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Research on the Construction of Garbage Classification and Resource Recycling System in Housing Communities under the Low Carbon Concept

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Abstract From the perspective of low-carbon concept and system construction principles, this topic initially formulates the evaluation index system of housing community waste classification and resource recovery, and in response to the problem of laxity in the index system, adopts the Delphi method to screen the evaluation indexes and determine the final evaluation index system. The entropy weight method in the theory of mathematical statistics is used to calculate its weight, and its weight value is substituted into the fuzzy comprehensive evaluation algorithm to arrive at the final evaluation results. The results show that the evaluation results of rubbish classification and resource recovery in a housing community under the concept of low carbon is good, and its data reflects 6.984, and at the same time reflects that there are still some problems in the construction of rubbish classification and resource recovery in a certain community, and gives corresponding suggestions to make the construction of rubbish classification and resource recovery system in a housing community more in line with the concept of low carbon and sustainable development.

Index Terms Delphi method, entropy weight method, fuzzy comprehensive evaluation, low carbon concept, housing construction, sustainable development

I. Introduction

As people's awareness of environmental protection increases and the process of urbanisation accelerates, waste separation in housing communities has become an increasingly important topic. Rubbish classification can not only reduce the pollution to the environment, but also realise the recycling of resources and promote the development of circular economy. Rubbish classification refers to the classification of household rubbish according to its different attributes, and then take corresponding disposal measures [1]-[4].

The implementation of rubbish classification in housing communities can effectively reduce the amount of rubbish and reduce environmental pollution. People's daily rubbish, industrial rubbish and construction waste in the city are increasing in number, and if they are not classified, they will pollute the environment. Through the classification of rubbish, recyclables, perishable rubbish and hazardous rubbish can be collected separately [5]-[8]. Resource recycling can be used twice, while perishable waste can be processed under suitable conditions to produce organic fertiliser, and hazardous waste can be treated in a special way to ensure environmental safety. Waste classification and resource recovery is an important environmental behaviour that has a positive impact on environmental protection and sustainable development [9]-[12]. Through waste classification, the consumption of resources can be reduced and the pressure on the environment can be alleviated. Through resource recycling, energy and raw materials can be saved and economic value can be created. Therefore, the government, enterprises and institutions, and the general public should work together to build a good rubbish classification and resource recycling system and contribute to the construction of a beautiful community [13]-[16].

Waste separation has far-reaching significance for environmental protection and sustainable development. By classifying rubbish, waste can be effectively utilised, reducing the need for new resources, and hazardous rubbish can be specially treated to avoid irreversible damage to the environment and human health. Literature [17] emphasises that waste classification is an important part of urban environmental management and one of the most effective ways to solve urban waste problems. The problems of waste classification and recycling system in China are analysed, and suggestions are made to improve the corresponding laws and regulations. Literature [18] discusses the impact of rubbish classification on residents' subjective well-being with the help of data from the China Land Economy Survey, and uses endogenous treatment regression models to deal with the corresponding problems of rubbish classification, and finds that rubbish classification has a great impact on residents' well-being and life satisfaction. Literature [19] explored the mechanism and urban-rural differences in the influence of social capital on waste classification in China using data from the China Integrated Social Survey. Analyses using descriptive analysis and other methods concluded that social capital to a certain extent promotes effective waste classification in China. Literature [20] explored the factors affecting the willingness and behaviour of waste classification at home. Based on the TPB model, residents' attitudes and moral obligations were comprehensively considered, and a survey was conducted to predict residents' household waste classification behaviour. The results showed that residents' subjective norms and perceived behavioural control were good predictors of waste separation behaviour.

Resource recovery is one of the core objectives of waste separation and the key to achieving sustainable development. Through resource recovery, waste can be reprocessed and reused, reducing resource waste and environmental pollution. Literature [21] affirms the environmental and economic promotion of reuse of renewable resources. Awareness and behaviour of residents towards recycling of renewable resources were investigated through interviews and questionnaires, and the results specified that the residents' motivation towards recycling of renewable resources was low. Literature [22] analysed the current situation of generation, treatment and recycling of industrial wastes in Korea as an example, identified its problems in recycling, and proposed the task of improving the national resource utilisation rate by recycling industrial wastes for reuse. Literature [23] proposes a strategy for joint treatment and resourcing of municipal waste resources and suggests a joint treatment and recycling approach to promote resource utilisation for the cost of facilities and energy loss for large-scale production in urban and remote areas.

The innovation of this study is to integrate the low-carbon concept into the construction of housing community waste classification and resource recycling, to propose a set of evaluation index system that combines the concepts of low-carbon green and sustainable development, and to integrate the Delphi method, entropy weight method, and fuzzy comprehensive evaluation to test the actual effect of its index system. According to the definition of low carbon concept and the principle of evaluation index system construction, the evaluation index system of rubbish classification and resource recovery in housing community with low carbon concept is initially constructed, and the Delphi method is applied to improve the evaluation index system and finally complete the task of evaluation index system construction. At this level, the entropy weight method is adopted to calculate the weights of the evaluation indexes, combining the weight values of each evaluation index and the fuzzy comprehensive evaluation algorithm to jointly explore the housing community rubbish classification and resource recovery under the low-carbon concept, and put forward the optimisation strategies and suggestions for the current community rubbish classification and resource recovery construction problems.

