Summer 5-28-2021

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Short Research Paper

Research on Location Optimization of Waste Transfer Center in Harbin

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Abstract: This paper puts forward the background of the topic, expounds the research status of waste transfer center location at home and abroad, and summarizes and establishes a nonlinear mixed 0-1 planning type of multi transfer center location model in the relevant theory. The model gives the location constraints when the alternative point of the transfer center has been determined. Under the constraints, it mainly considers the total transportation cost of the waste passing through the transfer center, the treatment cost due to the classification, compression and packaging of waste, and the fixed investment cost of the construction of the waste transfer center, so as to minimize the total cost of these four parts. Based on Gaode map, on the basis of establishing the model, the investigation, statistics and analysis data are substituted to solve the optimal location result.

Keywords: Waste; Transfer Center; Site Selection; Waste Treatment Plant

1. INTRODUCTION

The problem of waste treatment has gradually become a problem for urban managers. If the city managers are not scientific enough in the site selection of waste treatment facilities and uneven distribution of facilities, it will not only affect people's production and life, but also affect the efficiency of waste transfer, making the overall cost of waste treatment larger.

2. LITERATURE REVIEW

Foreign countries have a deep research history on the location of transshipment center. As early as 1909, Weber's problem was proposed to study the location of single warehouse. The minimum transportation distance between warehouse and user was explored, and the graphic method was given. Since then, many related problems have evolved from Weber problem, such as location allocation problem, dynamic location problem and so on. With the development of society and the rapid development of economy, the location problem is constantly enriched, resulting in many new theories and methods, and put forward many models and methods to solve all kinds of transfer center location problems, such as Kuehn hamburger model method[1], flexible allocation method [2], Baumol wolf method [3], and p-median method [4] etc..

As early as around 1970, foreign countries put forward the problem of optimizing the transportation route of urban garbage collection vehicles. Beltrami (1974) [5] and ulusoi (1985) [6] found that when the capacity of garbage reached the upper limit, it was necessary to transport the garbage to the transfer center, so they divided the problem into two steps. The first step was to find the itinerant path. The second step was to consider which collection point could reach the upper limit according to the capacity of garbage truck, and then analyzed the problem. The obtained path is decomposed to find a feasible result. Since the 21st century, there have been more and more researches on the garbage transportation path, resulting in many new ideas and methods, and many classical models and methods have emerged in this period. For example, Tung (2004)[7] used mixed 0-1 planning model to study site selection, and amponsah (2004) [8] proposed double objective model with two constraints of

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environment and cost, ghose (2006)[9]. The optimization model of garbage collection and transportation route is proposed with combining garbage collection with vehicle loading capacity limitation and using GIS technology. Gruler (2015) 错误!未找到引用源。 designed and proposed a heuristic algorithm: WCP by combining Monte Carlo simulation with heuristic algorithm.

3. LOCATION MODEL OF WASTE TRANSFER CENTER IN HARBIN

3.1 Assumptions and elements of the model

(1) Hypothesis

The location problem studied in this paper is to select a certain number of addresses from the address set of all known candidate points to establish a garbage transfer center minimize the total cost.

In order to facilitate modeling and make the model easy to understand, the assumptions are made in the following:

① Garbage transportation is completed at one time;

② Select the most suitable transfer center within the scope of the location to be selected

③ One transfer center can transport waste to multiple waste treatment plants, and one transfer center can also receive waste from multiple transfer stations. Transfer centers cannot transport waste to each other;

④ System transportation includes transportation from waste treatment plant to transfer center and from transfer center to transfer station;

⑤ The transportation cost of garbage is directly proportional to the transportation volume and distance;

⑥ The unit transportation cost between the waste treatment plant and each transfer center and between the transfer center and each transfer station is known constant;

⑦ The average daily output of each transfer station is a known constant;

⑧ Fixed investment in establishing and operating transit centers;

⑨ The waste disposal cost of the transfer center is known;

⑩ The capacity and number of transfer centers are limited.

