Advances in Computer, Signals and Systems (2021) 5: 71-74
Clausius Scientific Press, Canada
DOI: 10.23977/acss.2021.050111
ISSN 2371-8838

Study on Optimization of Aquatic Product Transportation Route in Haikou Area Based on Simulated Annealing Algorithm

Qianqian Xu, Jie Wang

School of Management, Hainan University, Haikou, Hainan, 570228

Keywords: *Aquatic product transportation, Cold chain logistics, Path planning, Simulated annealing algorithm*

Abstract: In the process of seafood sales, the choice of transportation route directly affects the transportation efficiency and sales cost. In this paper, based on the investigation of main aquatic products markets in Haikou, a mathematical model of path planning is built with the goal of minimizing the cost, and the simulated annealing algorithm is used to solve the problem.

1. Introduction

Hainan Island is encircled by the sea and has rich marine fishery resources including fish, shrimp, crab, shellfish and so on. Haikou city is the political, economic, cultural and educational center of Hainan Province and logistics plays an important role in its modern service industry. For aquatic products, storage environment is strictly required in transportation. After fishing, aquatic products are shipped from wholesale centers to various retail markets. In order to meet consumers' needs of aquatic products in Haikou area and achieve efficient supply, it is necessary to find appropriate distribution routes within this region.

Chaudhuri et al. (2018) conducted a literature review of 38 research articles published between 2000 and 2016 and recognized the need for adopting a comprehensive analysis through data analytics in cold chain management. Drezner and Scott (2013) considered a single distribution center location serving a limited number of perishable product outlets and presented an effective method to solve the positioning problem in planar environment. Tian et al. (2019) shows that the improved ant colony algorithm can be used to calculate the optimal distribution path of chilled aquatic products and effectively improve the logistics transportation efficiency of frozen aquatic products in practical application. In this paper, we establish a distribution path planning model with multiple centers for aquatic product wholesale in Haikou city. Simulated annealing algorithm is used to solve the problem and the optimal path planning scheme is obtained. It simulates the realities and enables effective delivery of aquatic products.

2. Mathematical Model

We assume that the transported objects are containers of the same kind of aquatic product. The distribution centers have adequate stock. The delivery vehicles are identical and travel at the same speed. The geographical location and demand of distribution centers and material demand locations are given. There might be traffic jams, extreme weathers or other unexpected circumstances in transportation` so the required storage environment for the products cannot be satisfied, resulting in loss of products and increase of overall cost.

Sets: I =set of all retail markets(demand points),$\{i, j = 1,2,3, \dots n\}$, M =set of all wholesale centers(distribution center), $\{m = 1,2,3, \dots M\}$, R = I ∪ M =set of all wholesale centers and retail markets, $\{r = 1,2,3, \dots R\}$, L =set of all vehicles of a certain wholesale center, $\{l = 1,2,3, \dots L\}$.

Parameters: G =Capacity of vehicle, c_p =Variable cost of a vehicle, F_i =Fixed cost of a vehicle, φ=Probability of loss for each container, P =Unit price of the product, Q_i = Demand of retail market i, t_{ij} =Travel time from demand point i to j,t_i = Time of arriving at retail market i, $S_{r1,r2}$ =Distance between positions r_1 and r_2 , $(\mathrm{ET_i}, \mathrm{LT_i})$ =Preferred reaching period, α =Unit time cost for reaching ahead of $\mathrm{ET_i}$, β =Unit time cost for being late of $\mathrm{LT_i}$.

Decision Variables:

$$X_{ijl} = \begin{cases} 1, & \text{if arc}(i,j) \text{ is traversed by vericle } l \\ 0, & \text{otherwise} \end{cases}$$

$$Y_{il} = \begin{cases} 1, & \text{if retail market } i \text{ is served by vericle } l \\ 0, & \text{otherwise} \end{cases}$$

$$Z_{im} = \begin{cases} 1, & \text{if retail market } i \text{ is served by wholesale center } m \\ 0, & \text{otherwise} \end{cases}$$

2.1 Model

$$\min Z = \sum_{l\in L} F_l + \sum_{m\in M}\sum_{l\in L}\sum_{i\in R}\sum_{j\in R} C_p X_{ijl} S_{r1,r2} Z_{im} + \sum_{i\in I}\varphi_i p\, Q_i + \alpha\sum_{i\in I}\max\{ET_i - t_i, 0\} + \beta\sum_{i\in I} max\{t_i - LT_i, 0\} \quad (1)$$

