The Optimization Analysis of Cold Chain Logistics Distribution Route based on Particle Swarm Optimization (PSO) Algorithm

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Abstract

Focusing that the goods delivered by cold chain has the characteristics of easy corrosion, distribution network and complicated distribution routes, we put forward particle swarm optimization (PSO) algorithm to make optimal distribution strategy and solve the VRP problem in the process of distribution. Aimed at optimizing the shortest distribution route we establish universal math model and build PSO solving model of cold chain logistics distribution to realize the distance distribution optimization problem. The results of experiments shows that the cold chain logistics distribution strategy of PSO can make the distance shortest and solve the nonlinear problem of cold chain logistics effectively.

Keywords: *Cold Chain Logistics, VRP Optimization, Shortest Path, PSO*

1. Introduction

Cold chain logistics generally refers that in each link of production, storage, sale and consumption cold storage refrigeration items are always under the stated low temperature to reduce the food loss. Graph 1-1 shows the transportation process of cold chain logistics in which raw materials start from the origin, travel by refrigerated trucks, cryogenic liquid and carrier vehicles to food processing plants, further process to made-up articles, travel again by refrigerated trucks, cryogenic liquid and carrier vehicles and finally arrive at commercial freezers of the supermarkets[1-2]. We have a high standard for the whole distribution process because of the unique characteristics of freshness and perish ability of cold storage refrigeration items. Therefore, the corresponding management and the investment of funds are larger than regular logistics[3-5].

As a VRP, the problem of cold chain logistics distribution is a combined problem with the important economic value. Normally the problem of cold chain logistics distribution has characteristics of many delivering points, sparse locations and complex distribution tasks and usually chooses the mode of "Level 1 match Level 2 send". How to choose an efficient distribution route, achieve distribution tasks fast, on time and guaranteed quality which is the main unsolved difficulty. In the essay based on the distribution model of cold storage refrigeration items we adopt the PSO algorithm and optimize the distribution strategy of cars according to the assigned distribution index to accomplish the distribution of cold storage refrigeration items in the complex route network[6].

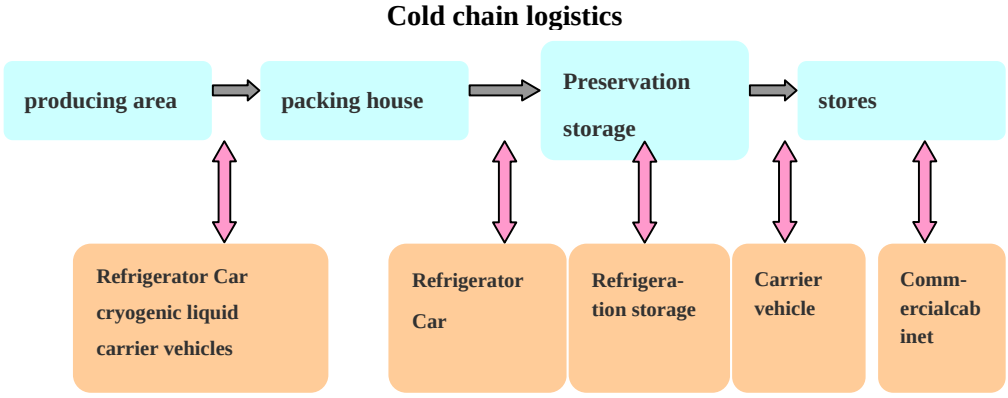

Figure 1. Flowchart of cold chain logistics and transport

2. The Present Situation and Countermeasure of Cold Chain Logistics in Our Country

2.1. The present situation and strategy research of cold chain logistics in our country

Currently the basic situation of cold chain logistics in our country is that self-support and third-party Logistics of enterprises or dealers of perishable food coexist. But the former is about 80 percent and the later is about 20 percent of the total logistics which shows that our cold chain logistics is still in the initial period of development. However, with the rapid development of Chinese economics, ceaseless improvement of our people's income and the enhancement of food safety consciousness the need for healthy and fresh food is larger and Larger and the development prospect of cold chain logistics is very wide[7].