II. Waste Separation and Resource Recovery under Low Carbon Construction

II. A. Low-carbon concepts

II. A. 1) Overview of definitions

In a narrow sense, low-carbon refers to lower and lower greenhouse gas (mainly carbon dioxide) emissions, which basically means to reduce the energy consumed in production and life, thereby reducing carbon dioxide emissions and reducing the greenhouse effect [24]. With the development of the economy, the continuous reduction of vegetation, the increasing carbon dioxide emissions, and the destruction of the earth's environment, the term low-carbon has been derived into a cutting-edge concept of society, involving a wide range of industries and fields. With the world's consensus on global warming caused by carbon dioxide, experts and scholars have put forward a series of new concepts on low carbon, such as "low-carbon economy", "carbon footprint", "low-carbon technology", "low-carbon city" and "low-carbon community", which have taken a new path for the world to move towards a sustainable ecological civilization. The concept of "energy saving" was better known before the concept of "low carbon", but compared with the concept of energy conservation, the concept of low carbon emphasizes the reduction of carbon dioxide emissions in all aspects of production, construction, management and other links, and is a new concept with ecological and sustainable characteristics. The most important content of low-carbon is to give full play to the special role of climate change mitigation and adaptation in research, development and promotion of low-carbon, garbage classification and resource recovery in housing communities.

II. A. 2) Extension of connotations

The concepts of low energy consumption and low emission derived from low carbon cover many areas of society, economy and construction, so the connotation of low carbon has gradually been extended to include: low carbon society, low carbon economy, low carbon landscape, low carbon life, low carbon city, low carbon community, low carbon building, low carbon concept, low carbon culture and so on. These concepts are all aimed at advocating the reduction of carbon dioxide emissions in the process of human activities in various aspects of life, economy and construction, reducing pollution to the environment and emphasising sustainable development.

II. B.Principles for establishing an institutional framework

II. B. 1) Direct relevance

Residents in the community are the main actors in the construction of community waste classification and resource recovery under the low-carbon concept, so the selection of indicators must adhere to the concept of ‘people-oriented’, and ensure that each indicator has a direct relevance to the construction of community waste classification and resource recovery under the low-carbon concept, and try to reflect the subjective feelings and needs of the residents of the community's buildings and environment. It also ensures that each indicator has direct relevance to the construction of community waste separation and resource recovery under the low-carbon concept, and reflects residents' subjective feelings and needs for community buildings and environment as much as possible.

II. B. 2) Systemic

There are many indicators related to low carbon, and the screening process should follow the principle of systematicity, and each indicator in the system should have a certain logical relationship with each other. The indicators should not only reflect the characteristics and status of the low carbon community from the three sub-systems of people, buildings and the external environment, but also reflect the intrinsic connection between people, buildings and the external environment.

The target layer of the system is supported by several sub-systems in the guideline layer, and each guideline layer contains a number of indicators, and each indicator and each sub-system maintains a relatively independent and interconnected relationship, which together form the organic whole of the assessment system. The indicator system has a clear logic and hierarchy, from the target layer to the guideline layer and then to the indicator layer, from top to bottom, from macro to micro layer to layer, and finally form a complete evaluation system.

II. B. 3) Scientific

Any scientific research is based on science, that is, the selected indicators should be able to truly represent the things described, the concept is clear and easy to understand, and can objectively reflect the construction of community waste classification and resource recovery under the concept of low carbon. The meaning of the indicators should be representative, reflecting the interconnection and needs between people, buildings and the environment. The selected indicators should be typical and general in the research field, and the number of indicators should be controlled within a suitable range; too many indicators will lead to a system that is not easy to operate, and the duplication of meanings among the indicators will inadvertently increase the workload; if the number of indicators is too small, it will lead to the omission of information, and reduce the reliability of the final results of the system.

II. B. 4) Practicality

Indicators are selected with attention to their practicality, the availability of raw data and the reliability of the information obtained. Indicators should be as operational and practically comparable as possible, with simple indicators, clear meanings and clear calculation methods. The selection of evaluation indicators should take into account scientificity, rationality, systematicity and a certain degree of foresight, and should not be too many or too few, so as to facilitate evaluation operations.

II. B. 5) Dynamics

The community is an ecosystem in constant development and change, the construction of community waste classification and resource recovery under the low-carbon concept is a dynamic construction process of the whole life cycle, the surrounding environmental conditions, man-made state and other factors are changing, so it is unscientific to examine and test the degree of sustainable development only through the results, and the results should be controlled in combination with the process of control to ensure dynamic management. The construction of the system should not only take care of the current development of the community, but also take into account the possible changes in the key indicators in the future. Compared with the previous evaluation system, the importance of process evaluation is increased, so that the community's low-carbon environmental planning and design is taken seriously, and then the green goals are transformed into green results.

II. B. 6) Combining quantitative and qualitative aspects

The study of low carbon community includes the study of community culture, and in order to evaluate the low carbon lifestyle and residents' satisfaction included in the community culture, subjective judgement is needed, and some qualitative factors are inevitably involved in the indicators. And in the whole system, in order to ensure objectivity, accuracy and reflect the material level of the community, there will be a large number of quantitative indicators.

Therefore, the whole process of constructing the system should ensure the combination of quantitative and qualitative indicators, and finally give a comprehensive and accurate evaluation.

II. C.Screening of evaluation indicators based on the Delphi method

II. C. 1) The Delphi Method Theory

Delphi consulting method (also known as expert survey method or expert consulting method) is a method of soliciting experts' opinions through correspondence, and after several consultations and exchanges, it gradually obtains a unified opinion in order to get a more consistent and reliable answer [25]. Based on the preliminary evaluation index system of waste classification and resource recovery in housing communities under the low-carbon concept, we designed the expert consultation questionnaire and invited experts in related fields to participate in this consultation by questionnaire star or email. The first and second rounds of expert consultation evaluated the degree of agreement on the connotation of the first-level indicators, the degree of agreement on the expression of the second-level indicators, the importance and representativeness of the indicators, and proposed specific additions, deletions and modifications of the indicators, so as to finally determine the evaluation indicator system of the construction of rubbish classification and resource recycling of the housing community under the low-carbon concept.

