal temperature logistics under stochastic demand. For example, Osvald et al. [2] researched Vehicle Routing Problem with time windows, time dependent and travel-times (VRPTWTD). The model was solved by Tabu Search Algorithm. A non-linear mathematical model was established to maximize the expected total profit of suppliers by Chen [3], and the model can determine the optimal production quantity, start-up time and vehicle routing simultaneously. Belo-Filho et al. [7] studied the supply chain planning of products with limited life span, and Adaptive Large Neighborhood Search Framework was proposed to solve the problem. Amorim et al. [8] taking Portugal food distribution company as an example, Adaptive Large Neighborhood Search Framework was designed to optimize the distribution routing, and the optimized routes were compared with the company's plan, which proves the advantages of the algorithm. Song et al. [9] constructed a nonlinear mathematical model, and the objective function of the model was to maximize the total level of customers' satisfaction. The validity of the model was proved by numerical examples. Ma et al. [10] proposed model of the vehicle routing with mixing windows. However, the shortage cost was not considered in the model. Wang et al. [13] constructed location–routing problem (LRP) model in cold chain logistics, and green and low-carbon was considered in the model. Zhao [15] established multi-objective vehicle routing model under stochastic demand with soft time window. The stochastic demand was processed by pre-optimization strategy, and A Hybrid Particle Swarm Algorithm based on Pareto was designed to solve the model. Marinaki et al. [17] proposed a new Hybrid Algorithm. Neighborhood Topology Glowworm Swarm and Variable Neighborhood Search were mixed in the new Hybrid Algorithm. The effectiveness of the algorithm was proved by the two test examples. Andres et al. [18] designed a Hybrid MetaHeuristic Algorithm to solve the Vehicle Routing Problem with stochastic demand. In order to show that the algorithm was superior to the existing Metaheuristic Algorithm in quality and efficiency, the new algorithm was tested on a 40 instances benchmark. Salavati-Khoshghalb et al. [19] proposed a more advanced rule-based recourse policy, which does not solely depend on the vehicle's residual capacity. Zhang et al. [20] proposed three probabilistic models for on-time delivery from different perspectives, and the three models were illustrated by numerical example.

It can be seen from above review that the research results of VRP in cold chain logistics considering customer stochastic demand are relatively few. Many studies assume that the probability distribution of customer demand was known. However, it is difficult to accurately measure the probability distribution of parameters in practical applications. In view of this, we establish a mathematical model of cold chain logistics VRP considering stochastic demand, the model objective function is minimum comprehensive cost, and the customers' satisfaction rate is introduced into the constraint conditions. Under the assumption that the probability distribution of customer demand is unknown, and customers' demand are evaluated in a bounded symmetric interval. Monte Carlo simulation method is introduced into the Periodic Evolutionary Genetic Algorithm to deal with the customers' stochastic demand and the opportunity constraint (8). Numerical example shows the effectiveness of the proposed algorithm.

The remainder of this paper is organized as follows: the description of the problem and a mathematical model are presented in Section 2; the designed algorithm is introduced in Section 3; a numerical example and concluding remarks are discussed in Section 4 and 5, respectively.

2. Model Formulation

2.1 Problem Description

The problem can be described as follows. Within a given area, a cold chain logistics distribution center provides cold chain products distribution services for multiple customers. Distribution center, vehicles' capacity and customers' geographical location are known, but customers' demand is unknown. Different customers have different requirements for the delivery time of goods. We try to solve problems: How to assign customers to each refrigerated vehicle, and customers delivery order, to minimize the total cost.

2.2 Parameters and Variables

To build the model, parameters and variables can be shown in Table 1.

