

Research on Location Problem of Distribution Center based on Coverage Location Model

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Abstract. We consider a type of covering problem in the e-commerce enterprise retail distribution network, the problem amounts to determining the location of the warehousing and distribution center. In order to adapt to the e-commerce distribution mode and ensure timely delivery, a demand point can be covered by multiple distribution centers, a set multi-coverage model with the shortest distribution distance and the minimum construction cost as the dual target is established to determine the location of the distribution center. Finally, the example is solved in IBM CPLEX, and the calculation results verify the effectiveness of the algorithm and model.

Key words: demand point; grid density; clustering algorithm; multi-covering; set covering location model.

1. Introduction

In order to occupy the market and gain profits in the rapidly developing online shopping environment, major e-commerce enterprises are actively seeking ways to optimize the distribution network layout to reduce transportation cost, enforce operation efficiency and logistic performance. Among these distribution network nodes, optimizing the number and layout of warehouse distribution centers (WDCs) has become one of the most important decision issues to cover the distribution area with a lower cost by covering the largest number of customers with the least number of facilities [1]. Zhang et al. [2] study the location problem of distribution centers in B2C model with fuzzy demand. Gutjahr and Dzibur [3] propose a bi-objective, bi-level optimization model for the location of relief distribution centers (DCs) in humanitarian logistics. Li et al. [4] established a mathematical model is proposed to enable an efficient and green distribution system by minimizing the total cost, which contains economics cost, environmental cost, and socio-economic cost.

This paper is focused on the location of WDC. A set covering location model is established, which takes distribution distance and construction cost as two objectives and takes the importance of demand points as constraints. A number of WDCs satisfying the coverage requirements of demand points are selected from multiple alternative locations. Then, taking the Capacitated VRP data set in VRP Instances as an example, the validity of the results is calculated and analyzed by CPLEX, and the results verify the effectiveness of the algorithm and the model.

2. Set covering Model based on Multiple Coverage

According to the alternate locations of WDCs obtained in Part 1, the minimum number of WDCs covering all distribution points is selected from a plurality of alternative locations, which is a problem of set covering location problem (SCLP), which was initially introduced by Toregas, Swain, ReVelle, and Bergman [5] and aims at minimizing the total cost associated with the installed facilities that guarantees the coverage of all demand points. Murray, Tong and Kim[6] proposed two models of LSCP-Implicit and LSCP-Explicit. Therefore, the location of this case is suitable for the LSCP implicit coverage location model.

2.1 Parameters and Decision Variables

- (1) i : The index for demand points,
- (2) j : The index for WDCs,
- (3) N_j : The set of distribution center alternative locations within S,

- (4) x_j : Binary variable, equal to 1 if and only if a facility is located at site j , otherwise equal to 0.
 (5) S : The maximum service distance of the distribution center,
 (6) c_j : Fixed cost of site selection at alternative location j ,
 (7) w_j : The capacity of the distribution center j ,
 (8) q_i : Demand of demand point i ,
 (9) d_{ij} : The delivery distance from the demand point i to the distribution center j ,
 (10) a_{ij} : Binary variable, equal to 1 if and only if the candidate location j of the distribution center to the demand point i does not exceed S , otherwise equal to 0.
 (11) e_i : The number of times the demand point i is covered.

2.2 Set Covering Location Model

The multiple set covering location model with the construction cost and the minimum delivery distance as the dual targets is as follows.

$$\text{Min} \sum_{i=1}^m \sum_{j=1}^n d_{ij} x_j a_{ij} \quad (1)$$

$$\text{Min} \sum_{j=1}^n c_j x_j \quad (2)$$

S.T.

$$\sum_{j=1}^n a_{ij} \cdot x_j \geq e_i, i = 1, 2, \dots, m \quad (3)$$

$$\sum_{i=1}^m q_i a_{ij} \leq w_j, j = 1, 2, \dots, n \quad (4)$$

$$a_{ij} (d_{ij} - s) \leq 0, i = 1, 2, \dots, m, j = 1, 2, \dots, n \quad (5)$$

$$x_j = \begin{cases} 1, & \text{if and only if a facility is located at site } j \\ 0, & \text{otherwise} \end{cases} \quad j \in \{1, 2, \dots, n\} \quad (6)$$

$$a_{ij} = \begin{cases} 1, & \text{if demand point } i \text{ is covered by distribution center } j \\ 0, & \text{otherwise} \end{cases} \quad j \in \{1, 2, \dots, n\}, i \in \{1, 2, \dots, m\} \quad (7)$$

The objective function (1) is to locate the distribution center with the shortest total delivery distance; the objective function (2) is to locate the distribution center with the least construction cost; the constraint (3) makes the number of WDCs covering the demand point i meet the demand point requirement; constraint (4) limit the demand point of the alternative distribution center to cover the demand point does not exceed the distribution center capacity limit; constraint (5) limit the distance between the covered demand point and the distribution center does not exceed S ; Constraints (6) and (7) are 0-1 constraints on the decision variables. The demand point here is similar to the transfer station in the distribution network, and the number of transfer stations in the area usually does not exceed 100. So, the model can be solved by CPLEX.

