Study on Waste Reduction Process Based on Hierarchical Analytical Method

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Abstract. With the rapid development of urbanization, the improvement of living standard and the conversion of lifestyle, municipal household garbage treatment is becoming a challenging issue. The hierarchical analytical method is used in the present paper to establish a classification model on the waste reduction, so that each factor in the waste reduction classification is quantitatively analyzed, and the weight is determined by the three-demarcation method; On this basis, the key measures for the reduction and classification work are determined and put forward, and the effect of the waste reduction and classification in the next 5 years is predicted by taking Shenzhen city as an example.

Introduction

The amount and constitution of the municipal household garbage are related with the population, economic level and living habit of a city. With the rapid development of urbanization, the improvement of living standard and the conversion of lifestyle, the municipal household garbage treatment is becoming a challenging issue, which could not be solved merely by measures of landfill and burning etc. The only way which could resolve the current problems and eliminate the root as well as maintaining sustained development of economy is to combine the above measures with reduction, harmlessness and recycle. Wherein, the section of reducing and classifying the waste from the source is a necessary and crucial one. The waste reduction and classification activity [1][2][3][4][5] is an intervention project of the human society influencing on the waste creation system of itself. The main content is the motivation for the personal or household waste generation (individual factors)[6][7] is influenced by the education, supervision, or inspiration from the society (social factors)[7][8], and finally the control process for the positive result of the waste reduction and sorted collection is achieved. Currently, the research and improvement for the control process mainly relied on the quantitative analysis from the summary of experience, the main reason of which is the lack of the quantitative model which could describe the “social factor”, the “individual factor” and the interaction of them, thus, the quantitative analysis with a certain precision is difficult to carry out.

Waste reduction classification model based on hierarchical analytical method

To describe the effects of the social and individual factors in the waste reduction process, the hierarchical analytical model is established in the present paper.

The waste reduction and classification process is described by the waste reduction classification index,

$$G = W_1X_1 + W_2X_2 + W_3X_3 + W_4X_4 + W_5X_5 + W_6X_6 + W_7X_7 \quad (1)$$

where, X_i is the index describing the education, supervision, inspiration, average family income, family structure, household register type and living habit, while W_i is the influential weight of each factor on the waste reduction and classification result, i=1,2, 3….,7.

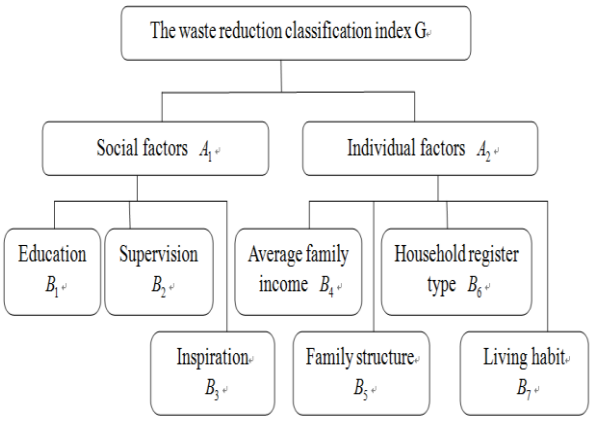

Fig. 1 Hierarchical structure for the influential factors on the waste reduction and classification

The relationship between each type of factors and the waste reduction classification index is determined by adopting the three-demarcation weight determination method. Firstly, the three-demarcation judgment matrix $P=(p_{ij})_{m\times n}$ on the importance degree between each two elements is given at each level.

$$p_{ij}=\begin{cases}2 & i \text{ was more important than } j;\\ 1 & i \text{ was equally important as } j;\\ 0 & j \text{ was more important than } i.\end{cases}$$

The relative importance of each element in the issue is reflected by judging the value of each element in the matrix, then:

The judgment matrix of A_1 and A_2 on G is:

$$P_1=\begin{pmatrix}1 & 2\\ 0 & 1\end{pmatrix};$$

The judgment matrix of B_1, B_2 and B_3 on A_1 is:

$$P_2=\begin{pmatrix}1 & 2 & 2\\ 0 & 1 & 2\\ 0 & 0 & 1\end{pmatrix};$$

The judgment matrix of B_4, B_5, B_6 and B_7 on A_2 is:

$$P_3=\begin{pmatrix}1 & 2 & 2 & 0\\ 0 & 1 & 2 & 0\\ 0 & 0 & 1 & 0\\ 2 & 2 & 2 & 1\end{pmatrix};$$