Table 1

The meaning table of parameters and variables

Parameters and Variables	Meaning
M	The number of customers
K	The number of refrigeration vehicle owned by the distribution center
Q	Maximum load of refrigerated vehicle
d_{ij}	The distance between customer i and customer j
t_{ik}	The time when the refrigerated vehicle k arrives at the i customer
t_{ijk}	The driving time of refrigerated vehicle k between customer point i and customer point j
s_j	The service time required by customer j
f_k	The fixed cost of refrigerated vehicle k

u_j	Remaining cargo volume when refrigerated vehicle reaches the customer *j*
b_j	Remaining cargo volume when refrigerated vehicle leaves the customer *j*
v	Average speed of refrigerated vehicles
S_k	The actual load of refrigeration vehicle *k*
Q_i	The demand of customer *i*
B_1	The refrigeration cost which generate during transportation process of unit time
B_2	The refrigeration cost which generate during unloading process of unit time
P	Price of unit commodity
c	The transportation cost of refrigerated vehicle per kilometer
θ_1	The spoilage rate which generate during transportation process of unit time
θ_2	The spoilage rate which generate during unloading process of unit time
θ_3	The cost of waiting for the unit time if refrigeration vehicle arrives at customer node in advance
θ_4	The cost of punishing for the unit time if refrigeration vehicle is late for customer node
$[ET_i, LT_i]$	The time window that the customer *i* expects to be served
$[EET_i, ELT_i]$	The time service window that the customer *i* can be accept
τ	Out of stock cost per unit cold chain product
N_k	The actual total demand for customer points served by refrigerated vehicle *k*
α	Customers' satisfaction rate.
x_{ijk}	$x_{ijk}=1$ represents the refrigeration vehicle *k* passes the section between customer *i* and *j*, otherwise $x_{ijk}=0$
x_{jk}	$x_{jk}=1$ represents refrigerated vehicle *k* provides service for customer *j*,otherwise $x_{jk}=0$
Y_k	$Y_k=1$ represents refrigerated vehicle *k* of distribution center is used, otherwise $Y_k=0$

2.3 Model Formulation

The stochastic demand vehicle routing model of cold chain logistics with minimum total cost as objective function is established as shown follows:

$$\min\ z=\sum_{k=1}^{K} f_k Y_k+\sum_{k=1}^{K}\sum_{i=0}^{M}\sum_{j=0}^{M} c x_{ijk} d_{ij}+P(\theta_1\sum_{k=1}^{K}\sum_{i=0}^{M}\sum_{j=0}^{M} d_{ij} x_{ijk} u_j / v+\theta_2\sum_{j=1}^{M} s_j b_j)$$

$$+B_1\sum_{k=1}^{K}\sum_{i=0}^{M}\sum_{j=0}^{M} x_{ijk}(t_{ijk}+\max\{ET_i-t_{ik},0\})+B_2\sum_{k=1}^{K}\sum_{j=1}^{M} x_{jk} s_j+\tau\sum_{k=1}^{K} Y_k \max\{N_k-S_k,0\}$$

$$+\sum_{k=1}^{K}\sum_{i=0}^{M}(\theta_3 \max\{ET_i-t_{ik},0\}+\theta_4 \max\{t_{ik}-LT_i,0\}) \quad (1)$$

Subject to $$\sum_{k=1}^{K}\sum_{j=0}^{M} x_{jk} \le K \tag{2}$$

$$\sum_{i=0}^{M} x_{ijk} = x_{jk},\ j = 0,1,2,\cdots,M;k = 1,2,\cdots,K \tag{3}$$

$$\sum_{j=0}^{M} x_{ijk} = x_{ik},\ i = 0,1,2,\cdots,M;k = 1,2,\cdots,K \tag{4}$$

$$\sum_{k=1}^{K} x_{jk} = 1,\ j = 1,2,\cdots M \tag{5}$$

$$t_{jk} = t_{ik} + t_{si} + t_{ijk} \tag{6}$$

$$S_k \le Q \quad k = 1,2,\cdots,K \tag{7}$$

$$P(Y_k S_k \ge Y_k N_k) \ge \alpha \quad k = 1,2,\cdots K \tag{8}$$

The objective function (1) contains fixed cost, transportation cost, damage cost, refrigeration cost, shortage cost, and penalty cost. When satisfying the constraint conditions (2)-(8), objective function is minimized. Constraint (2) represents the existence of unused refrigerated vehicles in distribution center. Constraints (3) and (4) represent the flow conservation limits for each customer point. Constraint (5) indicates that every customer point is served only one time by a refrigerated vehicle. Refrigerated vehicle keeps service continuing between two customers' nodes imposed by constraint (6). The capacity limit of refrigerated vehicle is expressed by constraint (7). The customers' satisfaction rate is expressed by constraint (8).