II. C. 2) Development of an expert advice questionnaire

By reviewing relevant literature, campus football coach training, etc., the evaluation index system of garbage classification and resource recovery construction in housing communities under the concept of low-carbon was preliminarily formulated, and the guidance and revision opinions of experts in the field of low-carbon community construction were obtained. Based on the research procedures of the Delphi method and the actual information requirements of the research questionnaire, the questionnaire design of the expert consultation is mainly divided into four basic parts: first, the basic description of the research questionnaire on the construction of the evaluation index system of garbage classification and resource recovery in housing communities under the concept of low carbon. The second is the basic information of the experts consulted by the Delphi method. The third is to use the Likert 5-level scoring method for the indicators at all levels and dimensions of the index system: "very unimportant", "unimportant", "general", "important" and "very important" correspond to 1-5 points respectively, the higher the expert score, the higher the importance of the index in the evaluation index system of garbage classification and resource recovery construction in housing communities under the low-carbon concept. Feedback can be collected in a timely manner. Fourth, the authority of consulting experts should be investigated and counted.

II. C. 3) Basic information on Delphi method experts

When using the Delphi method for expert consultation on the construction of the evaluation index system for the construction of waste classification and resource recovery in housing communities under the low-carbon concept, the first consideration was given to the authority and experience of the experts in the field, and the number of consulting experts was controlled in accordance with the ideal number of experts for the application of the Delphi method. The basic information of the experts is shown in Table 1, and a total of 20 experts in the field were found in this study. According to the investigation needs of this study and the feasibility analysis of the study, an indicator construction consulting group consisting of community neighbourhood committees and experts in the field of low carbon was established. After deliberations with the public and consultation and exchange of experts, the final expert consultation of this study determined the analysis of the basic information of experts, units, education, etc.

Table 1: Expert basic information

Title	Educational background	Number
Low-carbon experts	Doctor	3
	Master	5
	Undergraduate	8
	Junior college	3
	High school student	1

II. C. 4) Distribution of questionnaires

According to the survey cycle plan and the actual difficulty of expert consultation in this study, this study distributes the expert consultation questionnaire for the construction of the evaluation index system for the construction of waste classification and resource recovery in housing communities under the low-carbon concept in the form of an electronic questionnaire on the Questionnaire Star platform, and informs the experts of the specific needs of the questionnaire survey by means of microblogging or electronic mail. The study used two rounds of questionnaire survey cycles for expert opinion data collection by the Delphi method. The first round of expert consultation issued a total of questionnaires, and by collating and analysing the expert consultation opinions on the evaluation index system for the construction of waste classification and resource recovery in housing communities under the low-carbon concept, SPSS software was used to carry out the mean M, the standard deviation of the scores SD, and the coefficient of variation (CV) for the indicators of each degree of importance of the first-level, second-level, and third-level indexes. CV, according to which the indicators are judged whether they are in line with the construction of waste classification and resource recovery in housing communities under the low-carbon concept.

II. C. 5) Positive coefficient for experts

The positive coefficient of experts is measured by the ratio of expert advice questionnaire recovery rate to the ratio of amendments proposed, which is the ratio of the sample size of valid expert advice recovered to the total number of questionnaires distributed, and is calculated by the formula:

$$C = M_j / M \tag{1}$$

(1) In the formula, M_j represents the sample size of valid expert advice and M the total number of questionnaires distributed, where C is the effective recovery rate.

The proportion of modifications proposed is the proportion of the number of experts proposing modifications to the indicators to the sample size of valid expert advice recovered, calculated by the formula:

$$D - M_i / M_j \tag{2}$$

(2) In the formula, M_i represents the number of experts who proposed changes to the indicator, M_j represents the sample size of effective expert consultation, where D is the effective recovery rate.

II. C. 6) Expert authority factor

The expert's authority coefficient (C_r) is determined by two aspects of data, on the one hand, the basis of judgement (C_a) on which the expert makes a judgement on the importance of the indicator, and on the other hand, the expert's familiarity with the content of the study, (C_s), and the expert's authority coefficient is equal to the average of the basis of judgement and the degree of familiarity. The formula is:

$$C_r = \frac{C_a + C_s}{2} \tag{3}$$

Academics believe that when the authority coefficient is higher than or equal to 0.7, the authority coefficient and credibility of the Delphi method research meets the requirements and the expert opinion is acceptable, and the higher the authority coefficient, the higher the authority of the Delphi method results.

II. C. 7) Harmonisation factor for expert advice

The coordination coefficient of expert opinion is mainly used to evaluate the consistency of the opinions given by all experts on the indicators, whether there is a large discrepancy, the coordination coefficient is expressed by the Kendall coefficient, in the value of 0-1, if its value is within 0.3-0.5, it indicates that the coordination coefficient is in line with the requirements [26]. If its significance test $P < 0.05$, it indicates that the degree of coordination of the opinions of all experts is high, the degree of consistency is high, and the evaluation of all experts is desirable. The formula for calculating the coordination coefficient is:

$$W = \frac{12}{m^2 - \left(n^3 - n\right)} \sum_{j=1}^{n} d_j^2 \tag{4}$$

Formula (4), n indicates the number of indicators for evaluation, m indicates the number of experts, while in order to ensure the reliability of the coordination coefficients, the chi-square test must be tested for significance, the significance of the test formula is as follows:

$$x^2 = \frac{1}{mn(n+1) - \frac{1}{n-1}\sum_{j=1}^{n} T_i} \sum_{j=1}^{n} d_j^2 \tag{5}$$

II. C. 8) Indicator screening criteria

The purpose of indicator screening is to retain those indicators that meet the criteria for importance and to exclude those that are of lower importance and where expert opinion varies considerably. Indicator screening is conducted using the critical value method, which calculates the arithmetic mean, standard deviation and coefficient of variation of the importance score of each indicator, and if the same indicator does not meet all three criteria, it is eliminated.

