Update evaluation of garbage classification and recycling equipment based on analytic hierarchy process

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Abstract. So as to achieve the reduction of urban household waste, resources and harmless, improve the level of urban development. Through analytic hierarchy process (AHP), the update of garbage classification and recycling equipment can be analyzed intuitively and quantitatively. The analytic hierarchy process (AHP) model was established to obtain the parameter proportion of the factors affecting the renewal of garbage classification and recycling equipment. So as to select the best scheme and make the resources play the biggest role.

1. Introduction
In pace with the continuous advancement of urbanization, urban domestic waste has become a thorny issue[1]. In response to the implementation of the sustainable development strategy, people's awareness of environmental protection has gradually increased, and the implementation of waste separation and recovery is imminent. However, the current garbage collection equipment is difficult to meet the needs of garbage sorting, which has caused the problem of updating the garbage sorting and recycling equipment. The analytic hierarchy process is used to evaluate the update of waste separation and recovery equipment, and the selection of the optimal solution is beneficial to improve the recycling rate of domestic waste, so that resources can play the most important role and avoid waste of resources. At the same time, it can effectively promote the urban waste separation and recycling, and build a resource-saving and environment-friendly society, which has important reference significance for China's ecological civilization construction[2].

2. Research method
Analytic Hierarchy Process (AHP) refers to the decomposition of elements that are always related to decision-making into goals, criteria, and programs[3]. On this basis, qualitative and quantitative analysis methods are used. It is a powerful tool for selecting and judging multiple programs according to the overall goal under the condition of multi-objective and multi-criteria combined with quantitative analysis and qualitative analysis. The core idea is that the key to decision-making problems is often to evaluate the choices of behaviors, programs and decision-making objects[4]. The choice of such evaluation schemes always requires that the decision-making objects be ranked in good or bad, and the advantages and disadvantages are obtained.
2.1. Determining the impact factor
According to the requirements of waste sorting, combined with local natural and social conditions, the updated waste sorting and recycling equipment is used as the decision-making level[5]. The first level indicators are the cost and benefit. The following eight indicators are secondary indicators: improving waste collection and transportation methods, updating garbage collection facilities, developing scientific classification methods, strengthening laws and regulations, recycling resources, improving waste treatment efficiency, reducing end-of-line treatment pressure, and promoting social construction.

2.2. Construction Discrimination Matrix
The first-level indicator is two elements, and the weights of benefits and costs are: \(x_1, x_2\). The weight of the second-level indicators relative to the first-level indicators, using the analytic hierarchy process[6]. The method for determining the discriminant matrix generally adopts: manually scoring each index to determine the importance between the two indicators. For the degree of importance, the 1-9 scale analysis method is generally used, that is, 1 indicates the equal importance of the two indicators in the effectiveness evaluation, 3 indicates that the former indicator is slightly more important than the latter indicator in the performance evaluation and 5 indicates that the former indicator is more obvious than the latter indicator in the performance evaluation. Important, 7 indicates that the former indicator is more important than the post indicator in the performance evaluation, 9 indicates that the former indicator is extremely important in the performance evaluation. 2, 4, 6, and 8 indicate the intermediate value of the two indicators in the above performance evaluation and the reciprocal indicates The two indicators in the performance evaluation are reversed. By manually subdividing the secondary indicators under the benefit and the cost, the two discriminant matrices are respectively: \(Z_1, Z_2\).