3. Algorithm Design

An algorithm combining Periodic Evolutionary Genetic Algorithm with Monte Carlo is designed to solve the model in this paper. The algorithm simulates the phenomenon of "evolving-degeneration" in the process of natural evolution and presents the characteristic of periodic reciprocation reference [21-23]. The algorithm basic steps are shown as follows:

Step 1: Chromosomes coding. The model primary decision variables are the number of refrigeration vehicles dispatched, the number of customers served by per vehicle and the order of service. Therefore, the chromosomes are encoded by the corresponding arrangement coding method of vehicle and the customers, the basic idea is customers permutation denoted by M natural numbers which do not repeat. Meanwhile a vehicle permutation is expressed by k natural numbers which can be repeated ($k \in [1, K]$). These two permutations correspond to each other, and then a solution is formed. The solution is a distribution route scheme.

Step 2: Generate feasible initial population at random. Encoding the chromosomes produces the initial population according to the step 1 coding method. Monte Carlo simulation is used to verify whether the chance constraint (8) is reasonable or not. Whether vehicle load and customers soft time window constraint are satisfied or not. The chromosomes can be preserved as a feasible solution if these conditions are satisfied, otherwise another chromosome will be produced until *N* feasible chromosomes are produced.

Step 3: Selection strategy. Calculate the fitness value of the individual, and the individuals are selected by roulette in the population.

Step 4: Crossover and mutation operation. Determine whether the evolution period is satisfied or not. Cycle crossover, insertion mutation, reversed mutation operations are performed on individual if the evolution period is satisfied. Otherwise, the cycle crossover and exchanged mutation operation are directly executed on individual. After obtaining the new generation individuals. Monte Carlo simulation is used to verify whether the chance constraint (8) is reasonable or not. Whether vehicle load and customers soft time window constraint is satisfied or not, the route is redivided if the constrains condition are not satisfied. Otherwise step 5 is executed.

Step 5: Judge the termination condition. Iteration will stop if the maximum number of iterations is satisfied, and the best individual found in the process of solving is regarded as the optimal solution. Otherwise, let *gen* = *gen* + 1, go to step 3.

4. Description of Experimental Problems and Analysis of Experimental Result

4.1 Data Description and Parameters Setting

Some of the data used are from reference [25], and we select 20 supermarkets as customers in the case. Suppose the customer's demand probability distribution are unknown. The value range of customer *i* demand is $[\overline{q_i}-\delta, \ \overline{q_i}+\delta]\,(\overline{q_i}-\delta \geq 0, \delta \geq 0)$, $\overline{q_i}$ and δ are customer average demand and maximum deviation of customers' demand fluctuation respectively. Based on historical data from the past years. The twenty customers average demand are 1.2, 0.5, 1.5, 1.5, 2, 2, 1.8, 2.5, 1.2, 1, 1.3, 1, 0.5, 1.5,2, 2.5, 1.5, 0.5, 2.5, 1.1 respectively. The coordinates, time window and service time of 20 customer points are shown in the table 2. The coordinate of distribution center is (35, 35). The refrigerated vehicles type is consistent with the maximum carrying weight of 9 tons in the delivery process. The model parameters are set as follows:
$v = 30$km/h, $c = 3$ Yuan/km, $f_k = 200$ Yuan, $B_1 = 15$ Yuan/h, $B_2 = 20$ Yuan/h, $P =$ 1000 Yuan/t, $\theta_1 = 0.002$, $\theta_2 = 0.003$, $\theta_3 = 60$ Yuan/h, $\theta_4 = 60$ Yuan/h, $\tau = 20$ Yuan/t.

The parameters setting for the algorithm exerts a great effect on the algorithm's ability solving the problem, thus influencing the solution result of the model. We refer to the algorithm parameters setting in reference [26], and combine with the model established in this paper. The algorithm parameters are set as shown follows: the initial population N is 100. The number of maximum generations is 500. The crossover probability P_c and mutation probability P_m are 0.7 and 0.1 respectively. 10 is set as the number of iterations of an evolution period.