2.1.1. The huge loss of cold chain transport

As reported by "The development planning of agricultural cold chain logistics 2012-2015", the loss of our agricultural product transportation is huge for a long time. The loss of meat, fruits and vegetables, and aquatic product respectively arrives at 12%, 13% and 15%. Only the loss of fruits and vegetables has passed one hundred billion RMB which both improved the price of agriculture and caused great waste. The wasted fruits and vegetables can meet the basic nutrition need and the loss occupies the world first place. Presently the gross development of cold chain logistics in Henan province is very slow and each link has not formed a closely related logistic network. Thus, 90 percent of Meat, 80 percent of aquatic product, a lot of dairy products, milk, fruits and vegetables are transported under ordinary condition which makes the product quality lower and loss larger.

Therefore, we should develop the market of our cold chain logistic rapidly, expand the refrigerated transportation capacity of food and reduce the loss of perishable goods. First we need to improve the refrigerated skill of transportation cars. The more important thing is to establish a modern, efficient, coordinate and green business logistics service system which couples with business service. It helps coordinate urban distribution, inter-city distribution and country distribution effectively and develop a business logistics service system in which markets at home and abroad mix together.

2.1.2. The equipment of cold chain logistic storage lags behind

The storage area of fruits and vegetables in our business system is about 200 square meters and capacity is over 1.5 million tons including mechanical refrigerated storage which is over 0.8 million tons. But all those still can't satisfy our huge supply of fruits and vegetables and not to mention to guarantee healthy and fresh fruits and vegetables. By this token one of the methods to make up for the loss of fruits and vegetables is to change regular refrigerated storage into mechanical refrigerated storage. Because in the process of storing fruits and vegetables mechanical refrigerated storage takes a clear advantage. For example, a mechanical refrigerated storage can control the temperature according to the need of fruits and vegetables, install the humidifying system and adapt to the need of fruits and vegetables. Moreover, the fruits and vegetables like grapes and bananas must be stored in a mechanical refrigerated storage which is stable, safe, neat and ventilating. Thus, one effective way to lower the huge loss of storage is to input capital to increase the number and quality of mechanical refrigerated storage and foster the corresponding cold chain logistic experts.

2.1.3. Seizing the opportunity period of cold chain development

NDRC, Ministry of Science and Technology and MIIT combine together to release a guide of the currently priority developed and high technology focused field in 2011 and cold chain logistics facilities are included into it. As shown in "The development planning of agricultural cold chain logistics 2012-2015", the cold chain of meat in the developed countries like European, America, Canada and Japan have achieved 100% and fruits and vegetables are above 95%. Compared with it the loophole of our cold chain is very huge.

According to statistics the number of constructed refrigerator is insufficient and their distribution is quite uneven. The total area of our business storeroom is about 1.5 billion square meters and the area of refrigerator is about 9 million square meters, only 6 percent of the total area. Moreover, the areas where refrigerators are built rapidly are concentrated on economic developed areas like coastal and big cities. This is because the construction cost of refrigerator is high and the economic development standard of coastal and big cities high which is more conducive to the construction of large cold storage. Basically the investment to cold storages can be divided into two parts, one is one-time investment in the early period including the investment of building structure and compressor unit which is above 5 million RMB and the other is later maintenance and electric charge. For the large cold storage the later input of equipment maintenance is about 30 percent of the total later input and electric charge is about 70 percent. Therefore, developing cold storage industry and enlarging the frozen and refrigerated capacity are one way to solve the problem of insufficient supply.

The annual eggs of our country is near 0.2 billion tons , fruit is about 0.61 billion tons, the quantity of aquatic product is 0.45 billion tons, increased by 4 percent annually, the number of meat products factories is over 2500 which produce 0.6 billion tons meat increased by 5 percent annually, the number of the quick-frozen food products factories is over 2000 and the annual production is over 85 million tons and the number of dairy industry is over 1500 which produce 0.1 billion tons increased by 20 percent annually.

The above data reveals that the large contradiction between the rapid expansion of food industry of our country and the seriously insufficient cold storage capacity which shows the inner potential of cold chain logistics market. With the improvement of people's life quality and the optimization and upgrade of enterprise structure the necessity and urgency of developing cold chain logistics is more to the show. So the chance of developing the cold chain logistics has arrived.

