Evaluation Of Jiamusi Landfill Site Selection Based on Analytic Hierarchy Process

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Abstract. Analysis of the appropriateness of existing landfills in Jiamusi City by Analytic Hierarchy Process, combining the natural and social conditions of the Jiamusi area, the environmental protection, environmental geology, social influence and other influencing factors are used as the criterion layer of the hierarchical model. The weighting method is used to determine the weight of each influencing factor, thus the comprehensive score of the landfill site is calculated. The result indicates that the landfill in Jiamusi City is a suitable site, which provides a theoretical basis for future site selection.

1. Introduction
The amount of domestic garbage produced in China is increasing rapidly for the past few years, so landfill site selection in a proper way is an important municipal planning process, which effectively prevents environmental issues including water pollution imposed for insanitary landfills[1]. These methods are commonly used in landfill suitability evaluation including gray clustering method, fuzzy evaluation method, geographic information system method and analytic hierarchy process (AHP)[2-3]. The analytic hierarchy process is proposed by the American operations researcher Saaty, T. L, which can effectively deal with the relationship between the various influencing factors in the hierarchy[4-5]. AHP can transform qualitative analysis into quantitative analysis, whose logical relationship is easy to understand and theoretical basis is profound, so this method is suitable for the case where the necessary data is lacking and the target structure is complex[6]. This paper evaluates the suitability of the existing landfills in the Jiamusi City by using the analytic hierarchy process and combining with the natural conditions, geological conditions and social conditions of the site[7]. According to the basis, this method not only provides a powerful science for the relevant departments to better use land planning and utilization, but also has great significance to reduce the pollution of urban garbage to the environment.

2. Basic situation of garbage dump
Jiamusi City Garbage Disposal Site is located 2km north of the morality of Simajia Township, Huachuan County, where is 8km away from the city center. The garbage disposal site spreads over 6.12×10⁶m³ of land with total capacity of 9.10×10⁶m³. Nowadays the project has completed the harmless treatment of the 1.68×10⁴m³ leachate, and the leachate treatment water reaches the national
secondary standard during the operation.

3. Research method

3.1 Determination of impact factors
According to the site selection requirements of landfills, combining with the natural geographical conditions of Jiamusi City, then the site selection of landfills is determined as the target layer A; environmental geological conditions, environmental protection conditions and social environmental impacts are used as the criterion layer B; perennial wind direction, distance from residential area, traffic conditions, landform type, terrain slope, land use value, distance from the city, site stability, underground diving, construction conditions, groundwater quality, and the distance between the scenic and protected areas are the impact factors C.

3.2 Construction judgment matrix
In the light of the relative proportion between site selection, environmental geology, and environmental protection, the importance is ranked: geological conditions > environmental conditions > social conditions.

The above influencing factors are compared two by two to construct the A-B and B-C judgment matrices:

\[ A = \begin{bmatrix} A_1 & B_2 & B_3 \\ B_2 & 1 & 2/3 \\ B_3 & 3 & 1 \end{bmatrix}, \quad B_1 = \begin{bmatrix} 1/2 & 1/2 & 1/3 \\ 1/2 & 1 & 2/3 \\ 2/3 & 3 & 3/2 \\ 2 & 2 & 1 \\ 3/2 & 4/2 & 1 \end{bmatrix}, \quad B_2 = \begin{bmatrix} 1/2 & 1/3 & 1/2 \\ 1/2 & 1 & 1/2 \\ 2/3 & 3 & 1/2 \\ 3 & 3 & 1 \\ 2 & 2 & 1/2 \\ 1 \end{bmatrix} \]

3.3 Calculation of theoretical weights
The theoretical weight calculation steps of B to A in AHP are as follows[8]:

3.3.1 Calculate the geometric mean of each element in each row of the judgment matrix

\[ W_i = \left( \prod_{j=1}^{n} a_{ij} \right)^{1/n}, \quad (i = 1, 2, ..., n) \approx \bar{W} = (\bar{W}_1, \bar{W}_2, ..., \bar{W}_n) \]  

(1)

3.3.2 Normalize \( w \), which is calculate

\[ \bar{W}_i = W_i \times \left( \sum_{i=1}^{n} W_i \right)^{-1}, \quad (i = 1, 2, ..., n) \approx \bar{W} = (\bar{W}_1, \bar{W}_2, ..., \bar{W}_n) \]  

(2)

3.3.3 Calculating the maximum eigenvalue of the judgment matrix \( \lambda_{max} \)

\[ \lambda_{max} = \frac{1}{n} \sum_{i=1}^{n} \left( Aw \right)_i W_i \]  

(3)

Note: the n means that the order of judgment matrix A

3.3.4 Verifying the consistency of the judgment matrix. The consistency indicator CI is used to check whether the judgment matrix is correct. If CI=0, it means that they are completely consistent. The larger the value, the more serious of the inconsistency. If CI \leq 0.1, the consistency of the judgment matrix is acceptable; otherwise, the influence factor of the criterion layer B must be readjusted, and then the two-two comparison judgment is performed. The larger the order n of the judgment matrix, the worse its consistency, so the correction value R•I is introduced (in Table 1), using C•R as an
indicator to judge the consistency of the judgment matrix[9].

\[
CI = \frac{\lambda_{\text{max}} - n}{n - 1}\quad (4)
\]

\[
C \cdot R = \frac{CI}{RI}\quad (5)
\]