2.3. Calculation weight vector
The weight vector refers to the relative weight of the secondary indicator for the primary indicator. According to the above indicator system, it is to recycle resources, improve the efficiency of waste treatment, reduce the pressure of end processing, promote the weight of social construction for efficiency and improve the collection and transportation methods, update the garbage collection facilities, formulate scientific classification methods, strengthen the weight of laws and regulations. The root method is used to solve the problem of solving the weight vector in the evaluation of waste sorting and recycling equipment:

\[
\begin{align*}
\text{(1)} & \quad \overline{v}_1 = \sqrt[4]{\prod_{j=1}^{4} a_{ij}} ; \quad \overline{v}_2 = \sqrt[4]{\prod_{j=1}^{4} b_{ij}} \\
\text{(2)} & \quad \overline{w}_1 = \frac{\overline{v}_1}{\sum_{i=1}^{n} \overline{v}_1} ; \quad \overline{w}_2 = \frac{\overline{v}_2}{\sum_{i=1}^{n} \overline{v}_2} 
\end{align*}
\]

(1) Calculate the square of the discriminant matrix by row, then the discriminant matrix of the second-level index for cost and benefit can be obtained by \(\overline{v}_1\) and \(\overline{v}_2\) respectively:

\[
\overline{v}_1 = \sqrt[4]{\prod_{j=1}^{4} a_{ij}} ; \quad \overline{v}_2 = \sqrt[4]{\prod_{j=1}^{4} b_{ij}}
\]

(2) Normalization obtains an approximate weight vector. The specific method is to obtain the sum of the above \(n\) square roots, and then use the square root obtained by each row to negotiate with it to obtain the normalized weight vector.

(3) The approximate weight vectors normalized by \(\overline{v}_1\) and \(\overline{v}_2\) are \(\overline{w}_1\) and \(\overline{w}_2\) respectively:

\[
\overline{w}_1 = \frac{\overline{v}_1}{\sum_{i=1}^{n} \overline{v}_1} ; \quad \overline{w}_2 = \frac{\overline{v}_2}{\sum_{i=1}^{n} \overline{v}_2}
\]

2.4. Consistency test
The feature vector corresponding to the largest eigenvalue is used as the weight vector of the second-level indicator for the first-level index, which will continue to be affected with its continuity, resulting in an increase in the degree of inconsistency, which affects the evaluation of the update of the garbage sorting and recycling equipment. Therefore, it is necessary to Consistency testing is performed to obtain scientific waste separation and recycling equipment results.

(1) Calculate the consistency index CI according to the garbage classification and recovery equipment update discriminant matrix:
CI= \frac{\lambda_{max}}{n-1} \tag{3}

(2) Check the table to determine the corresponding average random consistency index RI. RI indicator table is defined, this evaluation can be directly used, the average random consistency index RI values are shown in Table 1.

| Matrix order | 1  | 2  | 3  | 4  | 5  | 6  |
|--------------|----|----|----|----|----|----|
| RI           | 0  | 0  | 0.52 | 0.89 | 1.12 | 1.26 |

(3) Calculate the consistency ratio CR and judge:

\[ CR = \frac{CI}{RI} \tag{4} \]

When \( CR=0 \), the discriminant matrix is considered to have complete consistency. When \( CR \leq 0.1 \), it is considered that the consistency of the discriminant matrix is acceptable. When \( CR > 0.1 \), it is considered that the discriminant matrix does not meet the consistency requirement and needs to be reconstructed.

2.5. Effectiveness evaluation model

The evaluation of the update of the garbage sorting and recycling equipment generally adopts the grade 5 evaluation grade, which is very good, good, average, range, and poor. So as to facilitate the quantitative calculation, it is assumed that the interval of assignment is 100–90, 89–80, 79–70, 69–60, 59–0. Each laborer will evaluate the eight secondary indicators under the two first-level indicators, so that two artificial evaluation ranking matrices can be obtained, namely \( D_{J1} \) and \( D_{J2} \).

So as to obtain a comprehensive evaluation of the garbage sorting and recycling equipment update, it is generally necessary to quantify two artificial evaluation level matrices. The median value of each assignment interval is its quantized value, that is, 95 is good, preferably 85, generally 75, poor is 65, and the difference is 30. To avoid the difference, the difference will be affected. 55, this can get a quantized evaluation matrix. Multiply it by the weight to obtain a comprehensive evaluation matrix for manual updating of the garbage sorting and recycling equipment, that is, the garbage sorting and recycling equipment update evaluation matrix is:

\[ E = x_1w_1D_{J1} + x_2w_2D_{J2} \tag{5} \]

According to the comprehensive evaluation matrix of the obtained garbage sorting and recycling equipment update, the method of average number, mode and the like can be used to finally determine the update evaluation result of the garbage sorting and recycling equipment.