2.1.4. Introducing the specialized and standard third-party cold chain logistics enterprise

Currently the comprehensive service offered by our third-party logistics enterprises is less than 5 percent of the total. The most logistics and distribution business of circulating fresh perishable agricultural products and quick-frozen food is accomplished by producers and dealers. Although the logistics concept aimed at fresh perishable agricultural products and quick-frozen food has been widely accepted. Currently established cold chain logistics enterprises are regional, not nationwide and most of their scales are small which makes their market sizes and volumes are small. The mechanism to promote the sustainable development has not been established and the corresponding and restrictive laws and regulations have been imperfect. Thus, the development of our cold chain logistics needs to be joined by more professional, standard and international third-party cold chain logistics enterprises [3]. As shown in "The development planning of agricultural cold chain logistics 2012-2015", until 2015 our development goals of cold chain logistics are as follows: the cold chain flow rates of fruits and vegetables, meat and aquatic product are respectively increased to 20%, 30% and 36%, their transport coverage rates are respectively increased to 30%, 50% and 65% and rotten product rates are respectively reduced to 15%, 8% and 10%. In order to achieve this goal, on one hand we need our government' guide to integrate the existing resource and promote the industry to sustainable development, on the other hand speeding up the upgrade of logistics hardware equipment by social capital injection and professional technical support.

2.2. The analysis of our cold chain logistics operation mode

Currently the international and more developed food cold chain logistics has two modes: one takes enterprise as the main body of the food cold chain model which is more popular in Japan, Western Europe, Australia, the United States, our Taiwan and the other ensures that the general quality of a large number of food and reduce the loss in the pipeline and storage which is generally adopted by developing countries. Our ability of agricultural cold chain logistics infrastructure is seriously insufficient, logistics technology promotion and the development of third party cold chain logistics enterprises are lagging behind, and laws and regulations system and standard system are imperfect and so on. So we should alter cases according to circumstances and consider common development of a variety of patterns to achieve complementary advantages. For example, the core enterprises like

Shuanghui, Mengniu and Erie adopt fresh agricultural cold chain logistics operation mode and the chain supermarkets like Carrefour and Wal-mart adopt fresh agricultural "green channel" cold chain logistics operation mode to promote the development of fresh agricultural cold chain logistics.

3. The Mathematical Description of the Problem

In reality a VRP problem of logistics system is consisted of several parts: service area, warehouse and service point distributed in the service area. In order to abstract such a practical VRP problem into a mathematical model we need to set some premise: only a warehouse A where vehicles load goods and transport the goods back to and the transportation cost of vehicles are consisted of fixed cost and variable cost. Fixed cost includes the salary of distribution personnel and refrigeration equipment installed for transport vehicles. Variable cost includes the gasoline price spent in the process of transportation[8-9].

Imagine that A needs to deliver goods to 20 customer and the capacity of vehicles are infinite. Cij represents the transportation cost from point i to point j which includes fixed cost 25 RMB and the gasoline price in the process of transportation is 10 RMB per kilometer. Supposing that A coordinates [30 40] and the customers are serviced by a vehicle whose number is 1,2,…,L,…,20. We need to arrange vehicle routes reasonably to make the total transportation distance minimum. The mathematical model is as follows:

$$X_{ij} = \begin{cases} 1, & \text{from i to j} \\ 0, & \text{otherwise} \end{cases}$$

Establishing a mathematical model:

$$\min Z = \sum_{i=0}^{L} \sum_{j=0}^{L} c_{ij} * x_{ij} \tag{1}$$

st.

$$X_{ij} = 0 \text{ or } 1, ij = 1, 2, 3, ..., l \tag{2}$$

(1)guarantees that the total distance Z minimum.

4. Particle Swarm Optimization Algorithm Process

Particle swarm optimization algorithm (PSO) is a random search algorithm which is based on the group cooperation and developed by simulating flock foraging behavior. Usually we take it as a kind of Swarm intelligence (SI) and can be taken into a Multi-agent Optimization System (MAOS). PSO is invented by Doctor Eberhart and Kennedy. PSO is a kind of evolutionary computation method which is presently and widely applied to some fields like function optimization, neural network training and other application.

STEP 1 PSO Algorithm parameter Settings

Set PSO algorithm operation parameters: $C1 = 4$, $C2 = 7$.