Table 2

Demand information of customers

Demand Point	X Coordinate (*km*)	Y Coordinate (*km*)	Prescribed time window	Acceptable time window	Service time(*min*)
1	29	21	6:00-8:00	5:30-11:00	15
2	35	53	7:30-9:00	7:00-10:30	10
3	15	25	6:00-8:00	5:30-8:30	15
4	15	50	6:30-8:20	6:00-9:00	15
5	55	40	6:40-8:30	6:10-10:00	20
6	45	40	7:00-9:00	6:30-10:20	20
7	50	20	7:20-9:00	7:00-11:30	20
8	60	27	7:30-9:00	7:00-10:00	25
9	40	10	7:00-8:30	6:40-9:30	15
10	50	5	7:00-9:00	6:30-11:40	10
11	40	45	7:30-9:30	7:00-12:30	15
12	55	60	7:30-9:00	7:00-12:00	10
13	40	65	7:30-9:30	7:00-10:30	10
14	60	50	7:30-9:00	7:00-11:00	15
15	65	40	6:50-8:30	7:00-12:00	20
16	50	30	7:00-8:40	6:20-11:30	25
17	55	10	7:00-8:40	6:40-11:30	15
18	25	50	7:50-9:00	7:00-12:00	10
19	25	60	6:30-8:30	6:00-11:30	25
20	15	20	7:50-9:00	7:00-11:00	15

4.2 Analysis of Experimental Result

The proposed algorithm and computations are worked out with the help of MATLABR2017a package; the numerical experiments are carried out on a computer with windows 7-x32 operating system, Intel Core i7, CPU @ 3.4GHz and memory 4GB.

4.2.1 Convergence Analysis of the Algorithm

The section assume α is 0.95, and δ equals 0.5. The demand of customer points is processed by Monte Carlo stochastic simulation. For each G value, Monte Carlo sample size G = [10,20,50,100,200,500,100] independently. The standard deviation of the objective function is shown in table 3, and it can be seen that the standard deviation of the objective function decreases with the increase of G and tends to stabilize. The results show that the algorithm designed has good convergence in this paper.

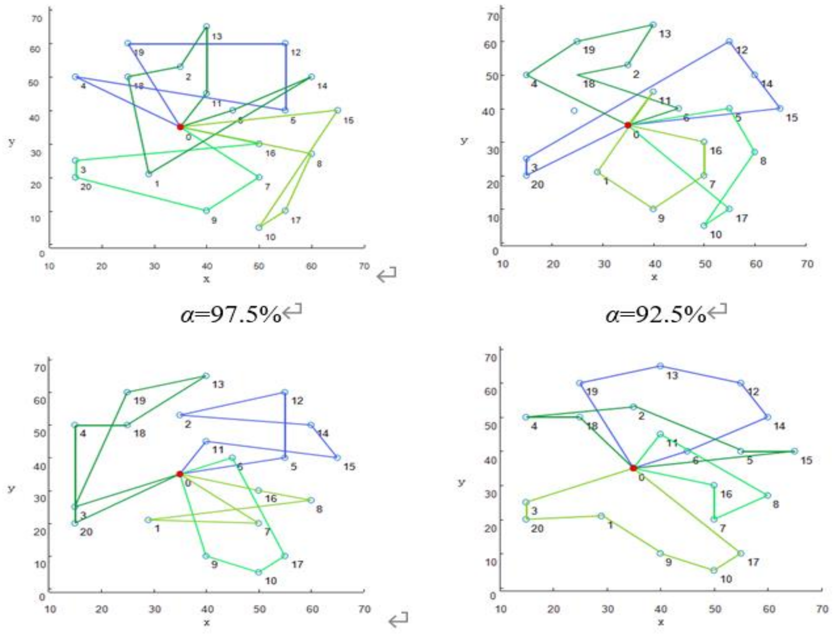
Table 3

Monte Carlo simulation results

Monte Carlo simulation times	10	20	50	100	200	500	1000
Standard deviation of objective function	228.8	120.1	93.1	78.1	67.8	26.7	15.6