Table 1. The value of the consistency indicator RI

| Matrix order | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|-------------|---|---|---|---|---|---|---|---|---|----|
| R\cdot I    | 0.00 | 0.00 | 0.58 | 0.90 | 1.12 | 1.24 | 1.32 | 1.41 | 1.45 | 1.49 |

3.3.5 Suitability evaluation model and criteria. The comprehensive evaluation model for the stratification analysis of landfill sites is as follows:

\[
S = 100 \sum_{i=1}^{n} S_i = 100 \sum_{i=1}^{n} \sum_{j=1}^{M} M_{ij} \cdot M_{ij,j} \cdots \cdot S_i = \sum_{i=1}^{n} M_{ij} \cdot M_{ij,j} \cdot M_{ij,jk} \quad (6)
\]

The S means that final score of site suitability; the S\_i means that actual weight of the influence factor B\_i on the target layer A; the n means that number of influencing factors in the criterion layer B; the M\_i means that number of influencing factors B; neutron factors; the M\_i0 means that weight of the ith factor in criterion layer B; the M\_ij means that weight of the jth factor in the influencing factor B\_i; the M\_ijk means that actual weight of the jth factor in the influencing factor B\_i.

The classification criteria for the suitability of urban landfills are shown in Table 2.

Table 2. Suitability level standard

| Grade                  | Suitable venue | More suitable venue | Reluctantly suitable for the venue | Unsuitable venue |
|------------------------|----------------|--------------------|-----------------------------------|-----------------|
| Score                  | 90–100         | 75–90              | 60–75                             | <60             |

4. Site Suitability Evaluation

4.1 Calculation of the theoretical weight of the impact factor

According to the proportion of Jiamusi City Development Plan and the influencing factors of landfill site selection as well as the judgment matrix A, the matrix is normalized to obtain the weight of B to A:

\[
\overrightarrow{W} = [0.1670,0.4840,0.349]T
\]

In the same way, the theoretical weight of C to B can be obtained, which is:

\[
\overrightarrow{W} = [0.141,0.141,0.263,0.443]T; \quad \overrightarrow{W} = [0.175,0.137,0.386,0.363]T; \quad \overrightarrow{W} = [0.173,0.137,0.386,0.309]T; \quad \overrightarrow{W} = [0.136,0.183,0.453,0.262]T.
\]

Then, the maximum eigenvalue of the judgment matrix and the consistency index CR are obtained for verification. The calculation results are shown in Table 3.

Table 3. The list of judgment matrix and CR value

| Judgment matrix | A   | B\_1 | B\_2 | B\_3 |
|-----------------|-----|------|------|------|
| \lambda_{\text{max}} | 3.1356 | 4.0104 | 4.2153 | 4.0710 |
| CR              | 0.117 | 0.0036 | 0.075 | 0.25 |

It can be obtained from Table 3 that the test index CR of each judgment matrix is less than 0.1, therefore the consistency test is satisfied, so the theoretical weights of the upper layers are calculated correctly.

4.2 The actual contribution weight and comprehensive evaluation of the influence factor C

The “Evaluation Specification for Urban Environmental Geological Survey” formulated by the China Geological Survey is used to determine the actual contribution weight of the factor through the specific evaluation criteria for each impact factor of the landfill[10]. According to the above equation(6), the actual score of each impact factor is calculated and the final score of the site suitability is obtained, then the suitability level of the landfill is obtained according to Table 2. The
results are shown in Table 4.

| Influencing factor B                        | Influence factor C                      | Weights | Score |
|--------------------------------------------|----------------------------------------|---------|-------|
| Environmental protection conditions        | Site stability                          | 0.024   |       |
| (weight 0.167)                             | Perennial wind direction                | 0.024   |       |
|                                            | Construction conditions                 | 0.044   | 16.60 |
|                                            | Land use value                          | 0.074   |       |
|                                            | Landform type                           | 0.085   |       |
|                                            | Groundwater level                       | 0.066   |       |
|                                            | Terrain slope                           | 0.187   | 44.30 |
|                                            | Underground diving depth                | 0.105   |       |
|                                            | Transportation                          | 0.058   |       |
|                                            | Distance from the city                  | 0.066   |       |
|                                            | Distance from residential area          | 0.158   | 37.30 |
|                                            | Distance from scenic reserve            | 0.091   |       |
| Environmental geological conditions        |                                        |         |       |
| (weight 0.484)                             |                                        |         |       |
| Social environmental impact                |                                        |         |       |
| (weight 0.349)                             |                                        |         |       |
| Evaluation total score                     | ----                                   | ----    | 98.20 |
| Evaluation results                         | ----                                   | ----    | Suitable venue |

It can be seen from Table 4 that the final score of the garbage dump is 98.20 points. According to the evaluation criteria of Table 2, the landfill is a suitable site.

5. Conclusion
Taking Jiamusi City Landfill as an example, taking into account the natural conditions and social conditions, the social impact, environmental protection, environmental geology and other impact factors are used as evaluation criteria. The impact factors of the site are weighted and the mathematical models are used to calculate the suitability score of the site. The evaluation results show that Jiamusi's existing landfill is a suitable site. This method not only provides theoretical and technical basis for site selection, but also plays an important role in environmental protection.

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