STEP 2 Initialize population

Initialize the position and particle velocity of particles and calculate particle fitness value according to fitness function, $N = 20$.

STEP 3 Looking for initial extremum

Looking for individual extremum and group extremum according to the initial particle fitness value.

STEP 4 Iterative optimization

According to the formula update particle position and speed, and according to the new particle fitness value update individual extremum and group extremum. PSO uses speed - position search model. In the PSO system each alternative city solution is called a particle, multiple particles coexist (this instance is 20), cooperate for optimization, each particle flies to better position according to its own experience and the best experience of adjacent groups in the problem space and looking for optimization until find the optimal solution. Each particle represents a candidate solution and the

quality of solution is determined by the optimization objective function. The computation formula of iterative optimization is as follows:

$$V_{id}^{k+1} = wV_{id}^{k} + c_1 r_1 (P_{id}^{k} - X_{id}^{k}) + c_2 r_2 (P_{gd}^{k} - X_{id}^{k})$$
$$X_{id}^{k+1} = X_{id}^{k} + V_{id}^{k+1}$$

W is inertia weight, $d = 1, 2..., D; i = 1, 2, ..., n$; k represents the current iteration times; V_{id} represents the particle speed; c1 and c2 are nonnegative constants and accelerated factors; r1 and r2 are random numbers distributed in [0,1]. To prevent particle blind search we generally advised to limit its position and speed in a certain interval $[-X_{max}, X_{max}], [-V_{max}, V_{max}]$.

STEP 5 Interpretation of result

PSO algorithm iterates 200 times and we draw a picture of every generation optimal individual fitness value change[10-12].

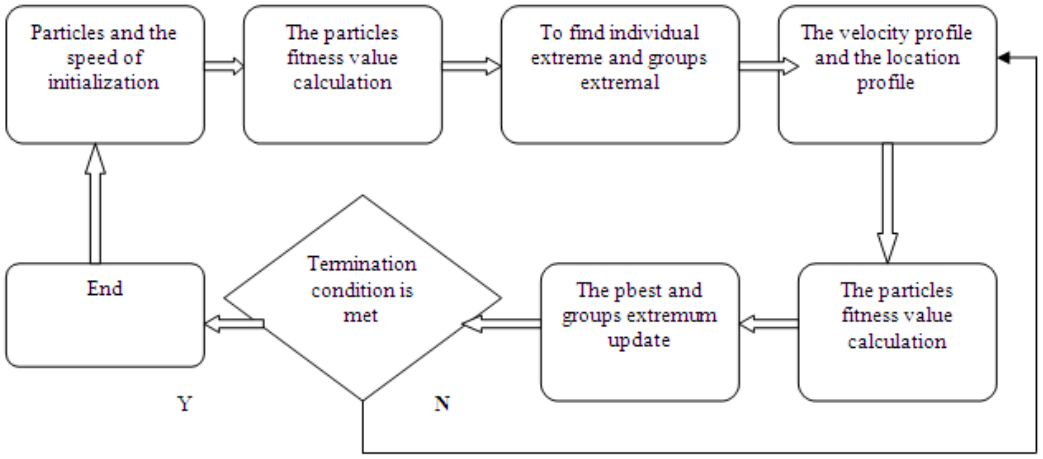

Figure 2. Algorithm processes

5. An Example of Simulation and Analysis

5.1. Simulation

Experimental environment: CPU2.1G, Intel®Core(TM)i3-2310M, RAM 2.00GB, DDR3, Windows 7, MATLAB7.0, VC ++ 6 0, the average time 30s.