(2) Elements

① Expenses

The costs considered in this model include: fixed cost of investment in transfer center, transportation cost of transporting waste from transfer station to transfer center, transportation cost of transporting waste to waste treatment plant, packing and compression cost of waste in transfer center.

② Refuse transfer volume

Because the data collection can not be carried out on site, according to the "code for design of domestic waste transfer station"[10], if there is no actual data, it can be estimated according to the following formula:

$$Q = \delta mw/1000$$

Where: Q-daily transfer capacity of transfer station (T / D);

M-the actual number of people in the service area;

W-per capita daily output of garbage in service area (kg / person · d), 1.0-1.2 kg / person · D

δ-coefficient of garbage output, δ value can be 1.3 ~ 1.4.

3.2 Establishment of location model

In order to construct the model conveniently, the related variables and parameters are defined as follows:

(1) Model parameters

The parameters of the model are shown in Table 1.

Table 1. Model parameters

Parameter symbol	Symbolic meaning
m	Number of waste treatment plants
n	Number of transfer centers to be selected
i	Number of transfer stations
c_{ji}	Unit distribution cost from the j transfer station to the i Transfer Center
j	Garbage output of the j transfer station
g	Operation days in planning period
f_i	Fixed fee of the i Transfer Center
P	f traMaximum number onsit centers selected

(2) Model variables

x_{ki}— The transportation volume from the k transfer center to the i waste treatment plant;

y_{ij}—The transportation volume from the i transfer station to the j transfer center each time;

z_i—0-1 integer variable, when the i transit center is selected, $z_i = 1$; when the i transit center is not selected, $z_i = 0$.

(3) Objective function

The total cost in the planning period is divided into four parts: the total transportation cost $\sum_{k=1}^{m}\sum_{i=1}^{n} g a_{ki} x_{ki}$ of garbage from the transfer center to the garbage treatment plant, the total transportation cost $\sum_{i=1}^{n}\sum_{j=1}^{l} g c_{ij} y_{ij}$ of garbage from the transfer station to the transfer center, the garbage treatment cost of the transfer center (where w_i is the flow of the I transfer center, and the index θ can be 1 / 2), and the fixed cost $\sum_{i=1}^{n} z_i f_i$ of the transfer center. Then the total cost is the sum of the above four items. It is easy to know that the above cost e should be the minimum, that is:

$$Min\ \ E = \min(\sum_{k=1}^{m}\sum_{i=1}^{n} g a_{ki} x_{ki} + \sum_{i=1}^{n}\sum_{j=1}^{l} g c_{ij} y_{ij} + \sum_{i=1}^{n} z_i v_i W_i^{\theta} + \sum_{i=1}^{n} z_i f_i)$$

(4) Constraints

I. Restriction of waste transfer

The total amount of garbage discharged from a transfer center to each garbage treatment plant shall not exceed the total amount of garbage received by the transfer center:

$\sum_{i=1}^{n} x_{ki} \le A_k, k = 1,2,\dots,m$

II. Waste output constraints

For each transfer, the total amount of garbage transported from each transfer station to the transfer center should be equal to the daily garbage production:

$\sum_{i=1}^{n} y_{ij} \ge D_j, j = 1,2,\dots,l$

III. Balance constraints

During the planning period, the flow is balanced, that is, the amount of garbage in and out of each transfer center is equal:

IV. Capacity constraints

For each transfer, the total amount of waste received by each transfer center shall not exceed the maximum capacity of the transfer center, that is:

V. Number constraint

The number of transfer centers allowed to be established does not exceed the given value p:

Non negative constraint

The variables in the model must be greater than or equal to zero:

VII. Integer constraint

(5) Model

The location model of transfer center is established based on the above analysis:

$$Min\ \ E = \min\left(\sum_{k=1}^{m}\sum_{i=1}^{n} ga_{ki}x_{ki} + \sum_{i=1}^{n}\sum_{j=1}^{l} gc_{ij}y_{ij} + \sum_{i=1}^{n} z_i v_i W_i^{\theta} + \sum_{i=1}^{n} z_i f_i\right)$$

$$\sum_{i=1}^{n} x_{ki} \le A_k, k = 1,2,\dots,m$$

$$\sum_{i=1}^{n} y_{ij} \ge D_j, j = 1,2,\dots,l$$

$$\sum_{k=1}^{m} x_{ij} = \sum_{j=1}^{l} y_{ij} = W_i, i = 1,2,\dots,n$$

$$\sum_{k=1}^{m} x_{ki} \le z_i M_i, i = 1,2,\dots,n$$

$$\sum_{i=1}^{n} z_i \le P$$

$$x_{ki} \ge 0, y_{ij} \ge 0, k = 1,2,\dots,m; i = 1,2,\dots,n; j = 1,2,\dots,l$$

$$z_i = \begin{cases} 1, \text{transfer center} \\ 0, \quad other \end{cases}$$

4. MODEL PARAMETER ANALYSIS

4.1 Scale standard of transfer station

The scale of transfer station can be divided into small, medium and large scale. The large scale standard is more than 450t / D, the medium scale standard is 150 ~ 450t / D, and the small scale standard is less than 150t / D[10]. The existing garbage collection methods in Harbin are mixed, including manual collection vehicles, small vehicles and large vehicles.

4.2 Selected sites and related parameters of municipal solid waste in Harbin

The existing population and the area of each district in Harbin can be found on the website of Harbin government. According to the estimation formula $Q = \delta mw/1000$ (δ = 1.3, w = 1), the daily garbage output of each district can be calculated, as shown in Table 2.

Table 2. Population and garbage output of Harbin

Index	Songbei District	Daoli District	Nangang District	Daowai District	Xiangfang District	Bungalow area	Hulan District	Total
Population (10000 people)	19.7	69	105	68.6	72.4	16	62.3	413
Area (km^2)	736.3	479.2	182.9	618.6	339.5	98	2185.9	4640.4
Garbage output (T / D)	256.1	897	1365	891.8	941.3	208	809.9	5369.1

The daily output of waste in Harbin is 5369.1t/d, which is 3758t / D when 70% of the waste is transported to the waste treatment plant for treatment. According to the area and garbage output of each district, the number of medium-sized transfer stations in each district is calculated. According to the principle of meeting the demand, a suitable number of suitable types of transfer stations are matched for each district. Table 3 is illustrated (because the population of cottage district is small, it is not suitable to set up a separate transfer station, so the demand is merged into the adjacent Xiangfang District).

Table 3. Quantity demand of transfer stations in Harbin

Transfer station	Songbei District	Daoli District	Nangang District	Daowai District	Xiangfang District	Bungalow area
Medium transit station	1	2	2	2	2	1
Processing capacity of each station (T)	154	269	410	268	345	486

According to the above principles, combined with the actual situation of Harbin, the following medium-sized transfer stations and large-scale transfer center type I and type II sites and waste treatment plants (Harbin domestic waste incineration power plant of Heilongjiang New Century Energy Co., Ltd., Harbin Yifeng ecological environment Co., Ltd. (Xiangyang domestic waste treatment plant), Harbin Shuangqi environmental protection resources utilization Co., Ltd.) are obtained Table 4 is illustrated the longitude and latitude coordinates of the waste treatment plant in Acheng District.

Table 4. Latitude and longitude coordinates of alternative points

model	Songbei District	Daoli District	Nangang District	Daowai District	Xiangfang District	Bungalow area
Type I	P_1 (126.61,45.83)	0	P_2 (126.55,45.61)	0	P_3 (126.81,45.67)	0
Type II	P_4 (126.47,45.79)	P_5 (126.49,45.71)	P_6 (126.58,45.69)	P_7 (126.74,45.79) P8 (126.82,45.86)	P_9 (126.77,45.74)	0
Medium 1	Y_1 (126.49,45.83)	Y_2 (126.60,45.72)	Y_3 (126.57,45.59)	Y_4 (126.84,45.80)	Y_5 (126.70,45.63)	Y10 (126.88,45.86)
Medium 2	0	Y_6 (126.43,45.65)	0	Y_7 (126.77,45.78)	Y_8 (126.50,45.68)	0
Medium 3	0	0	Y_9 (126.51,45.66)			0
Garbage factory	Yifeng garbage disposal plant	G_1 (126.92, 45.78)		Acheng waste treatment plant	G_2 (127.05,45.57)	
	New energy	G_3 (126.69,45.74)		Shuangqi	G_4 (126.82,45.71)	