If an indicator fails to meet one or two of the criteria, the experts' opinions on modification are combined, and after discussion, the decision is made to modify or exclude it. Arithmetic mean:

$$M_j = \frac{1}{m_j}\sum_{i=1}^{m} C_{ij} \tag{6}$$

In formula (6), m_j represents the number of experts evaluated, C_{ij} represents the importance rating of the i rd expert for the j th indicator, M_j represents the arithmetic mean of the importance of the j th indicator, and the higher the value, the higher the degree of importance of the indicator. The higher the value, the higher the importance of the indicator. V_j represents the coefficient of variation of indicator j, S_j represents the standard deviation of indicator j, and the formula is (7):

$$\sigma_j = \sqrt{\frac{n}{n-1}\sum_{i=1}^{n}\left(C_{ij} - M_j\right)^2} \tag{7}$$

C_{ij} indicates the score of the i nd expert on the j indicator, and n indicates the number of indicators. Coefficient of variation:

$$V_j = \frac{\sigma_j}{M_j} \tag{8}$$

In formula (8), σ_j indicates the standard deviation of the j nd indicator, M_j indicates the arithmetic mean of the j th indicator, and V_j indicates the coefficient of variation of the evaluation of the j th indicator; the smaller the value, the smaller the degree of dispersion of the expert opinion of the indicator, and the more unified the expert opinion. When the coefficient of variation of the indicator evaluation is lower than 0.25 points, the expert evaluation has less variability, and the degree of dispersion of the indicator is smaller and meets the requirements.

In this study, EXCEL2016 and SPSS25.0 software are used for calculation and statistics, and the positive coefficient, authority coefficient, arithmetic mean, standard deviation, full score rate and coefficient of variation of experts are counted by EXCEL2016, and the coordination coefficient of experts' evaluation and its significance test are calculated by SPSS25.0 software.

II. D.Indicator weights based on the entropy weight method

II. D. 1) Theory of entropy law

Entropy weighting method is an objective assignment method that uses the concept of information entropy to determine the weight of each evaluation index [27]. Information entropy is a measure of the degree of disorder in a system, which reflects the amount of information contained in the system. The greater the information entropy, the higher the uncertainty of the system and the more information it provides. The smaller the information entropy, the lower the uncertainty of the system and the less information it provides. Therefore, the entropy weighting method holds that the greater the information entropy of an evaluation indicator, the greater the influence of the indicator on the evaluation results and the higher its weight. On the contrary, if the information entropy of an evaluation indicator is very small or even zero, it means that the indicator has no contribution to the evaluation results, and the lower its weight is.

II. D. 2) Calculation process

(1) Data standardisation of indicators

Multi-indicator comprehensive evaluation involves different types of indicators, which affect the evaluation results in different directions. Some indicators are better the higher they are, which we call positive indicators or efficiency indicators. Some indicators are lower and better, which we call reverse or cost indicators. Others are optimal within a certain range or at a specific value, which we call moderate indicators. Since different indicators have different scales and units, they cannot be directly evaluated comprehensively, so before calculating the weights, the raw data need to be standardised. Data standardisation includes two steps: indicator non-negativity processing (that is, all indicators are converted into positive indicators) and indicator dimensionless processing (that is, to eliminate the impact of the outline and unit). Assuming that the original data is x_{ij} and the standardised data is y_{ij}, the specific steps of the algorithm are as follows:

Inverse indicator forwarding processing using inverse buckling transformation method or inverse inverse transformation method, the formula is:

$$y_{ij} = Max\ x_{ij} - x_{ij}\ \text{Or}\ y_{ij} = -x_{ij} \tag{9}$$

The forwarding of the fitness indicator is handled using the inverse inverse transformation method or the inverse buckling transformation method, which is given by Eq:

$$y_{ij} = Max\left|x_{ij} - k\right| - \left|x_{ij} - k\right|,\ Or\ y_{ij} = -\left|x_{ij} - k\right| \tag{10}$$

The dimensionless treatment of the indicators was done using the homogenisation method with the formula:

$$y_{ij} = \frac{x_{ij}}{\bar{x}_j} \tag{11}$$

The standardised data mean is 1, and its variance is the square of its coefficient of variation, which fully retains the variation information of different indicators.

(2) Solving the information entropy value of indicators

The information entropy value of the indicator can be calculated according to the following formula:

$$E_j = -\ln(n)^{-1}\sum_{i=1}^{n} p_{ij}\ln p_{ij} \tag{12}$$

Where the value of the I nd element under the j st indicator is the weight of that indicator:

$$p_{ij} = \frac{\gamma_{ij}}{\sum_{i=1}^{n}\gamma_{ij}} \tag{13}$$

When $p_{ij} = 0$, then define $\lim_{p_{ij}\to 0} p_{ij}\ln p_{ij} = 0$.

(3) Calculation of the coefficient of variation for each indicator

The coefficient of variation of each indicator is calculated according to the following formula:

$$G_j = 1 - E_j \tag{14}$$

(4) Determine the weight of each indicator

The information entropy of each indicator is known to be $E_1, E_2 \cdots E_n$, and the entropy weight of each indicator is:

$$W_j = \frac{G_j}{\sum_{j=1}^{m}\sigma_j}\left(1,2,3\cdots,m\right) \tag{15}$$

II. E. Fuzzy integrated evaluation

II. E. 1) Theoretical foundations

The theoretical basis of the fuzzy comprehensive evaluation method is the fuzzy mathematical affiliation theory, which can transform the qualitative analysis of the problem into a quantitative analysis, and is particularly suitable for various types of problems where the data are unclear and difficult to quantify [28]. Through quantitative analysis to determine the problem affiliation criteria, so as to determine the specific level of the problem.

