Reverse logistics of municipal solid waste------Study on the Location of transfer stations

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Abstract: Reverse logistics optimization design for recyclable municipal solid waste is a social and economic problem. This paper mainly studies the location problem of reverse logistics network transfer station, which involves how to select the most effective location from the set of points to be selected. In this paper, an improved P median location selection model is proposed on the premise of minimizing the impact on residents, and greedy extraction heuristic algorithm is adopted to solve the model. Finally, the effectiveness of the model in the construction of MSW reverse logistics site selection is illustrated through an example analysis, and theoretical reference is provided for the actual site selection problem.

1. Introduction

At present, the academic circles have extensive discussions on the resource utilization of municipal solid waste, and the research on the reverse logistics of municipal solid waste is gradually carried out with the continuous extension of logistics. Foreign developed countries have formed a complete management system for the management of municipal solid waste, which integrates the information flow, logistics and capital chain of municipal solid waste to achieve efficient operation. The research on reverse logistics has attracted widespread attention, and the main body of the research is mostly carried out from residential areas and operating stations. For example, Murat (2010) [1] used the customer demand density function to define the area to study the location-allocation problem, and used a locally optimized heuristic algorithm to determine the service area of each facility; Hashim (2014) [2] established and solved a mathematical model based on the requirements of the number and location of distribution centers, and provided certain reference value and guiding significance for the location of distribution centers; Tong Xu, Liang Huan, etc. (2016) [3] constructed the transfer station by constructing the P-median value location model, and quickly solved the model through the greedy take away heuristic algorithm to study the location of the transfer station. The existing literature mostly combines qualitative and quantitative to maximize efficiency. For example, Zhao Ai (2017) [4] and others adopted the AHP method, through qualitative and quantitative research, and established the Xuzhou City logistics location evaluation index system with the impact factors of logistics transfer stations; Li Haijun (2017) [5] and others solved the problem of optimizing the site selection of domestic solid waste stations based on the improved maximum covering location problem (MCLP) model. The purpose is to reduce the operating costs in the logistics process through the optimization of site selection. Improve logistics efficiency; Zhou Xianghong (2018) [6] and others based on the uncertainty and multi-periodical characteristics of the remanufacturing and recycling process, established a reverse logistics location model under the self-operated mode, and used the algorithm to solve the problem and draw the
conclusion that the amount of recycling has little influence on site selection and the social negative effect target coefficient has great influence; Sheng Lijun et al. (2019) designed and used quantum particle swarm algorithm to solve the problem of optimizing the location of logistics distribution centers; Zhang Sisi (2018) uses the ANP method to determine the impact factors of recyclable packaging, and at the same time builds a social effect and cost minimization model to determine the location of the facility; Xia Mingyan (2012) defines a negative utility function to measure the impact of facilities on residential areas, and transforms uncertain models into deterministic models through robust optimization; Bin Hou (2016) and others took the niche suitability model as the first screening factor based on ecological environment analysis, established a mixed-integer programming model, and conducted simulation analysis to obtain the best distribution center location. Since the recyclable municipal solid waste reverse logistics network is constructed by the government, this study will restrict the comfort of residents as the main constraint, and take the minimum total cost and maximize the ecology as the objective function, and propose an improved P-Median model.

2. Establishment of discrete network location model
Discrete network location is to select the most suitable part of the facility based on the best plan of limited potential facilities, the corresponding model is called the discrete point model. In the discrete network location model, the number of potential facility nodes is less than the number of demand nodes, that is, the demand node set contains the set of potential facility nodes, and the distance is calculated by the shortest path. Discrete network site selection has a wide range of applications, including public services and companies, and its importance in strategic planning is self-evident.

2.1 Problem description
With the development of social economy, the problem of urban household garbage becomes increasingly serious. In a region, residents produce more household garbage. In order to timely dispose of these garbage, reduce environmental pollution and realize sustainable development of resources. It is necessary to set up some garbage transfer stations, whose main function is to transport garbage in time to improve residents' comfort level. As for the construction of such facilities, the farther away the residents are, the better. Since the transfer station belongs to public health, it is the government department that makes the decision. On the premise of considering the transportation cost, it is more important to consider the impact on the residents, which is represented by the utility function in this paper.

