Application of P-median Method in the Location of Logistics Nodes

Changyu Tang 1*, Hongjuan Tang 1, Anzhen Jia1 and Wang Yin1

1Transportation Logistics Department, Shandong jiaotong university, Jinan, Shandong Province, 250357, CHINA
2029745858@qq.com

Abstract. The location of logistics nodes and the concept of P-median method are analyzed in detail. In view of the problem of logistics node location, using P-median theory model, using greedy take-away heuristic algorithm, the Jinan A fruit and vegetable company provides a precise algorithm on the location of logistics node in Jinan. Realizes the rapid solution of the model, removes unqualified address from multiple candidate addresses, and selects the optimal logistics node location option.

1. Introduction
Logistics nodes play an important role in promoting the concentration of logistics industry, economies of scale, adjusting urban functional land, improving the investment environment of logistics, promoting the growth of third-party logistics enterprises and stimulating local economic development[1]. Many domestic enterprises have planned or are planning to build various logistics nodes. While the construction of logistics nodes is booming, many problems are also exposed.

2. Location of logistics nodes
Logistics node location refers to the decision-making problem of selecting one or more addresses to set up logistics nodes in an economic area with several supply points and several demand points. That is, to determine the number of nodes required by the logistics system, geographical location and the distribution scheme of the service object within the scope of planning[2].

2.1. Influence factors in site planning decision-making
The influence factors of logistics node location are divided into six categories: cost structure, legal regulation, population statistics, transportation, competitive characteristics and alternative location characteristics[3]. As shown in Table 1.

| Classify                  | Factors                                                                 |
|---------------------------|-------------------------------------------------------------------------|
| Cost structure            | Land acquisition methods and costs, construction costs, taxes, insurance and other |
| Legal regulations         | Zoning planning, lease terms, local business regulations                 |
| Vital statistics          | Population base, income, labor supply                                    |
| Traffic                   | Type of transport and convenience in the flow, mode of transport, arrival at the station or port |
| Competition characteristics| Competitors, types                                                      |
| Alternative location characteristics| The convenience of parking, the condition of buildings, visibility from other main streets to the area |
2.2. The basic requirements of logistics node site selection

(1) Close to integrated transport hubs; (2) Close to industrial areas or large professional markets; (3) A town on the edge of a city or in a suburb; (4) Developed road network support[4]. As shown in Figure 1.

![Figure 1. Location of logistics park](image)

3. Application of P-median method

3.1. P- median theory model

That means under a set of requirements which number and location are fixed and a location set of facilities need to be selected, find a suitable location for P number of facilities and then give each demand point a given facility to get a balance that makes the total transport costs between factories and demand points come to lowest[5].

3.2 Objective function of the P- median theoretical model

P—objective function of the median problem is:

$$\min \sum_{i \in N} \sum_{j \in M} d_{ij} c_{ij} y_{ij}$$  \hspace{1cm} (1)

The constraints:

$$\sum_{j \in M} y_{ij} = 1, i \in N$$  \hspace{1cm} (2)

$$\sum_{j \in M} x_{j} = p$$  \hspace{1cm} (3)

$$y_{ij} \leq x_{j}, i \in N, j \in M$$

$$x_{j} \in \{0,1\}, j \in M$$

$$y_{ij} \in \{0,1\}, i \in N, j \in M$$

In this expression:

- $N$ means the demand points, $N = \{1, 2, \ldots, n\}$;
- $d_{ij}$ means the demanding number of customer $i$;
- $M$ means $m$ candidate sites in the study subjects, $M = \{1, 2, \ldots, m\}$;
- $c_{ij}$ means Unit transportation costs from location $i$ to $j$;
- $p$—the number of facilities that we can build ($p < m$);
- $x_{j} = \begin{cases} 1, & \text{if we can build facility in } j \in M; \\ 0, & \text{other cases} \end{cases}$
- $y_{ij} = \begin{cases} 1, & \text{if customer } i \in N, \text{ serviced by facility } j \in M; \\ 0, & \text{other cases} \end{cases}$
4. Case Study on Location of Logistics Node of Jinan A Fruit and Vegetable Company