3. Garbage classification and recycling equipment update evaluation model

3.1. Construct discriminant matrix and solution

When constructing the discriminant matrix, due to the professionalism of the garbage sorting and recycling equipment, the importance of each of the second-level indicators is generally determined manually. When conditions permit, the importance of the two-level indicators can be established manually. The scoring matrix is constructed by comparing the scores:

\[ \overline{Z}_1 = \begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & 3 & \frac{1}{3} & 5 \\ 3 & 1 & \frac{1}{3} & 5 \\ 5 & 3 & 1 & \frac{1}{5} \end{bmatrix}, \quad \overline{Z}_2 = \begin{bmatrix} 1 & 3 & \frac{1}{3} & 7 \\ \frac{1}{3} & 1 & \frac{1}{5} & 3 \\ 3 & 5 & 1 & 5 \\ \frac{1}{1} & \frac{1}{3} & \frac{1}{3} & 1 \end{bmatrix} \]

Using Matlab to solve the above discriminant matrix, the weight vectors are \( w_1 \), \( w_2 \) and their respective consistency ratios CR are:

\[ w_1 = \begin{bmatrix} 0.0636 \\ 0.1219 \\ 0.2706 \\ 0.5439 \end{bmatrix}, \quad CR_1 = 0.0742 \]

\[ w_2 = \begin{bmatrix} 0.2886 \\ 0.1166 \\ 0.5370 \\ 0.0579 \end{bmatrix}, \quad CR_2 = 0.0888 \]
Since the $CR_1 \leq 0.1$, the consistency of the discriminant matrix $Z_1$ is acceptable. Therefore, the secondary classification indicators in the waste assessment and recycling equipment update evaluation index system, the efficiency of waste treatment, the reduction of end treatment pressure, and the promotion of social construction for the benefit of the first-level indicators are: 0.0636, 0.1219, 0.2706 and 0.5439.

Similarly, $CR_2 \leq 0.1$, so the consistency of the discriminant matrix $Z_2$ is acceptable. The secondary indicators improve the collection and transportation methods, update the garbage collection facilities, formulate scientific classification methods, strengthen laws and regulations for the first level. The weights of the indicator costs are: 0.2886, 0.1166, 0.5370, 0.0579.

3.2. Manual evaluation

The manual evaluation refers to the evaluation of the eight secondary indicators that are manually based on the above-mentioned performance evaluation index system. The evaluation of the eight indicators is carried out by 10 people, and the evaluation level matrix for benefit and cost is obtained:

\[
D_{J_1} = \begin{bmatrix}
95 & 85 & 75 & 85 & 75 & 95 & 75 & 85 & 65 & 75 \\
75 & 95 & 85 & 30 & 95 & 85 & 65 & 95 & 75 & 85 \\
85 & 75 & 95 & 75 & 85 & 75 & 85 & 75 & 85 & 95 \\
65 & 65 & 65 & 95 & 65 & 75 & 95 & 75 & 95 & 30 \\
85 & 95 & 95 & 65 & 65 & 75 & 85 & 30 & 95 & 85 \\
30 & 65 & 30 & 85 & 95 & 85 & 95 & 75 & 85 & 65 \\
75 & 30 & 85 & 95 & 85 & 30 & 75 & 85 & 65 & 30 \\
65 & 75 & 75 & 75 & 65 & 65 & 65 & 75 & 75 & 75
\end{bmatrix}
\]

\[
D_{J_2} = \begin{bmatrix}
85 & 95 & 95 & 65 & 65 & 75 & 85 & 30 & 95 & 85 \\
30 & 65 & 30 & 85 & 95 & 85 & 95 & 75 & 85 & 65 \\
75 & 30 & 85 & 95 & 85 & 30 & 75 & 85 & 65 & 30 \\
65 & 75 & 75 & 75 & 65 & 65 & 65 & 75 & 75 & 75
\end{bmatrix}
\]