II. E. 2) Constructing a Fuzzy Evaluation Rating Criteria Set

The set of fuzzy evaluation rating criteria is a collection of fuzzy evaluation results of the evaluator on the evaluation object, not the exact evaluation value, but the fuzzy evaluation conclusion. The evaluation level criteria are determined by the organiser according to the evaluation requirements and can generally be divided into five levels: poor, poor, average, good, better or low, medium-low, medium, medium-high and high. It can be expressed as:

$$V = \left(v_1, v_2, v_3, v_4, v_5\right) \tag{16}$$

II. E. 3) Single-factor fuzzy evaluation

Single-factor fuzzy evaluation is for a certain factor by experts or experienced people according to the experience of the next level of fuzzy evaluation of the factor indicators, and then according to the fuzzy evaluation of the degree of affiliation of the corresponding assignment to get a single-factor fuzzy evaluation of the vector, and then finally the evaluation of the vector of factors to form a whole evaluation matrix. Such as:

If the evaluation vector for a factor i is $R_i = \{r_{i1}, r_{i2}, r_{i3}, \cdots r_{in}\}$, there are m one-factor evaluation sets $R_1, R_2, R_3, \cdots R_m$. This leads to a fuzzy composite evaluation matrix R_{m*n}. i.e.:

$$R_{m*n}=\begin{pmatrix} r_{11} & r_{12} & r_{13} & \cdots & r_{1n} \\ r_{21} & r_{22} & r_{23} & \cdots & r_{2n} \\ r_{31} & r_{32} & r_{33} & \cdots & r_{3n} \\ r_{41} & r_{42} & r_{43} & \cdots & r_{4n} \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ r_{m1} & r_{m2} & r_{m3} & \cdots & r_{mn} \end{pmatrix} \tag{17}$$

II. E. 4) Fuzzy integrated evaluation

The fuzzy composite evaluation vector Q can be obtained by mathematically combining the single factor weights W and matrix R_{m*n} as shown below:

$$W\cdot R_{m*n}=\left(w_1,w_2,w_3\cdots,w_m\right)\begin{pmatrix} r_{11} & r_{12} & r_{13} & \cdots & r_{1n} \\ r_{21} & r_{22} & r_{23} & \cdots & r_{2n} \\ r_{31} & r_{32} & r_{33} & \cdots & r_{3n} \\ r_{41} & r_{42} & r_{43} & \cdots & r_{4n} \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ r_{m1} & r_{m}2 & r_{m3} & \cdots & r_{mn} \end{pmatrix} \tag{18}$$

According to the judgment criteria and fuzzy evaluation vector calculation values can be integrated to judge the evaluation object grade.

III. Evaluation and Analysis of Community Waste Separation and Resource Recovery

III. A. Analysis of the screening of the evaluation indicator system

III. A. 1) Preliminary development of an evaluation indicator system

The preliminary formulation of the evaluation index system is shown in Figure 1. Combined with expert opinions and relevant literature, a preliminary evaluation index system of community waste classification and resource recovery construction under the low-carbon concept is formulated, which mainly consists of 32 secondary indicators (number of bins Q11, layout of bins Q12, clarity of classification labelling Q13, maintenance of classification facilities Q14, intelligent classification equipment Q15, updating of classification facilities Q16, distribution of publicity materials Q21 , number of publicity activities Q22, participation of residents Q23, popularity of classification index Q24, construction of education bases Q25, diversity of publicity channels Q26, accuracy of classification Q31, effectiveness of reduction Q32, resource utilisation Q33, efficiency of harmless treatment Q34, economic benefits Q35, social benefits Q36, perfection of policies and regulations Q41, setup of management institutions Q42, Implementation of management system Q43, Supervision Q44, Incentive measures Q45, Non-compliance handling mechanism Q46, Participation of residents Q51, Participation of social organisations Q52, Enterprise cooperation Q53, Cross-regional cooperation Q54, Application of technological innovations Q61, Exploration of model innovations Q62, Continuous improvement mechanism Q63, Promotion of successful cases Q64), and 6 Level 1 indicators (Classification facilities Q1, Classification Publicity and Education Q2, Classification Effectiveness and Benefits Q3, Policy Management Q4, Community Participation and Co-operation Q5, Innovation and Continuous Improvement Q6), the Community Waste Classification and Resource Recycling Construction Evaluation Indicator System is an important tool to measure the effectiveness of the community in waste classification and resource recycling.