4.1. Demand Point and Demand Analysis
With the development of living standard in Jinan, the rise of tourism, the demand for fruits and vegetables by the catering industry and the community has increased significantly. A fruit and vegetable company provides fresh fruit and vegetable business for 10 large supermarkets in Jinan, They are Grand Runfa Supermarket (Tianqiao Store), Grand Runfa Supermarket (Licheng Store), Grand Runfa (Zhongshi Store), Carrefour (Jiefangqiao Store), Hualian Supermarket (Shun Geng Road Store), Metro supermarket (Huaiyin Mall Store), Hualian Supermarket (Square Store), Hualian Supermarket (Guangyou Store), Grand Runfa (Licheng Store), China Resources Wanjia Supermarket (Zhonghai Ring City). Each supermarket has different geographical locations and different mobility, so the demand is different. There is a large demand for supermarkets near tourist attractions and residential areas, and a relatively small demand for supermarkets near office buildings in the commercial district. After comparative analysis, determine the demand for fruits and vegetables in each supermarket, as shown in Table 2.

Table 2. Requirements information table

| Demand point | Name of supermarket | Quantity demanded |
|--------------|---------------------|-------------------|
| 1            | Grand Runfa Supermarket (Tianqiao Store) | 200               |
| 2            | Grand Runfa Supermarket (Licheng Store)   | 220               |
| 3            | Grand Runfa (Zhongshi Store)              | 250               |
| 4            | Carrefour (Jiefangqiao Store)             | 100               |
| 5            | Hualian Supermarket (Shun Geng Road Store)| 80                |
| 6            | Metro supermarket (Huaiyin Mall Store)    | 100               |
| 7            | Hualian Supermarket (Square Store)        | 100               |
| 8            | Hualian Supermarket (Guangyou Store)      | 50                |
| 9            | Grand Runfa (Licheng Store)               | 150               |
| 10           | China Resources Wanjia Supermarket (Zhonghai Ring City) | 100 |

4.2. Location Analysis of Logistics Node
A Fruit and Vegetable Company plans to establish 3 facility candidate sites near 10 demand points as a multifunctional warehouse for temporary storage of fresh fruits and vegetables, to meet the needs of the 10 supermarkets in Jinan for fruits and vegetables with minimal transportation costs, after a period of field visits, five candidate addresses have been formed, as shown in Table 3.

Table 3. Location condition analysis table

| Candidate address | Favorable factor | Location conditions |
|-------------------|------------------|---------------------|
| 1                 | Near the second Ring Road West, the land cost is relatively low compared with the city center, the nearby road, the railway transportation junction, the transportation is convenient, the available land scale is larger, the distance from the market is close, the labor force is sufficient, the national policy supports. | Close to Integrated Transportation Hub: Jinan South Station. Near the residential area is located in suburban towns, with developed road network support. |
| 2                 | Beiyuan viaduct, the junction of the second ring west road, convenient transportation, far away from the city center, the land Cost is relatively low, and the available land scale is larger than 1 candidate address, close to the market, sufficient labor force, national policy support. | Close to the industrial zone is located in suburban Towns, with developed road network support. |
| 3                 | Near the Beiyuan viaduct, the land cost is lower than the city center, the relative 1,2 candidate address is high, the available land scale is small, the nearby highway, the railway transportation junction, the transportation is convenient, the distance from the market is close, the labor force is sufficient, the national policy support. | Near Integrated Transportation Hub: Jinan Station Near the tourist area is located in the suburban town, with developed road network support. |
Near the intersection of yanshan overpass and the east viaduct of the second ring, the transportation is convenient, far away from the city center, the land cost is lower than 1, 2, 3 candidate addresses, and the available land scale is larger than 1, 2, close to the market, sufficient labor force, and state policy support. Close to the district is located on the edge of the city, with developed road network support.