4.2 Building cost matrix

4.2.1 Constructing distance matrix

The shortest driving distance between two points can be obtained by path optimization of Gaode map, as shown in Table 5 and Table 6

Table 5. GP distance matrix

P	G_1	G_2	G_3	G_4
P_1	40.703	62.721	15.999	44.455
P_2	53.087	54.125	27.583	31.448
P_3	29.515	37.007	16.802	23.909
P_4	70.085	71.123	28.648	48.516
P_5	67.307	68.345	21.721	45.738
P_6	34.185	52.510	14.430	31.176
P_7	15.971	40.466	10.406	38.049
P_8	18.577	48.951	23.812	46.133
P_9	21.121	39.220	8.489	29.303

Table 6. PY distance matrix

Y	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9
Y_1	12.784	28.709	37.351	8.757	48.312	25.819	26.502	39.025	33.03
Y_2	19.743	15.552	21.526	25.889	10.789	4.534	17.554	31.069	17.205
Y_3	35.169	3.406	26.145	40.414	26.051	1.115	31.043	12.874	26.602
Y_4	37.672	55.115	25.506	53.115	57.614	31.006	12.985	12.874	19.178
Y_5	33.146	23.347	19.257	38.446	28.072	16.502	24.155	45.101	19.714
Y_6	33.003	17.74	37.315	24.476	10.322	17.93	32.065	55.401	34.54
Y_7	18.045	35.083	21.899	31.794	31.532	21.132	3.737	14.837	6.954
Y_8	26.522	12.145	29.219	24.194	31.532	11.091	25.584	55.119	29.676
Y_9	27.433	10.266	30.13	25.105	9.19	12.002	26.495	56.03	30.587
Y_{10}	32.869	68.798	32.877	48.312	57.125	38.377	17.563	7.741	26.549

4.2.2 Unit transportation cost

The unit transportation cost is 1.5 yuan (t · K) combined with the actual situation. Transportation cost is calculated according to the above data. The construction of Shanghai waste collection and transportation system is complete. Therefore, the cost and processing capacity of the equipment are estimated by referring to the facility data of Shanghai waste transfer station.

Table 7 and Table 8 are illustrated the unit freight between facilities in this paper

Table 7. Unit freight from transfer center to waste treatment plant

Waste treatment plant	Treatment capacity (T)	Unit freight from transfer center to waste treatment plant (100 yuan / ton)								
		P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9
G_1	1200	61.05	79.63	44.27	105.13	100.96	51.28	23.96	27.87	31.68
G_2	380	94.08	81.19	55.51	106.68	102.52	78.77	60.70	73.43	58.83
G_3	200	24.00	41.37	25.20	42.97	32.58	21.65	15.61	35.72	12.73
G_4	1600	66.68	47.17	35.86	72.77	68.61	46.76	57.07	69.20	43.95

Table 8 Unit freight from transfer station to transfer center

Transfer Center	Fixed cost (10000 yuan)	Capacity (T)	Unit freight from each transfer station to transfer center (yuan / ton)									
			Y_1	Y_2	Y_3	Y_4	Y_5	Y_6	Y_7	Y_8	Y_9	Y_{10}
P_1	1000	1000	19.18	29.61	52.75	56.51	49.72	49.50	27.07	39.78	41.15	49.30
P_2	1000	1000	43.06	23.33	5.11	82.67	35.02	26.61	52.62	18.22	15.40	103.20
P_3	1000	1000	56.03	32.29	39.22	38.26	28.89	55.97	32.85	43.83	45.20	49.32
P_4	500	500	13.14	38.83	60.62	79.67	57.67	36.71	47.69	36.29	37.66	72.47
P_5	500	500	72.47	16.18	39.08	86.42	42.11	15.48	47.30	47.30	13.79	85.69
P_6	500	500	38.73	6.80	1.67	46.51	24.75	26.90	31.70	16.64	18.00	57.57
P_7	500	500	39.75	26.33	46.56	19.48	36.23	48.10	5.61	38.38	39.74	26.34
P_8	500	500	58.54	46.60	19.31	19.31	67.65	83.10	22.26	82.68	84.05	11.61
P_9	500	500	49.55	25.81	39.90	28.77	29.57	51.81	10.43	44.51	45.88	39.82
Garbage output of each transfer station (T)			154	269	410	268	345	269	268	345	410	486