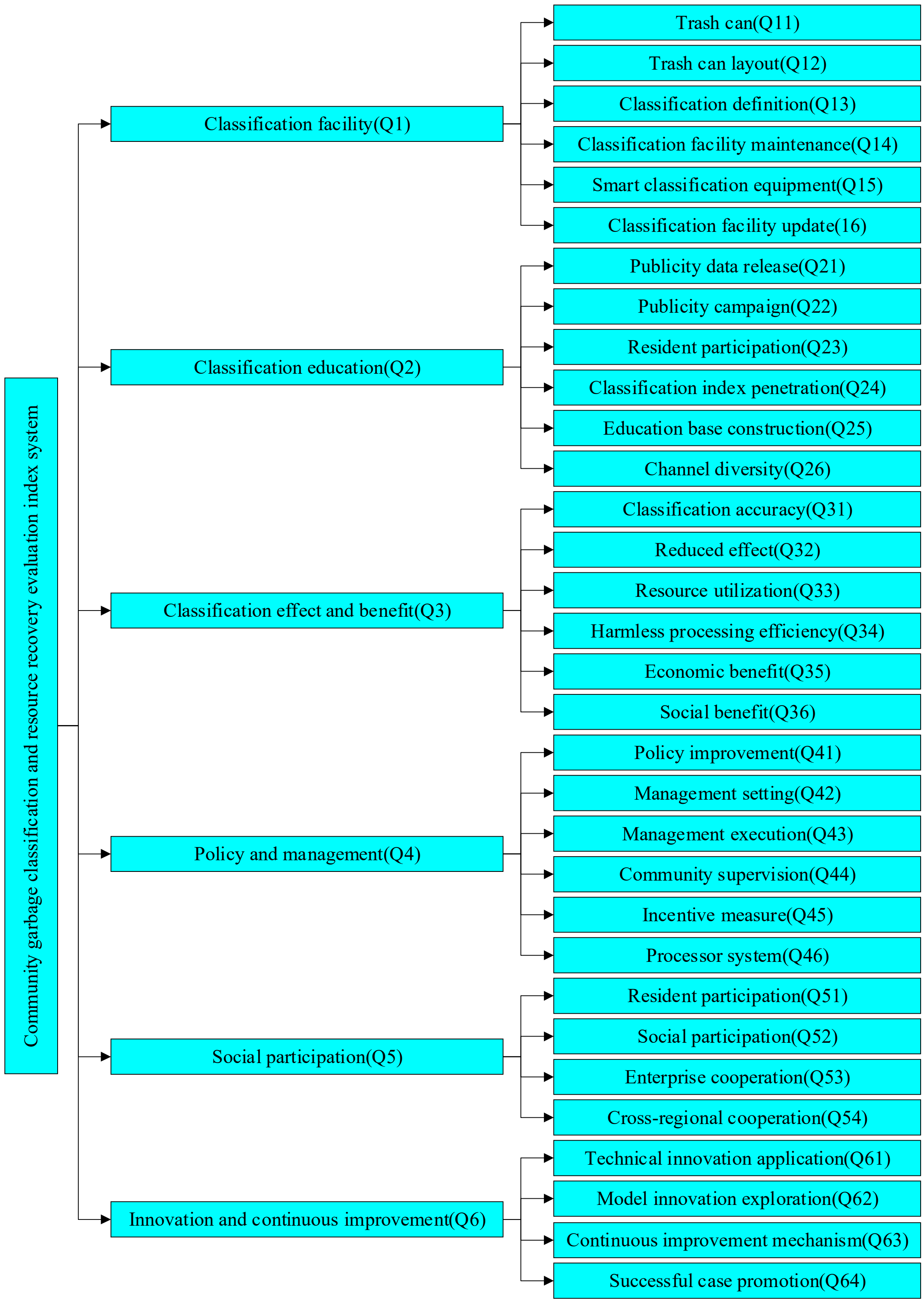


Figure 1: Preliminary evaluation index system

III. A. 2) Analysis of the Expert Positivity Factor

The positive degree of the expert group is shown in Table 2, this topic takes the way of expert consultation, with to carry out community waste classification and resource recovery construction evaluation index system screening, a total of two rounds, a total of 20 questionnaires recovered, to get the effective questionnaires 20, according to the above formula (1), to calculate the positive coefficient of its experts as:

$$C = M_j / M = 10/10 = 100.00\%$$

Based on an expert positivity factor of 100.00 per cent, indicating a high level of overall activity in the CGE.

Table 2: The team of experts is positive

Experts consult the rotation	The number of questionnaires issued	Number of questionnaires collected	Effective recovery
1	10	10	100.00%
2	10	10	100.00%

III. A. 3) Expert authority factor analysis

The reliability of the expert group is judged by applying the expert authority coefficient, and when the expert authority coefficient is greater than or equal to 0.7, it indicates high reliability. The degree of familiarity of the expert panel is shown in Table 3, and the degree of familiarity of the expert panel is divided into five levels, with values of 0.8, 0.6, 0.4, 0.2, and 0, respectively.

Table 3: Expert group familiarity

Title	Familiar with	Be familiar with	General	Be unfamiliar with	Unacquaintance
Valuation	0.8	0.6	0.4	0.2	0
Number	10	8	1	1	0

The basis of judgement of the expert panel is shown in Table 4, which judges the expert panel from four aspects, namely, theoretical analysis, practical experience, peer understanding and personal intuition, and assigns different values to each of them in three degrees, namely, high, medium and low. Based on the above formula (3), the expert authority coefficient can be derived. The calculation process is as follows:

$$Degree\ of\ familiarity\ (Ca) = (0.8*10 + 0.6*8 + 0.4*1 + 0.2*1)/20 = 0.67$$

$$Judgment\ basis\ (Cs) = [(12*0.5 + 0.4*4 + 0.3*3) + \ldots\ldots + (0.1*11 + 0.1*5 + 0.1*4)] = 0.87$$

From this, an expert authority coefficient of $(Cr) = (0.67 + 0.87)/2 = 0.77$ can be derived, and an expert authority coefficient greater than or equal to 0.7 indicates a high degree of reliability and can be used in the evaluation and analysis.