Then the sum of the row elements of the three-demarcation judgment matrix is calculated as:

$$r_i = \sum_{j=1}^{n} a_{ij}; i = 1,2,3,\cdots,n$$

The maximum and minimum value $r_{\max}$ and $r_{\min}$ are obtained, and the corresponding elements with $r_{\max}$ and $r_{\min}$ are compared and judged by 1 to 9, then the relative importance b_m is obtained. By utilizing

$$d_{ij} = \begin{cases} \dfrac{r_i - r_j}{r_{\max} - r_{\min}}(b_m - 1) + 1 & r_i - r_j \geq 0 \\ 1 \Big/ \left[\dfrac{r_j - r_i}{r_{\max} - r_{\min}}(b_m - 1) + 1 \right] & r_i - r_j < 0 \end{cases}$$

The direct comparison matrix is transformed to the indirect judgment matrix.

From P_2, it is calculated that $r_{\max}=5, r_{\min}=1, b_m=4$, thus the indirect judgment matrix P_4 is obtained as:

$$P_4 = \begin{pmatrix} 1 & 5/2 & 4 \\ 2/5 & 1 & 2/5 \\ 1/4 & 2/5 & 1 \end{pmatrix}$$

The maximum eigenvalue $\lambda_{\max} = 3.0222$, and the weight vector $w = (0.5581,\ 0.3142, 0.1277)^T$.

Since $\lambda_{\max} = 3.0222 > 3$, the consistency check is needed.

$$CI = \frac{\lambda_{\max} - n}{n-1} = 0.0111, RI = 0.58, \quad CR = \frac{CI}{RI} = 0.0191 < 0.10$$

Table 1. Value of the random consistence indicator *RI*

Order	1	2	3	4	5
RI	0	0	0.58	0.9	1.12
Order	6	7	8	9	10
RI	1.24	1.32	1.41	1.45	1.49

From the analysis above, the consistency check is passed, thus the sorting weight vector of B_1, B_2 and B_3 on A_1 is $(0.5581, 0.3142, 0.1277)^T$. For the same reason, the sorting weight vector of B_4, B_5, B_6 and B_7 on A_2 is also obtained as

$$(0.2633, 0.1219, 0.0569, 0.5579)^T.$$

Since the weight coefficient of the household register factor is especially small, it could be ignored as discussing the influence of the individual factor on the waste reduction classification. The matrix P_4 is then updated to the importance degree among the family income level, family structure and living habit.

The three-demarcation judgment matrix of B_4, B_5 and B_7 on A_2 is :

$$P_5 = \begin{pmatrix} 1 & 2 & 0 \\ 0 & 1 & 0 \\ 2 & 2 & 1 \end{pmatrix},$$

It could be obtained that $r_{\max}=5, r_{\min}=1, b_m=5$, thus, indirect judgment matrix:

$$P_6 = \begin{pmatrix} 1 & 3 & 1/3 \\ 1/3 & 1 & 1/5 \\ 3 & 5 & 1 \end{pmatrix},$$

The maximum eigenvalue $\lambda_{\max} = 3.0387$, and the weight vector

$w = (0.2605, 0.1062, 0.6333)^T$.

For $\lambda_{\max} = 3.0387 > 3$, the consistency check is needed.

$$CI = \frac{\lambda_{\max} - n}{n-1} = 0.0194, RI = 0.58, CR = \frac{CI}{RI} = 0.0334 < 0.10$$

From the analysis above, the consistency check is passed, thus the sorting weight vector of B_4, B_5 and B_7 on A_2 is $(0.2605, 0.1062, 0.6333)^T$.