4.2.2 Sensitivity Analysis of the Customers' Satisfaction Rate

The optimal distribution path, corresponding total cost and distribution distance when δ equals 0.5 and α is 97.5%, 95%, 92.5% and 90% respectively are shown in Fig. 1 and Table 4. Its can be concluded that no matter how the customers' satisfaction rate change. The number of vehicles used is always 4. When the customers' satisfaction rate is 90%, the minimum total delivery cost and the shortest total delivery mileage are 2797.3 yuan and 394.78 kilometers respectively. When the customers' satisfaction rate is 97.5%, the maximum total delivery cost and the longest total delivery mileage are 3618.32 yuan and 536.69 kilometers respectively. With the improvement of customers' satisfaction rate. The total cost and total mileage are increasing continuously. Therefore, in the context of customers stochastic demand. Enterprises must make rational planning of vehicle distribution routes in order to decrease cost and meet customers' need.



α=97.5% α=92.5%

α=95% α=90%

Fig. 1. The optimal distribution route under different customers' satisfaction rate

Table 4

The cost detail under δ is 0.5 and different α

α value	97.5%	95%	92.5%	90%
Distribution route	0-4-5-12-19-0 0-15-10-17-8-0 0-16-3-20-9-7-0 0-6-14-1-18-2-13-11-0	0-5-12-2-14-15-11-0 0-9-10-17-6-0 0-3-19-13-18-4-20-0 0-7-1-8-16-0	0-15-14-12-3-20-0 0-5-8-10-17-0 0-4-19-13-2-18-6-0 0-16-7-9-1-11-0	0-19-13-12-14-6-0 0-16-7-8-11-0 0-15-5-2-4-18-0 0-3-20-1-9-10-17-0
Total cost	3618.32	3483.21	3052	2797.3
Distribution distance	536.69	486.24	438.74	394.78

4.2.3 Sensitivity Analysis of Maximum Deviation Value for Customers' Demand

This part analyses the situation when the customers' satisfaction rate equals 95% and maximum deviation value is 0, 1, 1.5 and 2 respectively. The number of vehicles required by the optimal distribution path, the total cost and the value of each sub-costs are shown in Table 5. When the maximum deviation value for customers' requirement δ is 0, namely the customers' demand is deterministic demand. The number of vehicles required is 4. The number of vehicles required to meet the customer's demand is 5, when maximum deviation value is 1, 1.5 and 2 respectively. The fixed cost is always 1000 yuan. Transportation cost, cargo loss cost and refrigeration cost fluctuate less, and are relatively stable. Mainly because these costs are affected by transportation distance. The fluctuation of penalty cost and shortage cost are relatively obvious. Because the penalty cost is determined by the customers service time window, and the shortage cost is determined by the customers' demand. When the customers' demand is satisfied at a certain extend. The total cost increases with the increase of maximum deviation value for customers' demand. Indicating that the total cost will increase correspondingly if customers' demand fluctuating over a large range. The customers' demand fluctuate will increase the operating cost of enterprises and reduce the profits. Therefore, it is necessary to predict the customers' demand of distribution nodes in advance. This will reduce the influence of stochastic fluctuation of customers' demand on the operation cost and customers' satisfaction rate of enterprises, thus maintaining a good relationship between distribution enterprises and customers.

Table 5

The cost detail under α is 0.95 and different δ

δ value	Number of vehicle	Fixed cost	Transportation cost	Damage cost	Refrigeration cost	Penalty cost	Shortage cost	Total cost
δ =0	4	800	1195.85	231.37	334.76	115.15	17.9	2695.03
δ =1	5	1000	1451.4	213.79	396.84	443.01	249.92	3754.96
δ =1.5	5	1000	1807.02	244.33	436.8	517.03	400.86	4406.04
δ =2	5	1000	1786.3	268.03	455.53	917.37	712.78	5140.01