Treatment cost: according to the literature, the treatment cost of 500t / D waste transfer station is 22.02 yuan / T; the treatment cost of 1000t / D waste transfer station is 19.08 yuan / T [11].

Therefore, the treatment cost of 500t / D waste transfer station is $w_z = 30.25$.1000t/d waste transfer station, $w_z = 27.31$. The treatment cost of the proposed transfer station is shown in Table 9.

Table 9. Transfer station processing cost

Cost	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9
Processing cost	27	27	27	30	30	30	30	30	30

5. EXAMPLE ANALYSIS

5.1 Example description

Harbin has four waste treatment plants; 10 transfer stations are selected to be distributed in each area; in order to provide transportation efficiency and save cost, the waste transfer center is planned to be established. After on-site investigation, three type I transfer centers P1, P2, P3 and six type II transfer centers P4, P5, P6, P7, P8, P9 are determined. Based on the economic principle, the best goal is to choose the plan with the lowest cost in the planning period of 10 years (336 working days per year).

According to the above calculation, the following data are obtained: the waste treatment cost of each type I transfer center is 27, 27, 27 (unit: yuan / ton), the waste treatment cost of each type II transfer center is 30, 30, 30, 30, 30, θ = 1 / 2; the unit freight from each transfer center to the waste treatment plant is shown in Table 10;

the fixed capacity cost of each transfer center and the waste output of each transfer station And the unit freight between them is shown in Table 11.

5.2 Solving process based on lingo

The above mathematical model and the calculated data are written into lingo software language, and the programming is input into the software for solving. Because the number of P (P_1-P_9) is unknown, the enumeration method is used to test, and the best one is selected.

Table 10. Treatment capacity of each treatment plant and unit freight from transfer center to treatment plant

Waste treatment plant	Treatment capacity (T)	Unit freight rate from transfer center to waste treatment plant (yuan / ton)								
		P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9
G_1	1200	61.05	79.63	44.27	105.13	100.96	51.28	23.96	27.87	31.68
G_2	380	94.08	81.19	55.51	106.68	102.52	78.77	60.70	73.43	58.83
G_3	200	24.00	41.37	25.20	42.97	32.58	21.65	15.61	35.72	12.73
G_4	1600	66.68	47.17	35.86	72.77	68.61	46.76	57.07	69.20	43.95

Table 11. Capacity of each transfer center, daily garbage output of each transfer station and unit freight between them

Transfer Center	Fixed cost (10000 yuan)	Capacity (T)	Unit freight from each transfer station to transfer center (yuan / ton)									
			Y_1	Y_2	Y_3	Y_4	Y_5	Y_6	Y_7	Y_8	Y_9	Y_{10}
P_1	1000	1000	19.18	29.61	52.75	56.51	49.72	49.50	27.07	39.78	41.15	49.30
P_2	1000	1000	43.06	23.33	5.11	82.67	35.02	26.61	52.62	18.22	15.40	103.20
P_3	1000	1000	56.03	32.29	39.22	38.26	28.89	55.97	32.85	43.83	45.20	49.32
P_4	500	500	13.14	38.83	60.62	79.67	57.67	36.71	47.69	36.29	37.66	72.47
P_5	500	500	72.47	16.18	39.08	86.42	42.11	15.48	47.30	47.30	13.79	85.69
P_6	500	500	38.73	6.80	1.67	46.51	24.75	26.90	31.70	16.64	18.00	57.57
P_7	500	500	39.75	26.33	46.56	19.48	36.23	48.10	5.61	38.38	39.74	26.34
P_8	500	500	58.54	46.60	19.31	19.31	67.65	83.10	22.26	82.68	84.05	11.61
P_9	500	500	49.55	25.81	39.90	28.77	29.57	51.81	10.43	44.51	45.88	39.82
Garbage output of each transfer station (T)			154	269	410	268	345	269	268	345	410	486