![Diagram of domestic transportation network of recyclable urban garbage](image)

Figure 1. Diagram of domestic transportation network of recyclable urban garbage
relatively unchanged. Through the distance relationship between collection points and transfer stations, P distribution centers are selected from N candidate points to ensure the maximum utility function.

2.2 Establishment of improved P-median model
Under the set of demand points (known quantity and location) and the set of to be selected, the P-median model finds a suitable location for P facilities and appoints each demand point to a specific facility, so as to minimize the total transportation cost between feature facilities and demand points\(^{[12]}\). The problem is an N-P puzzle\(^{[13]}\). In general, the principle of site selection is the minimum transportation cost from the point of demand to the point of operation, and this paper takes the comfort of residents as the main basis of site selection.

2.3 Hypothesis and Description
(1) With the community as the demand point and the inherent garbage transfer station as the candidate point, the garbage collection point within this scope is only transported to the designated garbage transfer station.
(2) The maximum processing capacity of each supply point is known.
(3) In order to ensure global optimization, the utility of forwarding station to the collection point in this area is the greatest.
(4) The distance between the operation center and each collection point is calculated as the actual distance mark in coordinates.

2.4 Definition of parameters and decision variables
\(i \in I\) A collection of collection points;
\(j \in J\) A collection of transfer stations;
\(a_i\) The amount of garbage generated by collection points;
\(\alpha_i\) The weight of the collection point;
\(d_{ij}\) Distance from the collection point to the transfer station;
\(P\) Number of transfer stations established;
\(x_j\) is a binary integer variable. When candidate garbage operation center \(j\) is selected, \(x_j = 1\), otherwise, \(x_j = 0\).
\(y_{ij}\) indicates whether garbage collection point \(i\) is assigned to candidate garbage operation center \(j\) or not. When garbage collection point \(i\) is assigned to garbage operation center \(j\), \(y_{ij} = 1\), otherwise, \(y_{ij} = 0\); When it is satisfied at the operation center \(j\), it is 1; otherwise, it is 0.

Objective function:
\[
\min Z = \sum_{i \in I} \sum_{j \in J} a_i d_{ij} y_{ij} + \sum_{i \in I} \sum_{j \in J} \alpha_i d_{ij} y_{ij} 
\] (1)

Constraints:
\[
\sum_{j \in J} y_{ij} = 1, i \in I 
\] (2)
\[
\sum_{j \in J} x_j = P 
\] (3)
\[
y_{ij} \leq x_j, i \in I, j \in J 
\] (4)
\[
y_{ij} \in \{0,1\}, i \in I, j \in J 
\]

In the model, the objective function (1) is the weighted distance between the garbage collection point and the garbage operation center and the minimum negative utility to residents. Constraint condition (2) means that each garbage collection point can only go to one garbage operation center; Constraint condition (3) limits the number of garbage operation centers to \(P\); Constraint condition (4) ensures that each garbage collection point has a garbage operation center corresponding to it.
3. Based on greedy retrieval heuristic algorithm

The P-median model location solution problem can be solved by precise calculation heuristic algorithm, but this solution method is aimed at small scale problems, for the study of this paper, it is more suitable for greedy retrieval heuristic algorithm, this method is to obtain satisfactory solution, do not pursue the optimal solution. In this algorithm, the specific solution target should be defined first, and a feasible greed criterion should be established, which will be taken as the foundation, and other possible situations of the whole should not be considered. Search from the initial state and find the most satisfactory target solution all the time. The method is simple and easy to understand, and the calculation is small, so it is suitable for qualitative analysis and quantitative research.