3. Numerical Example

3.1 Relevant Data

The data for the study is derived from the n69 of the Set A collection of the Capacitated VRP in VRP Instances (<http://neo.lcc.uma.es/vrp/vrp-instances/capacitated-vrp-instances/>) is taken as input, and the model is solved in IBM CLPEX. The data in the data set is 69, distributed in the grid area of 5*5. As shown in Fig. 1, each grid is divided by 20*20 unit distance, assuming that each unit distance represents 10km and the distance is Euclidean distance.

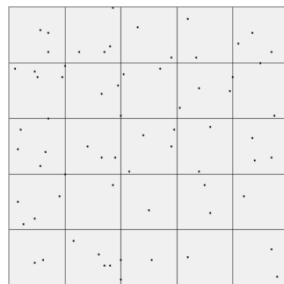


Fig. 1 Demand point distribution map

3.2 Set Multi-Covering Location Model Results and Analysis

The set multi-covering location model uses relevant information such as demand point information, number of distribution center settings, and alternative locations. The demand point information and the number of WDCs and the candidate positions are known. The maximum service distance of the distribution center is still set to $S=180\text{km}$. Assume that the number of times of coverage, e_1 , e_{24} , and e_{53} of demand points 1, 24, and 53 is twice, and the number of times of coverage of the remaining demand points is once. Assume that the capacity w_j of the alternative distribution center is 185. The greater the population density in the area where the distribution is larger, the higher the cost of setting up the distribution center. According to the distribution amount and location, the value of the setting cost c_j of the alternative location is shown in Table 1. Also assume that the construction cost budget acceptable to e-commerce is 330.

Table 1. Setting costs for WDCs at each alternative location

c_1	c_2	c_3	c_4	c_5	c_6	c_7	c_8	c_9	c_{10}	c_{11}	c_{12}	c_{13}	c_{14}
323	376	318	311	368	321	340	280	230	246	267	218	275	232

The final location results of the model calculation are shown in Fig. 2, and each big black dot is a WDC.

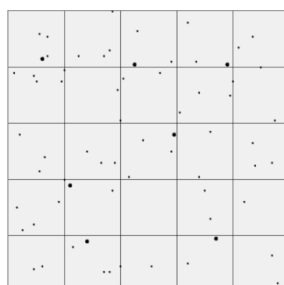


Fig. 2 WDCs location results

Comparing the data of Fig. 9 and Fig. 10 reveals that except for the distribution center where the 13th grid is located is located near the demand point, the other WDCs are located near the center point of the cluster. This is because the model targets the minimum total distribution distance. Unless the current demand point is larger than the other demand points, the cluster center point must be the closest to the sum of all the distribution points. In addition, the setup costs for alternative locations 2, 5, and 7 are directly eliminated by exceeding acceptable construction costs. The calculation results and analysis of the above examples show that the construction cost, maximum service distance and multiple coverage requirements enable the location of the distribution center location with cost constraints.

4. Summary

In the context of e-commerce self-built network retail distribution, based on the research of demand point distribution, the WDCs in the distribution network are studied from the aspects of quantity and location selection. Firstly, based on the set coverage location model, the shortest distribution distance and the minimum construction cost are taken together as the objective function,

and the set multi-covering distribution center location model is established. Finally, the data in the VRP Instances is taken as the example data. Considering the computational complexity of the solution of the model is not high, the model is precisely solved directly in IBM CPLEX. In the set multi-covering model, the distribution center location results are obtained by setting the multiple coverage values of the demand points and the construction cost of each candidate location.

References

- [1]. Chen C T. A fuzzy approach to select the location of the distribution center [J]. *Fuzzy Sets and Systems*, 2001, 118 (1): 65-73.
- [2]. ZHANG Xiaonan, FAN Houming, LI Jianfeng. Bi-objective fuzzy location model and algorithm for the design of logistics distribution network in B2C e-commerce [J]. *Systems Engineering-Theory & Practice*, 2015, 35 (5): 1202-1213.
- [3]. Gutjahr W J, Dzubur N. Bi-objective bilevel optimization of distribution center locations considering user equilibria [J]. *Transportation Research Part E Logistics & Transportation Review*, 2016, 85:1-22.
- [4]. Li Shilong, Wei Zhenlin, Huang Ailing. Location Selection of Urban Distribution Center with a Mathematical Modeling Approach Based on the Total Cost [J]. *IEEE ACCESS*, 2018, 6: 61833-61842.
- [5]. Toregas, C., Swain, R., ReVelle, C., & Bergman, L. The location of emergency services facilities [J]. *Operations Research*, 1971, 19: 1363–1373.
- [6]. Murray, A. T., Tong, D., & Kim, K. Enhancing classic coverage location models [J]. *International Regional Science Review*, 2010, 33 (2): 115–133.