So as to facilitate the quantitative analysis, the above evaluation level matrix is quantized, it is preferably 95, preferably 85, generally 75, poorly 65, and difference 55. By multiplying the weight vector $\bar{w}_1$ and $\bar{w}_2$ respectively, you can get the scores of the benefits and the cost separately. The score matrix obtained by Matlab is:

\[
E_1 = \begin{bmatrix}
74 & 73 & 76 & 81 & 81 & 75 & 77 & 87 & 54 & 88 \\
72 & 55 & 81 & 84 & 77 & 51 & 80 & 67 & 77 & 53
\end{bmatrix}
\]

\[
E_2 = \begin{bmatrix}
73 & 66 & 78 & 82 & 76 & 67 & 84 & 59 & 83 & 55
\end{bmatrix}
\]

The comprehensive evaluation matrix for the update of the garbage sorting and recycling equipment needs to be determined according to the weight of the scores of the first-level indicators and the scores of the scores. The weights of the benefits and the costs are 0.6 and 0.4 respectively. Use Matlab programming to get a comprehensive scoring matrix $E$ is:

\[
E = \begin{bmatrix}
73 & 66 & 78 & 82 & 76 & 67 & 84 & 59 & 83 & 55
\end{bmatrix}
\]

3.3. Evaluation results

Through the establishment and solution of the above model, the evaluation of ten manual updates on the garbage sorting and recycling equipment is shown in Table 2.

| Serial number | 1  | 2  | 3  | 4  | 5  | 6  | 7  | 8  | 9  | 10 |
|---------------|----|----|----|----|----|----|----|----|----|----|
| fraction      | 73 | 66 | 78 | 82 | 76 | 67 | 84 | 59 | 83 | 55 |

So as to avoid the impact of the individual manual scoring and recycling equipment update. So as to avoid the impact of individual manual scoring on the overall performance evaluation, the average score of the garbage sorting and recycling equipment is obtained by the average method: $E=72.3$, the evaluation result is better. According to the weighted arithmetic average method of multi-level structure, the final weights of the eight secondary indicators relative to the total target layer are 0.0636, 0.1219, 0.2706, 0.5439, 0.2886, 0.1166, 0.5370, and 0.0579. Respectively, it can be seen that reducing the pressure of end processing, promoting social harmony, improving the mode of collection and transportation, and formulating scientific classification methods have a greater weight, and priority is given to implementing these four measures, which can achieve better benefits in early urban waste separation and recovery.
The above analytic hierarchy process (AHP) is used to evaluate the adaptability of waste sorting and recycling equipment. It considers the efficiency and cost. It will improve the efficiency of waste treatment and formulate scientific classification methods as the evaluation criteria. The weight is determined and the mathematical model is used to calculate the equipment update suitability score. This method provides theoretical and technical basis for the future update of waste separation and recovery equipment, and has important significance for promoting waste classification and reducing environmental pollution.

4. Appendices
In pace with the increasingly prominent garbage problem, waste separation and recycling is not only an in-depth and deepening of the understanding of garbage, but also an inevitable requirement of urban development. The promotion of waste separation and recycling is also related to the cost of the previous investment. In reality, it is impossible to achieve high cost but low cost, and the cost is often increased with the increase of benefits. Therefore, the analytic hierarchy process is used to evaluate the update of waste sorting and recycling equipment. Find the right points by calculation and maximize the benefits within a reasonable range[7].

In the process of urbanization, urban living garbage is increasing. Through various measures to solve the dilemma faced in the process of garbage separation and recycling, promoting the utilization of domestic garbage, promoting the construction of urban ecological civilization in China, is conducive to the sustainable development of society[8]. And the classification of garbage is gradually transformed from simple classification behavior into human civilization creation.

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