Imagine that we study city road sections, a fixed distribution center A to distribute quick-frozen food to 20 customers, the fixed cost of vehicles is 25 RMB and gasoline price is 10 RMB per kilometer In the process of transportion. The distances between A and customers are shown in the figure 3. The experimental data adopts the 21 node map shown in the chart 4 (a) , as shown in the 21 node map A is a starting point and end point and we need to find a closed path to realize the shortest distance connection. For simplicity the weights of edges are calculated as Euclidean distance between nodes. Supposing that particle number n=20, c1=4, c2=7 and iterations are 200. Conducting 25 times calculation randomly, achieving optimal value every time and the average time is only 2.1s.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
1	0	12	19	31	22	17	23	12	24	34	12	21	42	27	36	19	31	28	46	21
2	12	0	15	37	21	28	35	22	16	28	11	25	50	38	35	9	34	36	51	12
3	19	15	0	50	36	35	35	21	31	43	25	38	61	46	51	23	48	47	64	8
4	31	37	50	0	20	21	37	38	33	31	27	13	15	18	19	35	8	8	15	49
5	22	21	36	20	0	25	40	33	12	14	11	9	35	30	15	16	15	23	32	33
6	17	28	35	21	25	0	16	18	34	40	22	18	27	10	34	32	25	15	35	38
7	23	35	35	37	40	16	0	14	46	54	33	34	40	22	51	41	41	30	50	40
8	12	22	21	38	33	18	14	0	36	46	24	30	45	28	46	30	39	32	52	26
9	24	16	31	33	12	34	46	36	0	12	13	21	48	41	23	8	27	35	44	25
10	34	28	43	31	14	40	54	46	12	0	22	23	46	44	16	20	24	36	39	37
11	12	11	25	27	11	22	33	24	13	22	0	14	40	30	26	10	23	26	40	23
12	21	25	38	13	9	18	34	30	21	23	14	0	27	21	17	23	10	14	26	37
13	42	50	61	15	35	27	40	45	48	46	40	27	0	18	32	50	22	14	14	62
14	27	38	46	18	30	10	22	28	41	44	30	21	18	0	35	40	24	10	29	48
15	36	35	51	19	15	34	51	46	23	16	26	17	32	35	0	30	11	25	23	47
16	19	9	23	35	16	32	41	30	8	20	10	23	50	40	30	0	31	36	48	18
17	31	34	48	8	15	25	41	39	27	24	23	10	22	24	11	31	0	14	17	46
18	28	36	47	8	23	15	30	32	35	36	26	14	14	10	25	36	14	0	20	47
19	46	51	64	15	32	35	50	52	44	39	40	26	14	29	23	48	17	20	0	63
20	21	12	8	49	33	38	40	26	25	37	23	37	62	48	47	18	46	47	63	0

Figure 3. The distance between distribution center A and 20 customers

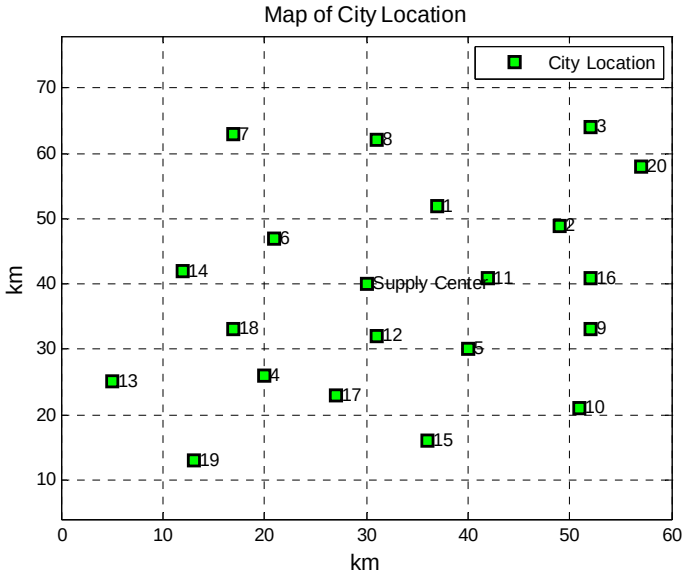

Figure 4. (a) city maps

5.2. The analysis of results

In the paper to solve the problem we used Matlab7.0 to program realization algorithm, totally iterated about 200 times and found when the iteration conducted roughly 63 times, the solution was stable. Finally as shown in figure 4 - (b) we get the optimal individual fitness value 235. We use PSO optimization algorithm to get the optimal value which is close to the actual optimal function value. It shows that PSO algorithm has stronger function extreme value optimization ability.