Near the intersection of the South Viaduct and Shunhe Viaduct in the second Ring Road, the transportation is convenient, far away from the city center, the land cost is relatively low, 1, 2, 3, 4, and the land available is larger than 1, 2, 4, close to the market, sufficient labor force and state policy support. Close to the district is located on the edge of the city, with developed road network support.

4.3. Model Building

A the total operating cost of the fruit and vegetable company to transport the goods to each supermarket is mainly the cost of the transportation process, that is, the transportation cost, and the other expenses of the transportation of the goods, such as labor costs, loading and unloading costs, vehicle maintenance costs, etc., are not considered in the operation cost. Therefore, the total operating cost = transportation cost = transportation distance (km)(6.5(Yuan/km)) in this case, the actual distance from the candidate address to each demand point is obtained by field measurement, and the transportation cost is calculated.

Distance and transportation cost P1, P2, P3, P4, P5 the candidate address to 10 large supermarkets as shown in Table 4.

Table 4. Distance and transportation costs information

| Candidate address | Distance to P1 (KM) and transportation costs (RMB) | Distance to P2 (KM) and transportation costs (RMB) | Distance to P3 (KM) and transportation costs (RMB) | Distance to P4 (KM) and transportation costs (RMB) | Distance to P5 (KM) and transportation costs (RMB) |
|-------------------|--------------------------------------------------|--------------------------------------------------|--------------------------------------------------|--------------------------------------------------|--------------------------------------------------|
| 1                 | 6.288 (41)                                       | 4.123(27)                                        | 2.130(14)                                        | 8.014(52)                                        | 8.626(56)                                        |
| 2                 | 9.144(59)                                        | 9.412(61)                                        | 3.992(26)                                        | 2.643(17)                                        | 6.596(43)                                        |
| 3                 | 4.444(29)                                        | 7.084(46)                                        | 5.441(35)                                        | 6.775(44)                                        | 3.698(24)                                        |
| 4                 | 10.213(66)                                       | 9.572(62)                                        | 3.612(23)                                        | 3.109(20)                                        | 8.210(53)                                        |
| 5                 | 7.530(49)                                        | 9.175(60)                                        | 5.176(34)                                        | 3.827(25)                                        | 4.162(27)                                        |
| 6                 | 4.720(31)                                        | 5.029(33)                                        | 10.457(68)                                       | 15.228(99)                                       | 11.530(75)                                       |
| 7                 | 3.231(21)                                        | 4.002(26)                                        | 4.703(31)                                        | 8.778(57)                                        | 6.753(44)                                        |
| 8                 | 4.375(28)                                        | 2.322(15)                                        | 4.403(29)                                        | 9.720(63)                                        | 8.636(56)                                        |
| 9                 | 12.677(82)                                       | 11.511(75)                                       | 5.360(35)                                        | 4.147(27)                                        | 1.627(11)                                        |
| 10                | 4.182(27)                                        | 8.387(55)                                        | 7.673(50)                                        | 8.219(53)                                        | 2.590(17)                                        |

4.4. P-median method model solution

\[
C_{ij} = \begin{pmatrix}
41 & 27 & 14 & 52 & 56 \\
59 & 61 & 26 & 17 & 43 \\
29 & 46 & 35 & 44 & 24 \\
66 & 62 & 23 & 20 & 53 \\
49 & 60 & 34 & 25 & 27 \\
31 & 33 & 68 & 99 & 75 \\
21 & 26 & 31 & 57 & 44 \\
28 & 15 & 29 & 63 & 56 \\
82 & 75 & 35 & 27 & 11 \\
27 & 55 & 50 & 53 & 17
\end{pmatrix}
\]

\[
d_1 = \begin{pmatrix}
200 \\
220 \\
250 \\
100 \\
80 \\
100 \\
50 \\
150 \\
100
\end{pmatrix}
\]

K=5, let i supermarket assign to the smallest candidate in the \(C_{ij}\).