Table 4: The panel of experts determines the basis

Judgment	Theoretical analysis			Practical experience		
Degree of judgment	Height	Medium	Low	Height	Medium	Low
Valuation	0.5	0.4	0.3	0.3	0.2	0.1
number	12	4	4	10	6	4
Judgment	Theoretical analysis			Practical experience		
Degree of judgment	Height	Medium	Low	Height	Medium	Low
Valuation	0.1	0.1	0.1	0.1	0.1	0.1
number	8	8	4	11	5	4

III. A. 4) Expert coordination factor analysis

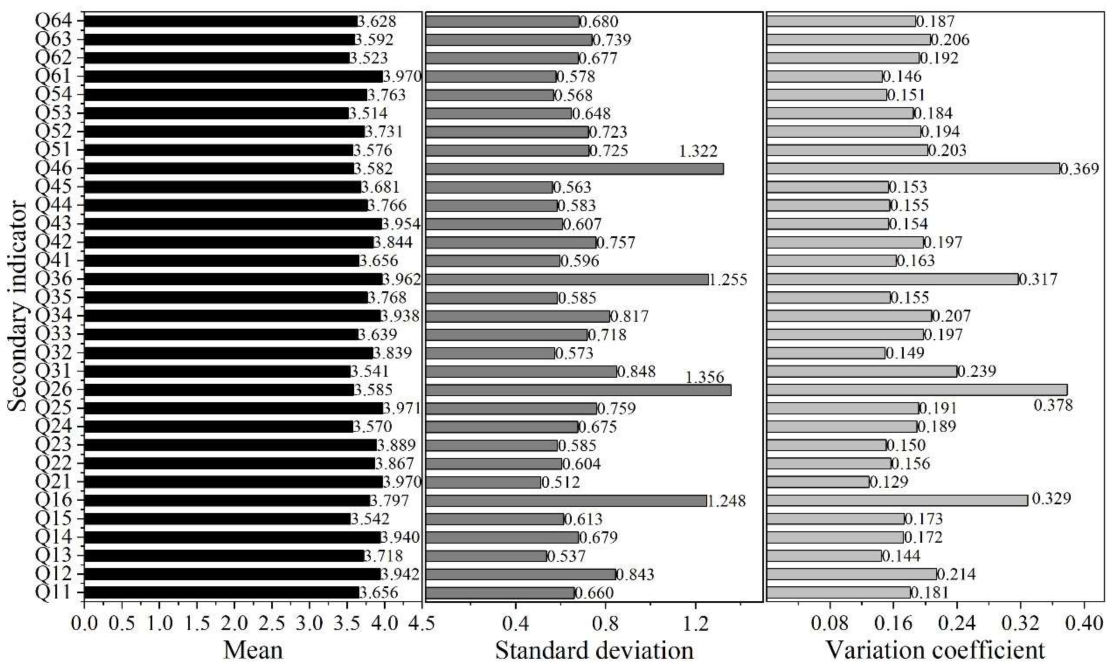
The coordination coefficient of expert opinion is mainly used to evaluate the consistency of the opinions given by all experts on the indicators, and it is an important indicator to measure the reliability of the results of the expert consultation, the coordination coefficient takes the value within 0-1, and the higher the value is, the higher the degree of coordination is indicated, and the analysis of the coordination coefficient of the experts is shown in Table 5. The results show that the first round of Kendall synergy coefficient is 0.385, the coordination coefficient is between 0.3 and 0.4, the chi-square test results chi-square value is 3.17.207, the degree of freedom is 20, the significance of P<0.05, the chi-square test is significant, and the degree of coordination in the first round meets the requirements. The second round of Kendall's coefficient of synergy is 0.408, the coordination coefficient is between 0.4 and 0.5, the chi-square test result chi-square value is 265.171, the degree of freedom is 20, the significance P<0.05, the chi-square test is significant, and the degree of coordination in the second round meets the requirements. The coordination coefficient of 0.408 in the second round is higher than that of 0.385 in the first round, indicating that after revision and improvement, the coordination coefficient of expert evaluation in the second round has increased and the degree of coherence has been improved. Generally speaking, the results of the two rounds of expert consultation meet the requirements, the degree of coordination of expert opinions is good, and the evaluation results are highly credible and can be analysed.

Table 5: Expert coordination coefficient analysis

Index	First round	Second wheel
Kendall	0.385	0.408
Card square	317.207	265.171
Freedom	20	20
Asymptotic significance	0.002	0.005

III. A. 5) First round of indicator screening analysis

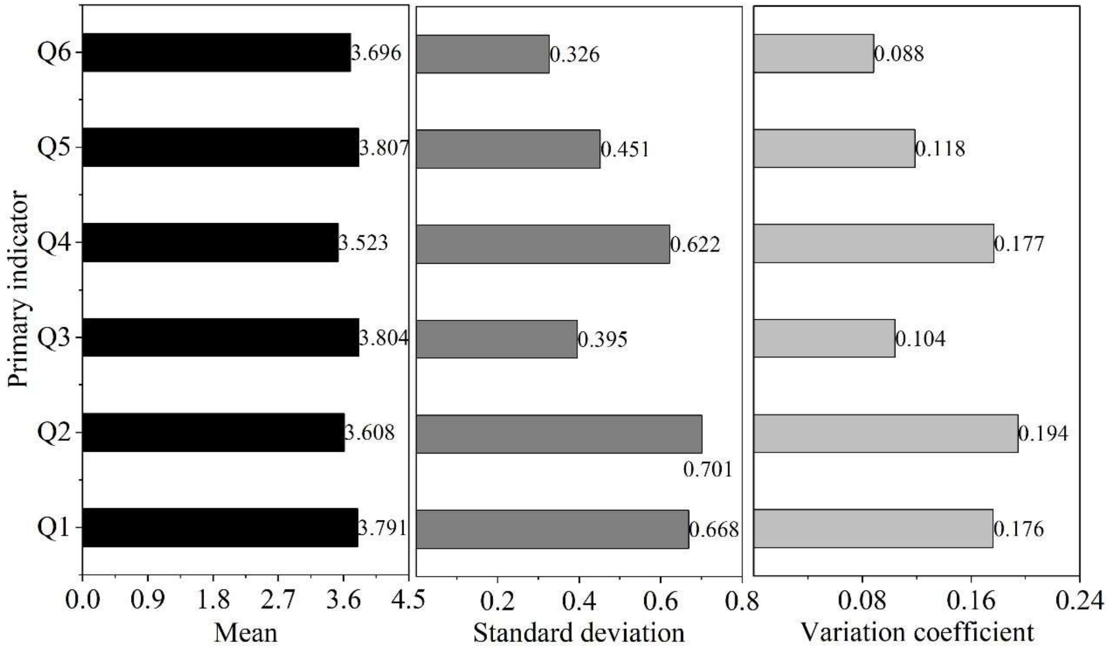
According to the formula of mean, standard deviation and coefficient of variation mentioned in subsection 2.3.8, the first round of indicator screening and analysis was carried out for the second-level indicators in the above preliminary formulation of the evaluation indicator system, and the results of the screening of the second-level evaluation indicators are shown in Fig. 2, in which (a)~(c) represent the mean, standard deviation and coefficient of variation, respectively. As can be seen from the figure, the coefficients of variation of Q16, Q26, Q36 and Q46 are greater than 0.25, which do not meet the requirements of indicator screening and need to be excluded, while other secondary indicators are retained.



