Research on Location of Sales Logistics Network Nodes Based on Chaotic Optimization Algorithm

CHUNGUANG JING

ABSTRACT

Logistics nodes are screened to obtain Alternative logistics nodes using principal component analysis. Sales logistics network location model is established to minimize the total cost of sales logistics network. Then Chaotic Genetic Algorithms is used to solve the model and obtain the position, number and size of logistics nodes, transport path and corresponding transportation volume from factory to nodes and nodes to customers. Finally, the validity of the model is verified by a practical example.

INTRODUCTION

Sales logistics network involves departure and arrival, namely the transport process from factory to logistics nodes and logistics nodes to customers\(^1\). On the issue of transported products, it includes the transport from semi-finished products to finished products, and both to logistics centers and demand points. Most existing logistics node location research take the transport of one single product as object, and does not consider the issue of transport of semi-finished and finished products\(^2-5\). In this paper, an effective location method of sales logistics network node of multiple product lines is proposed, which aims to the minimum total cost of logistics network.

PROBLEM ANALYSIS

Sales logistics network is shown in Figure 1. Products include semi-finished and finished products; the number and location of logistics centers are unknown; logistics centers serve for demand points. The total cost includes transportation costs, inventory costs, construction costs and penalty cost. Among them, the penalty cost is the cost loss when distance between logistics nodes and served demand points exceeds a certain range, transport costs and consumption will increase with distance increases. In summary, model constructed in this paper takes the minimum total cost as objective.
MATHEMATICAL MODELS

Assumptions

(1) The annual output of each factory, the amount from semi-finished products factory to logistics center, and the demand of semi-finished and finished products of each demand point are fixed and known;
(2) Inventory of each sales logistics nodes are able to meet its demand points;
(3) Unit transport cost is fixed, which is related to transport modes and volume;
(4) Unit transport cost of semi-finished and finished products within a fixed transport distance, and there would be penalty function exceeds it.
(5) The construction costs and inventory costs of different candidate logistics nodes are different;
(6) Average inventory time of semi-finished and finished products in logistics center is one week;

Symbol Definition

M—The total number of semi-finished products factory m=(1,2,3,…,M);
N—The total number of finished products factory n=(1,2,3,…,N);
Q—The total number of alternative logistics nodes q=(1,2,3,…,Q);
K—The total number of demand points k=(1,2,3,…,K);
A—The total number of existing logistics nodes a=(1,2,3,…,A);
R—The number of product species;
C_{ij}—Unit transport cost from point i to point j;
C_{rij}—Unit transport cost of product r from point i to point j;
D_{ij}—Distance between two point;
c_0—Unit transport cost of empty car;
t_{ij}—Annual transport volume of semi-finished products from point i to point j;
t_{rij}—Annual transport volume of product r from point i to point j;
x_i—Longitude coordinates of point i
y_i—Latitude coordinate of point i
gr_k—Demand volume of product r of demand point k;
D_q—Construction costs after depreciation;
D_0—Construction costs if the existing logistics node is selected;
S_q—Inventory costs;
Θq—When alternative logistics node q is chosen, 1. Otherwise, 0;
Ha—Annual rental fee of existing logistics node;
L—Ideal transport radius;
Uqk—Penalty coefficient, proportional to the exceeding distance;
Ei—Supply capacity of factory i.
Fk—The maximum capacity of the node k.

Model

(1) Objective function
\[
\min Z = \sum_{m=1}^{M} \sum_{n=1}^{N} (c_{mn} + c_0) d_{mn} + \sum_{m=1}^{M} \sum_{q=1}^{Q} (c_{mq} + c_0) d_{mq} + \sum_{r=1}^{R} \sum_{n=1}^{N} \sum_{q=1}^{Q} (c_{nq} + c_0) d_{nq} + \sum_{q=A+1}^{Q} \theta_q D_q
\]
+ \sum_{r=1}^{R} \sum_{q=1}^{Q} \sum_{k=1}^{K} (c_{rpk} + c_0) d_{rpk} + \sum_{q=1}^{Q} \left( D_0 - H_q \right) D_0 + \sum_{q=1}^{Q} \sum_{r=1}^{R} \sum_{k=1}^{K} \max \{ d_{rpk} - L, 0 \} U_{qk} t_{rpk} \tag{1}
\]