Subject to:

$$\sum_{i\in I} Q_i Y_{il} \le G_l\,, \ \forall l \in L \quad (2)$$

$$\sum_{i=m\in M}\sum_{l\in L}\sum_{j\in I} X_{ijl} Z_{im} \le L, \forall m \in M \quad (3)$$

$$\sum_{l\in L}\sum_{j\in I} X_{ijl} = 1, \forall i \in I, \forall l \in L \quad (4)$$

$$\sum_{l\in L}\sum_{i\in I} X_{ijl} = 1, \forall j \in I, \forall l \in L \quad (5)$$

$$\sum_{l\in L} Y_{il} = 1, \forall i \in I, \forall l \in L \quad (6)$$

$$\sum_{l\in L}\sum_{i\in I}\sum_{j=m\in M} X_{ijl} Z_{im} = \sum_{l\in L}\sum_{j\in I}\sum_{i=m\in M} X_{ijl} Z_{jm}\,, \forall m \in M, l \in L \quad (7)$$

$$\sum_{l\in L}\sum_{m\in M}\sum_{j\in I} X_{ijl} Z_{im} = 1, \forall i \in I \quad (8)$$

$$\sum_{l\in L}\sum_{m\in M}\sum_{i\in I} X_{ijl} Z_{im} = 1, \forall j \in I \quad (9)$$

$$\sum_{i\in H}\sum_{j\in H} X_{ijl} = 0, \forall l \in L \quad (10)$$

The objective function of the model is given in equation (1), which minimizes the total costs. Constraint (2) represents the vehicle load limitation. Constraint (3) guarantees that the number of vehicles must not exceed the total number. Constraint (4) and (5) guarantee that each customer is visited exactly once by the same vehicle. Constraint (6) guarantees that each customer is visited by exactly one vehicle. Constraint (7) guarantees that vehicles start at the distribution center and finally return to the same place. Constraint (8) and (9) guarantee that each retail market is delivered by only one distribution center. Constraint (8) guarantees that there is no direct path between two distribution centers.

3. Solution Methodology

In view of the multi-distribution center problem studied in this paper, we first allocate the demand points to the distribution center with the shortest corresponding distance according to the distance between each demand point and the distribution center. Then we use simulated annealing algorithm which simulates the annealing process of the metal and searches for the satisfactory solution in the global scope through Metropolis rule. The algorithm flow chart in this paper is shown in Figure 1.

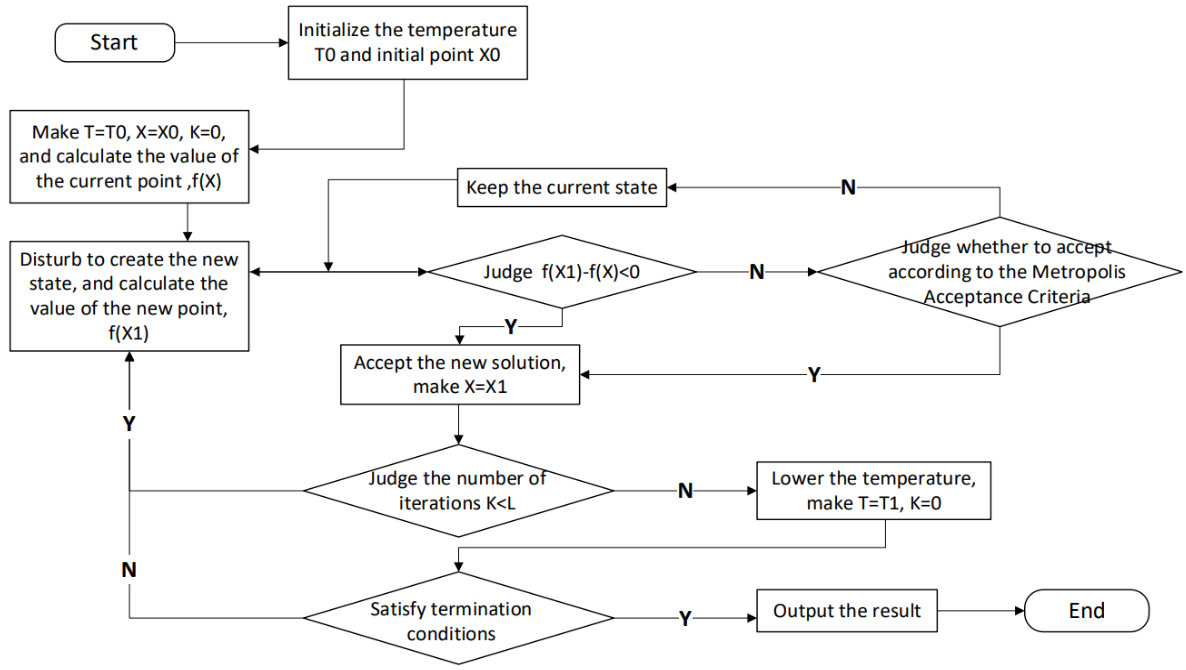

Figure 1: Algorithm flow chart

3.1 Solution Representation

Through investigation, the demand of main aquatic products markets in Haikou was obtained. Yanjiang Farmers' Market and Banqiao Road Seafood Market are the two main aquatic products wholesale centers in Haikou. The retail market information is shown in Table 1:

Table 1: Requirement point information

longitude	latitude	demand	longitude	latitude	demand	longitude	latitude	demand
110.258176	20.009996	137	110.348645	20.033758	154	110.35482	20.047123	156
110.259058	19.986296	125	110.348973	20.034214	136	110.3558	20.047799	153
110.286527	20.010958	250	110.349304	19.977341	121	110.356155	20.048366	98
110.305387	19.974827	155	110.349349	19.977408	97	110.357253	20.006387	80
110.307903	20.023555	121	110.352053	20.004619	126	110.357344	20.048842	217
110.310233	19.979174	245	110.352741	20.047807	231	110.336023	20.040648	127
110.313327	20.013025	109	110.353171	20.053894	111	110.338318	20.050459	202
110.314343	19.980862	94	110.353171	20.053894	136	110.338677	20.047315	201
110.31631	20.021016	161	110.353402	20.046817	158	110.338812	20.04699	106
110.319534	20.077351	132	110.354067	20.04697	196	110.339486	20.0486	133
110.3546	20.046122	206	110.346313	20.047791	217			

The coordinates of the distribution center are(110.346661, 20.056981)and (110.368357, 20.054157), The total number of vehicles is 8. Unit driving fee is 10 yuan /km, The fixed cost of per vehicle trip is 200 yuan. The average driving speed is 40km/h. Maximum deadweight of the vehicle is 900kg. The price per container is 800 yuan. The probability of loss is 0.02.

MATLAB was used for the experiment in this paper, and the distribution path of the experimental results is shown in Figure 2.

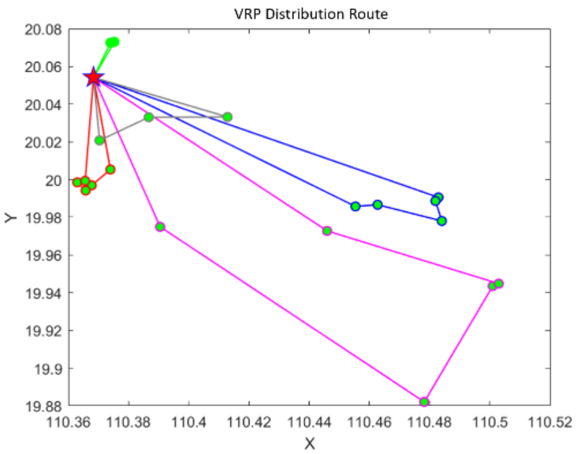

Figure 2: Vehicle distribution route

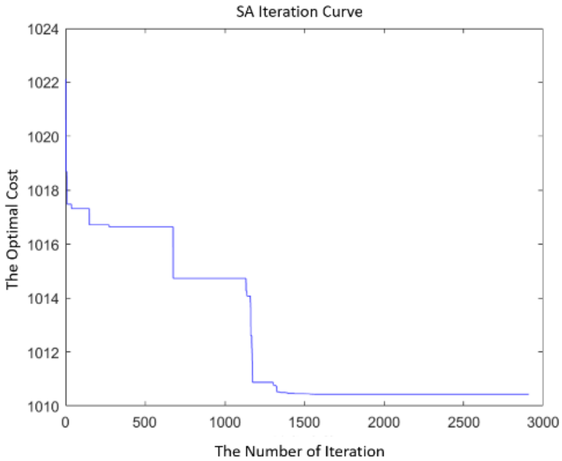

Figure 3: Iterative curve of simulated annealing algorithm

Figure 3 shows the optimization curve of the objective function. The optimal value of the objective function is reduced to 1010.4308 yuan. The number of vehicles used is 5 out of provided 8. It can be seen from the example that the simulated annealing algorithm performs well in the process of calculation and has good convergence effect. The calculation results are shown in Table 2.

Table 2: The experimental results

Vehicle number	Distribution path	Travel distance	Loading weight	Capacity utilizing ratio	Variable cost
1	0—>6—>4—>3—>1—>2—>0	0.126	740	0.822	1.268
2	0—>11—>10—>9—>7—>8—>0	0.041	874	0.971	0.412
3	0—>21—>20—>22—>18—>17—>0	0.285	802	0.891	2.874
4	0—>13—>19—>23—>24—>16—>0	0.454	900	1	4.575
5	0—>5—>12—>15—>14—>0	0.126	617	0.686	1.303

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