After software calculation, only when x = 4, 5, 6, 7, 8 and 9, the model has the optimal solution. The optimal solution is shown in the Table 12 as follow.

Table 12. Site selection results

X value	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9	Total cost (yuan)
x=4	√	√	√				√			8.726942×10^8
x=5		√	√			√	√	√		6.324238×10^8
x=6		√	√			√	√	√	√	6.466272×10^8
x=7		√	√		√	√	√	√	√	6.134563×10^8
x=8		√	√	√	√	√	√	√	√	6.260074×10^8
X=9	√	√	√	√	√	√	√	√	√	6.398269×10^8

When x = 7, the results are as follows

Z (P_1) = 0, Z (P_2) = 1, Z (P_3) = 1, Z (P_4) = 0, Z (P_5) = 1, Z (P_6) = 1, Z (P_7) = 1, Z (P_8) = 1, Z (P_9) = 1, which indicates that the transfer center should be set up at the alternative points P_2, P_3, P_5, P_6, P_7, P_8, P_9 to minimize the total cost of 6.134563 × 108 yuan. Table 13 and Table 14 are illustrated the transportation relationship between waste treatment plant , and transfer center and between transfer center and transfer station respectively.

Table 13. Quantity of waste transported to the waste treatment plant by each transfer center (unit: ton)

Waste treatment plant	P_2	P_3	P_5	P_6	P_7	P_8	P_9
G_1	0	0	0	0	500	500	200
G_2	0	224	0	0	0	0	0
G_3	0	0	200	0	0	0	0
G_4	1000	100	0	500	0	0	0
Circulation of Transfer Center	1000	324	200	500	500	500	200
Margin	0	676	300	0	0	0	300

Table 14. Quantity of garbage transported from each transfer station to transfer center (unit: ton)

Transfer station	Y_1	Y_2	Y_3	Y_4	Y_5	Y_6	Y_7	Y_8	Y_9	Y_{10}	Total
P_2	0	0	176	0	0	69	0	345	410	0	1000
P_3	0	0	0	0	324	0	0	0	0	0	324
P_5	0	0	0	0	0	200	0	0	0	0	200
P_6	0	266	234	0	0	0	0	0	0	0	500
P_7	154	0	0	254	0	0	92	0	0	0	500
P_8	0	0	0	14	0	0	0	0	0	486	500
P_9	0	3	0	0	21	0	176	0	0	0	200
Refuse output of transfer station	154	269	410	268	345	269	268	345	410	486	3224

The optimal planning scheme is illustrated in Table in the following: P_2, P_3, P_5, P_6, P_7, P_8, P_9 are selected as the location of the transfer center, and the total cost is expected to be 6.134563 × 108 yuan within the planning period (10 years).

6. CONCLUSION

In this paper, the related theories of garbage transfer center and its location are studied comprehensively. A multi transfer center location model based on nonlinear mixed 0-1 programming is established, and the model is solved by lingo software. By inputting site selection parameters, the site selection results of waste transfer center in Harbin are calculated.

The concept and development process of waste collection and transportation system and transfer center are studied. A location model with the objective function of minimizing the total cost of the system is established under the condition that the selected points of the waste transfer center have been determined and the capacity and number of transfer centers are limited. Through the path planning of Gaode map, the actual driving distance between each point is obtained, which improves the credibility and authenticity of the location results.

ACKNOWLEDGEMENT

This research was supported by Student Research Project (key technology of enterprise knowledge map and its intelligent application) South China University of Technology projects (Granted No. X202010561159)

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