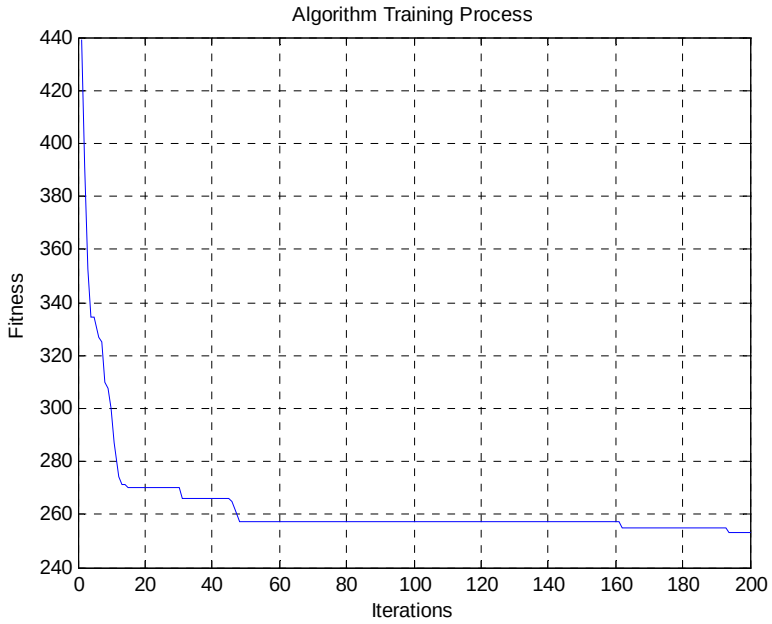

Figure 4. (b) best individual fitness value

The specific operation results are as shown in figure 4 (c):
Opt-tour= A 12 17 4 19 13 18 14 6 7 8 13 20 2 16 9 10 15 5 11 A
Opt-distance=253.1577
Opt-cost= 253.1577*10+25=2556.577

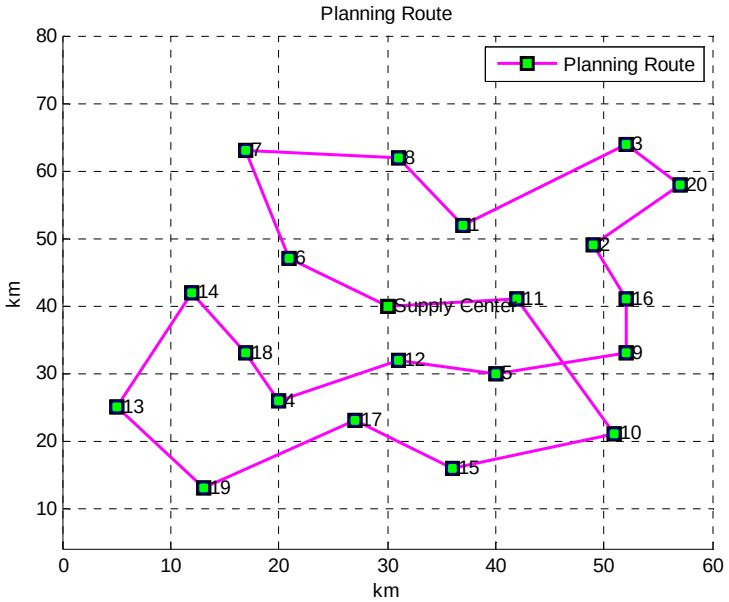

Figure 4. (c) Optimal path

6. Conclusion

In the actual distribution process the goods delivered by cold chain are all fresh and perishable goods which put forward a strict requirement about hardware facilities like the distribution vehicles,

the cold storage, the commercial fridges, and management mechanism. In the essay we first talk about the characteristics about cold chain and the development of our cold chain logistics. Through the contrast with developed countries, we find the future development direction of cold chain logistics and show the huge development potential of the cold chain logistics industry in the future. Then based on the particle swarm optimization algorithm (PSO) we solve actual VRP problems and find out the optimal path and the shortest distance. Through the comparison and analysis of the above initial operation results and optimal path results, we can see that particle swarm optimization algorithm (PSO) has a quick solution speed and the result is also optimal. Therefore, in the actual application, this model provides a theoretical basis in the planning vehicle optimal path for cold chain logistics and offering optimized distribution scheme for the distribution center which can not only help the distribution center improve efficiency, reduce costs and increase profits but also help more distribution centers to deliver fresh agricultural products, frozen food and special drugs to each customer conveniently.

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