The first assignment resulted in: \(A=(a_1, a_2, \ldots, a_8)=(3,4,5,4,4,1,1,2,5,5)\), total transportation costs \(Z = \sum_{i=1}^{10} C_{ia}d_1 = 4560\).

The deletion of candidate points 1, 2, 3, 4, 5 were analysed and their respective increments were calculated:
If you delete candidate 1, \((a_1, a_2, \ldots, a_8) = (3,4,5,4,2,2,2,5,5)\), Z=5760, increments of 4760-4560=200;
If you delete candidate 1, \((a_1, a_2, \ldots, a_8) = (3,4,5,4,4,1,1,5,5)\), Z=4510, increments of 4510-4560=-50;
If you delete candidate 1, \((a_1, a_2, \ldots, a_8) = (2,4,5,4,4,1,2,5,5)\), Z=4360, increments of 4360-4560=-200;
If you delete candidate 1, \((a_1, a_2, \ldots, a_8) = (3,3,5,3,5,1,1,2,5,5)\), Z=4430, increments of 4330-4560=-130;
If you delete candidate 1, \((a_1, a_2, \ldots, a_8) = (3,4,4,1,1,2,4,1)\), Z=3010, with increments of 3010-4560=-1550;
Therefore, the increment generated by removing the fifth candidate is minimal, so the first candidate removed is the candidate location 5.
At this point K=4, \((a_1, a_2, \ldots, a_8) = (3,4,4,4,1,1,2,4,1)\), Z=3010, the deletion of candidate points 1,2,3,4 as follows:
If you delete candidate 1, \((a_1, a_2, \ldots, a_8) = (3,4,4,2,2,4,3)\), Z=3910, increments of 3910-3010=900;
If we delete candidate 2, \((a_1, a_2, \ldots, a_8) = (3,4,1,4,4,1,1,4,1)\), Z=2960, increments of 2960-3010=-50;
If you delete candidate 3, \((a_1, a_2, \ldots, a_8) = (2,4,1,4,4,1,1,2,4,1)\), Z=2810, increments of 2810-3010=-200;
If you delete candidate 4, \((a_1, a_2, \ldots, a_8) = (3,3,3,3,1,1,2,3,1)\), Z=2840, increments of 2840-3010=-170;
Therefore, the increment generated by removing the third candidate point is minimal, so the second candidate point removed is the candidate point position 3.
At this point, K=3 K=P, calculation is finished, the result is to build new warehouse at candidate position 1,2,4, total transportation cost 2840. p1, p2, p4 logistics node address is responsible for the transport of the supermarket as shown in Table 5.

| Logistics node address | Name of supermarket |
|-----------------------|---------------------|
| P1                    | Metro supermarket (Huaiyin Mall Store), Hualian Supermarket (Square Store), Grand Run Fat Supermarket (downtown), China Resources Wanjia supermarket (Zhonghai Ring City) |
| P2                    | Grand Runfa Supermarket (Tianqiao Store), Hualian Supermarket (Guangyou Store) |
| P4                    | Grand Runfa supermarket (Licheng store), Carrefour (Jiefangqiao store), Grand Runfa supermarket (Lixia store), Hualian supermarket (Shun Geng Road store) |

5. Conclusion
The optimal logistics node location scheme p1, p2, p4 Jinan A Fruit and vegetable Company is obtained based on the above model. The optimal candidate address meets the basic requirements of logistics node location, and is located in the area where land resources are well developed, with sufficient land use and low cost. Located near the logistics node of the city, the existing logistics base is good, and the existing logistics resources can be utilized and integrated, which is beneficial to the optimization of the logistics network and the utilization of information resources in the whole region.

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