5. Conclusion and Discussion

In this paper, under stochastic demand, the chance constraint model of cold chain logistics distribution routing with soft time window is established. The objective function of the model is to minimize the sum of fixed cost, transportation cost, damage cost, refrigeration cost, penalty cost and shortage cost. We have assumed that the customers' demand is unknown, to solve this problem, we design a hybrid algorithm which combines Monte Carlo with Periodic Evolutionary Genetic Algorithm. Through practical application cases, the convergence of the algorithm is illustrated. The influence of the change of customers' satisfaction rate and customers' demand maximum deviation value on the total distribution cost are analyzed. The results show that the model and the algorithm are effective and feasible, which can reflect the impact of customers demand fluctuation and customers' satisfaction rate on enterprise distribution cost. Thus, the model and algorithm provide certain application value for distribution enterprises route plan. At the same time, the case analysis result indicates that enterprises must investigate and understand customers' demand well in advance. Thus, the enterprises arrange distribution vehicles routing reasonably to reduce the impact of customers' stochastic demand on the distribution cost of enterprises, which can ensure that the distribution enterprises maximize the benefits while customers' demand is satisfied.

Although scholars have done a lot of research on the vehicle routing problem of stochastic demand. There were still few studies on cold chain logistics delivery routing. The cost functions are not comprehensive in the literature [10]. The literature [10] did not take the shortage cost into account. In terms of stochastic demand processing, assumption that the probability distribution of customers' demand was known in the literature [10,17,18]. But in fact, customers' demand information may present discrete or interval form stochastic change. Thus, in this paper, we assumption that customers' demand is evaluated in a bounded symmetric interval. The Monte Carlo method was introduced to deal with customers' stochastic demand. However, this paper also has some shortcomings. For example, the delivery routing planning can't take a real geographical situation into account. Therefore, we will introduce a road congestion index into the model in the future research in order to better solve the actual problem.

Acknowledgments

This work is supported in part by National Key Research and Development Program of China（2017YFE9134700）, the EU Horizontal 2020 project (690713); National Natural Science Foundation of China (51408321); Natural Science Foundation of Zhejiang Province (LY15E080013) and Ningbo Natural Science Foundation (2016A610233, 2018A610200).

REFERENCES

[1]. *Q. Wang, Y. Q. Duan, B. Zhan,* "Main method and experience of overseas farm produce cold chian logistic development", in Logistics & Material Handling, **vol. 12**, no. 2, pp. 89-91, 2007.

[2]. *A. Osvald, L. Z. Stim,* "A vehicle routing algorithm for the distribution of fresh vegetables and similar perishable food", Journal of Food Engineering (S0260-8774), **vol. 85**, no. 2, pp. 285-295, 2008.

[3]. *H. K. Chen, C. F. Hsueh, and M. S. Chang,* "Production scheduling and vehicle routing with time windows for perishable food products", Computers & Operations Research, **vol. 36**, no.7, pp. 2311- 2319, 2009.

[4]. *Y. Zhang, X. D. Chen,* "An Optimization Model for the Vehicle Routing Problem in Multi-product Frozen Food Delivery", Journal of Applied Research and Technology, **vol. 12**, no. 2, pp. 239-250, 2014.

[5]. *Z. Yong, J. I. Ying-Feng, Y. Hua-Long, et al.,* "Optimization of Vehicle Routing Problem with Simultaneous Delivery and Pickup for Cold-chain Logistics", Mathematics in Practice and Theory, **vol. 46**, no. 20, pp.70-74, 2016.

[6]. *X. Xing, Z. Yun, T. Nyberg, et al.,* "Study on optimization of the food cold chain transportation service network based on the extenics", **vol. 11**, no. 2, pp. 131-136, 2016.

[7]. *Belo-Filho, M. A. F., P. Amorim, and B. Almada-Lobo,* "An adaptive large neighborhood search for the operational integrated production and distribution problem of perishable products," International Journal of Production Research, **vol. 53**, no. 20, pp: 1-19, 2015.

[8]. *P. Amorim, S. N. Parragh, F. Sperandio, et al.,* "A rich vehicle routing problem dealing with perishable food: a case study", TOP: An Official Journal of the Spanish Society of Statistics and Operations Research, **vol. 22**, no. 2, pp. 489-508, 2016.

[9]. *B. K. Song, Y. D. Ko,* "A vehicle routing problem of both refrigerated- and general-type vehicles for perishable food products delivery", Journal of Food Engineering, **vol. 169**, pp. 61-71, 2016.