(2) Restrictions
\[
d_{mn} + d_{nq} > d_{mq} \tag{2}
\]
\[
\sum_{q=1}^{Q} t_{mq} + \sum_{r=1}^{R} \sum_{q=1}^{Q} t_{nq} \leq E_M + E_N \tag{3}
\]
\[
\sum_{m=1}^{M} t_{mq} + \sum_{r=1}^{R} \sum_{n=1}^{N} t_{nq} = \sum_{r=1}^{R+1} \sum_{k=1}^{K} t_{rpk} \tag{4}
\]
\[
\sum_{m=1}^{M} t_{mq} + \sum_{r=1}^{R} \sum_{n=1}^{N} t_{nq} \leq F_k \theta_q \tag{5}
\]
\[
\sum_{q=1}^{Q} \theta_q \leq q \tag{6}
\]
\[
V_{qk} = \begin{cases} 
1 & \text{if } \sum_{r=1}^{R+1} t_{rpk} > 0 \\
0 & \text{if } \sum_{r=1}^{R+1} t_{rpk} = 0 
\end{cases} \tag{7}
\]
\[
\sum_{r=1}^{R+1} \sum_{q=1}^{Q} t_{rpk} = \sum_{r=1}^{R+1} g_{rk} \tag{8}
\]

SOLUTION ALGORITHMS

Chaos genetic algorithm is selected, and the detailed design shows as follows:
(1) Encoding and decoding
It mainly points to the distribution relationship between logistics point and demand points, and 3-layer coding is adopted. In the first layer, k demand points are randomly shuffled; q logistics points are randomly shuffled in layer 2. Then generate \([1, q-1]\) different numbers as nodes between \([1, k-1]\) randomly in layer 3.

(2) Population initialization
Produce encoding individual with length of K+Q+N to constitute initial population randomly, \(0 \leq N < Q\). Former K-bit represent demand points of chromosome, intermediate Q-bit indicates alternative logistics nodes, back N-bit represent separation.

(3) Fitness function
Take the objective function as the fitness function.

(4) Crossover and mutation
Disrupt the numbers of all individual randomly, and transform as a group of eight. Select two points A and B between them randomly, \(1 \leq A < B \leq k\).

(5) Chaos
Set chromosome bits as L. First generate a chaotic sequence \(X_n\) using Logistic Mapping, and then map the sequence \(X_n\) to gene space of chromosome to complete crossover or mutation in the corresponding position.

CASE STUDY
Storage and distribution of existing logistics nodes are known. And there are 5 semi-finished product factories and 10 finished product ones both known with position and annual output. There are 101 demand points with information of annual demand and position of each point. Select some demand points with larger demand as alternative nodes. Then elect 28 alternative logistics nodes using principal component analysis method. Select \(N\) logistics node among them to minimize the overall cost. Set \(C_0 = 0\) and \(L = 600\). Table 1 shows part of distribution and demand of demand point.

Logistics node location results shows in Figure 2, which select point ‘2, 24, 15, 16, 18, 14, 1, 19’ as logistics node. And the optimal logistics cost is 13,197.84 million, among them, transportation costs from logistics nodes to demand points is 5,151.84 million, penalty cost is 241.25 million, construction cost is 681.48 million, inventory costs is 514.41 million, transportation costs from semi-finished product factory is 5,451.89 million, and transportation costs from finished product factory is 1,158.05 million. Delivery demand point of each logistics node, transport path and corresponding transportation volume from factory to nodes and nodes to customers can be also obtained. Due to the limited space, it is not displayed.

<table>
<thead>
<tr>
<th>Region</th>
<th>Semi-finished products (10,000 tons / year)</th>
<th>finished products (10,000 tons / year)</th>
<th>Longitude</th>
<th>Latitude</th>
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<tr>
<td>(k_1)</td>
<td>13.2</td>
<td>50.7</td>
<td>117.27</td>
<td>31.86</td>
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<tr>
<td>(k_2)</td>
<td>0</td>
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<td>118.73</td>
<td>31.95</td>
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<td>(k_3)</td>
<td>16.6</td>
<td>64.3</td>
<td>118.44</td>
<td>32.33</td>
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<tr>
<td>(k_4)</td>
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<td>30.1</td>
<td>116.77</td>
<td>33.97</td>
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<tr>
<td>(k_5)</td>
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<td>118.48</td>
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<tr>
<td>(k_6)</td>
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<td>47.1</td>
<td>118.31</td>
<td>32.33</td>
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</table>
SUMMARY

Sales logistics network has the features of varied products and complicated demand. This paper thereby constructs model to minimize the total cost of logistics network, and obtains results by chaos genetic algorithm, which is an efficient multi-product sales logistics network node location method.

REFERENCES