Solution steps:
1. Initialize, make the currently selected facility points P=M, i.e. all candidate facility points are selected;
2. Assign each requirement point to the nearest point in P facilities to minimize the objective function;
3. To select and remove a facility point, the following conditions should be met: if it is removed and its demand points are reallocated, the total average cost increase will be minimal; And then I'm going to set P equal to p-1;
4. Repeat step 4 until P= I (where I is the number of distribution centers to be selected).

4. The example analysis

A certain area plans to build 2 garbage transfer stations to meet the garbage disposal requirements of the 5 garbage collection points in the area. After detailed analysis of environmental analysis and resource status, the collection of 4 garbage transfer stations that meet the conditions will be selected. The parameters are shown in Table 1.

|            | 1  | 2  | 3  | 4  | 5  | Capacity |
|------------|----|----|----|----|----|----------|
| 1          | 2.05 | 1.04 | 1.36 | 2.63 | 4.43 | 85        |
| 2          | 4.84 | 5.46 | 6.01 | 3.61 | 4.20 | 85        |
| 3          | 2.69 | 1.49 | 1.10 | 3.42 | 4.83 | 85        |
| 4          | 2.77 | 1.77 | 1.00 | 3.70 | 4.78 | 85        |

Firstly, the weight of demand points should be determined and the weight of each demand point should be determined according to the proportion of each demand point. See Table 2.

| Weighted distance weight of demand point | \(a_1\) | \(a_2\) | \(a_3\) | \(a_4\) | \(a_5\) |
|----------------------------------------|---------|---------|---------|---------|---------|
| 0.12                                   | 0.21    | 0.20    | 0.25    | 0.22    |

Greedy extraction heuristic algorithm is used for analysis and solution.

Step 1: Set P=4 and allocate the five requirement points to the largest potential facility point in \(d_{ij}\).

First assign the result for \((z_1,z_2,z_3,z_4,z_5)=(2,2,2,4,3)\), the target function is 796.85;

Step 2: Analyze the removal of distribution center 1,2,3 and 4 respectively.

If take facilities point 1, the \((z_1,z_2,z_3,z_4,z_5)=(2,2,2,4,3)\), objective function is 796.85, the change of 0;Same as above, if the point 2 and 4, respectively take facilities are \((z_1,z_2,z_3,z_4,z_5)=(4,4,1,4,3)\), \((z_1,z_2,z_3,z_4,z_5)=(2,2,2,4,4)\), \((z_1,z_2,z_3,z_4,z_5)=(2,2,2,2,3)\), is the objective function were 481.40, 795.05, 793.25, compared with P = 4 decreased by 315.45, 1.8, 3.6. Since the reduction of facility point 1 is the minimum, the facility point 1 is taken out the first time, and the objective function is 796.85.

Step 3: According to the repeat operation in the second step, the facility points 2,3 and 4 were respectively analyzed, then \((z_1,z_2,z_3,z_4,z_5)=(2,2,2,4,3)\), \((z_1,z_2,z_3,z_4,z_5)=(4,4,3,4,3)\), \((z_1,z_2,z_3,z_4,z_5)=(4,4,3,4,3)\),
(z1, z2, z3, z4, z5) = (2, 2, 2, 4, 4), (z1, z2, z3, z4, z5) = (2, 2, 2, 3), the objective function were 796.85, 473.12, 795.05, 793.25. It can be known that the reduction of removal facility point 3 is the minimum 1.81. So P is equal to 2, and we’re done. Select {1, 3} from the candidate result set {1, 2, 3, 4} to establish the transfer station.

5. Conclusions
In the process of the reverse logistics network site selection of recyclable MSW, the heuristic algorithm of greedy extraction can be used to get a more ideal solution. Heuristic algorithm has certain theoretical guiding significance for actual site selection decision, and it is also highly complementary to existing site selection models. This paper makes up for the previous siting problem that pays attention to the economic effect through the shortest path, but due to the social and surrounding environment, there are certain limitations in the decision of siting. In the future, the research direction of siting problem should combine environmental, economic, sustainable development and other factors.

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