[10]. *X. G. Ma, T. J. Liu, P. Z. Yang,* "Vehicle Routing Optimization Model of Cold Chain Logistics Based on Stochastic Demand", Journal of System Simulation, **vol. 28**, no. 8, pp. 1824-1832, 2016.

[11]. *B. Yao, C. Chen, X. Song, et al.,* "Fresh seafood delivery routing problem using an improved ant colony optimization", Annals of Operations Research, **vol. 273**, no. 2, pp. 1-24, 2019.

[12]. *W. Yang, Q. Zhang, G. D. Li,* "Agricultural Optimization of Cold-Chain Logistics Distribution Routing Based on PSO", Journal of Shanxi University of Science &Technology, **vol. 31**, no. 3, pp. 150-153, 2013.

[13]. *S. Y. Wang, F. M. Tao, Y. H. Shi,* "Optimization of Location–Routing Problem for Cold Chain Logistics Considering Carbon Footprint", International Journal of Environmental Research & Public Health, **vol.15**, no. 1, pp.86-103, 2018.

[14]. *H. Lei, G. Laporte, B. Guo,* "The capacitated vehicle routing problem with stochastic demands and time windows", Computers and Operations Research, **vol. 38**, no. 12, pp. 1775-1783, 2011.

[15]. *Y. W. Zhao, C. Li, J. L. Zhang, et al.,* Research on Vehicle Routing Problem with Stochastic Demand Based on Multi-objective Method, Advanced Intelligent Computing - 7th International Conference, Zhengzhou, China, August, pp. 11-14, 2011.

[16]. *Y. W. Zhao, C. Li, J. L. Zhang, et al.,* "Novel algorithm for multi-objective vehicle routing problem with stochastic demand", Computer Integrated Manufacturing Systems, **vol. 18**, no. 3, pp. 523-530, 2012.

[17]. *M. Marinaki, Y. Marinakis,* "A Glowworm Swarm Optimization algorithm for the Vehicle Routing Problem with Stochastic Demands", Expert Systems with Applications, **vol. 46**, pp. 145-163, 2016.
[18]. *G. Andres, D. Laurence, L. Nacima, et al.,* "A Hybrid metaheuristic algorithm for the vehicle routing problem with stochastic demands", Computers & Operations Research, **vol. 99**, pp. 135-147, 2018.
[19]. *M. Salavati-Khoshghalb, M. Gendreau, O. Jabali, et al.,* "A hybrid recourse policy for the vehicle routing problem with stochastic demands", EURO Journal on Transportation and Logistics, **vol. 8**, pp. 269-298, 2019.
[20]. *J. Zhang, W. H. K. Lam, B. Y. Chen,* "On-time delivery probabilistic models for the vehicle routing problem with stochastic demands and time windows", European Journal of Operational Research, **vol. 249**, no. 1, pp. 144-154, 2016.
[21]. Baidu encyclopedia. Disaster theory, http://baike.baidu.corn/view/229124.htm, 2011-4-29.
[22]. *Z. Z. Fang,* Searching for the Logic of Life, Shanghai: Shanghai Jiaotong University Press, pp. 45-50, 2005.
[23]. *L. Xu, J. Wang, M. Huang,* "Application research on improved cyclical virus evolution genetic algorithm", Computer Integrated Manufacturing Systems, **vol. 13**, no. 4, pp. 777-781, 2007.
[24]. *B. Carlos, G. Patricia, S. Natalia, et al.,* "Comparison of Recombination Operators in Panmictic and Cellular GAs to Solve a Vehicle Routing Problem", Inteligencia Artifical Revista Iberoamericana De, **vol. 14**, no. 5, pp. 34-44, 2010.
[25]. *J. X. Li,* Study of Aquatic Products Cold Chain Logistics Network Distribution Optimization in Dalian, Dalian Maritime University, 2016.
[26]. *Y. Schwartz, R. Raslan, D. Mumovic,* "Implementing multi objective genetic algorithm for life cycle carbon footprint and life cycle cost minimization: A building refurbishment case study", Energy, **vol. 97**, no. 1, pp. 58-68, 2016.