For there are only two factors in the interlayer, the sorting weight vector of A_1 and A_2 on G is $(0.6667, 0.3333)^T$; The comprehensive influence weight coefficient vector of B_1, B_2, B_3, B_4, B_5 and B_7 is obtained from the hierarchy sequencing formula $a^k = B_j^k a^{k-1}$ as

$w = (0.3957,\ 0.1850, 0.0861, 0, 0868, 0.0354, 0.2111)^T$.

Thus, the waste reduction classification index model could X_1 be described as:

$$G=0.3957\,X_1+0.1849\,X_2+0.0861\,X_3+0.0868\,X_4+0.0354\,X_5+0.2111\,X_6 \qquad (2)$$

where, X_i could be described by the number 1-10, which indicated the emphasis degree on X_i.

Table 2. Index of education, supervision and inspiration factor

1-2	3-4	5-6	7-8	9-10
No attention	Little attention	Moderate attention	High attention	Extreme attention

According to the household consumption level in 2012 from China Statistical Yearbook, the family income situation is as follows: the family whose monthly income is lower than 3000 is defined as low-income family, and the families whose monthly income is between 7000 and 15000, between 15000 and 30000 and higher than 30000 are defined as the middle-income, middle/high income and high income family respectively.

Table 3. Index of family income level

1-2	3-4	5-6	7-8	9-10
High-income	Middle/High-income	Middle-income	Middle/Low-income	Low-income

Table 4. Index of family structure

1	2	3	4	5	6	7	8	9	10
Single	2members	3members	4members	5members	6members	7members	8members	9members	10members

Table 5. Index of living habit

1-2	3-4	5-6	7-8	9-10
Pay no attention to waste classification	Pay little attention to waste classification	Pay moderate attention to waste classification	Pay high attention to waste classification	Pay extreme attention to waste classification

The change of waste reduction classification index will trigger the change of the index of each type of factor, and the change of the waste reduction classification index reflects the waste reduction classification process. The bigger of the waste reduction classification index, the better of the waste reduction classification effect.

Crucial measures and predictions on the waste classification treatment

It can be known from the waste reduction index model that the education and supervision factors have the biggest influence on the waste reduction classification, hence, the crucial measure of carrying out the waste reduction classification work is to enhance the education and supervision factor. While the kitchen waste had the greatest potential development in the waste reduction process, and had the big influence on the recycle degree of the recyclable material, thus the construction of the kitchen waste treatment facilities is an inevitable trend, and the completion of the kitchen waste treatment facilities is also a crucial measure.

Taking Shenzhen city as an example and analyzing the current social status, the social factor is set as intermediate state, i.e., the education index is 5, the supervision index is 5, the inspiration index is 5, for the individual factor, the family income level index is 7, the family basic structure index is 3 and the living habit index is 3, then the waste reduction classification index G_0 is calculated from Formula (2) as 4.6806.

After five years of implementing the key measures, i.e., the enhancement of the education and supervision factors and the completion of the kitchen waste treatment facilities, the education index should be developed to the biggest, which is set as 9, in the similar way, the supervision index is also set as 9, the inspiration index and the family structure still remain unchanged, the GDP per person of Shenzhen city would increase after 5 years, hence, the family income would increased, then the family income level index is set as 6. For the education and supervision factors had the influence on the living habit factor, the best result is the living habit factor reached 9. Each factor index after 5 years is listed in the following table.

According to Eq.2, it can be predicted that the optimum value of the waste reduction classification index G_1 is 8.1828.

For the worst result, by implementing the key measures, the education and supervision factors are only enhanced a little, thus, the education index and the supervision index are set as 6, the inspiration index is 5, the family income level is 6, the family structure is 3, and the living habit is the same, which is 3. According to Eq.2, it is predicted that the worst value of the waste reduction classification index G_2 is 5.1744.

In conclusion, the predicted interval for the waste reduction classification index is [5.1744,8.1828].

Conclusion

By utilizing the hierarchical analytical method, the waste reduction classification index model is established in the present paper, which describes the quantitative relationship between the social factor, individual factor and the waste reduction, and represents the waste reduction classification effect using the value of the index. In the weight determination process, the three-demarcation method is applied, then subjective assumption is decreased by a large degree, and the scientificalness and objectivity of the weight determination are enhanced.

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