(a)mean (b)Standard deviation (c)Variation coefficient

Figure 2: Secondary evaluation index screening results

After the first round of screening the second-level indicators, the first-level indicators were then screened, and the results of the first round of screening the first-level indicators are shown in Fig. 3, (a)~(c) as above. Based on the data in Figure 3, it can be seen that there are no cases of Mean<3.5 and coefficient of variation<0.25, and the initially formulated level 1 indicators meet the requirements of indicator screening, for which all level 1 indicators are retained.

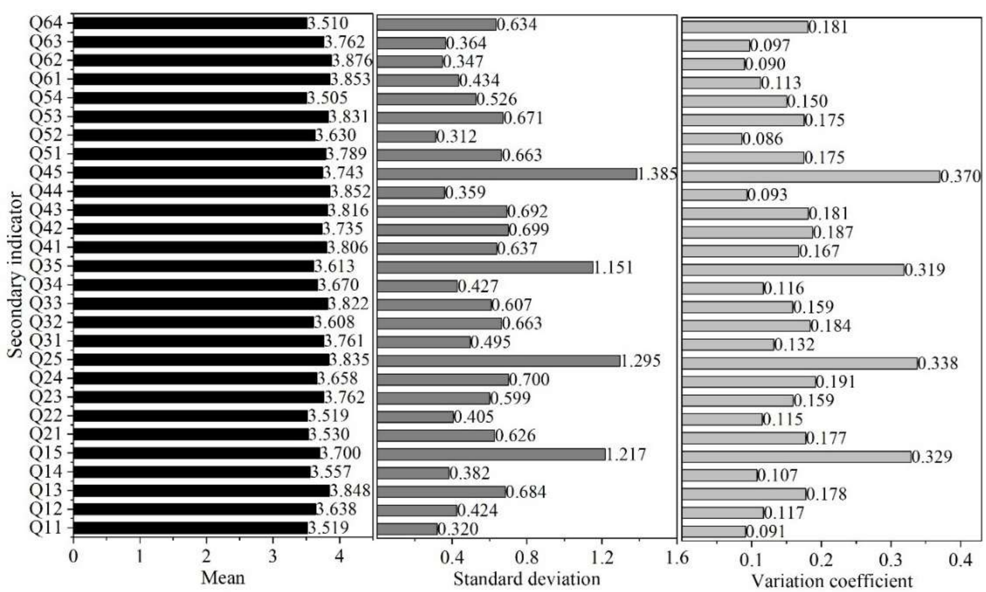


(a)mean (b)Standard deviation (c)Variation coefficient

Figure 3: The first round of indicators screening results

III. A. 6) Second round of indicator screening analysis

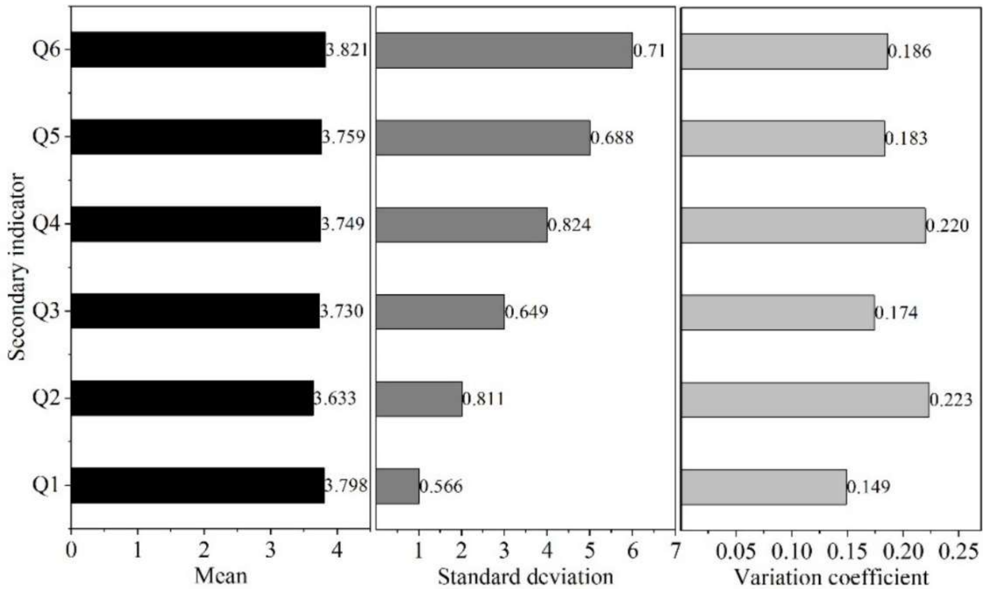
After analysing the first round of indicator screening above, this subsection starts the second round of indicator screening and analysis of the preliminarily formulated evaluation indicator system, with the same methodology as above, and the results of the second round of secondary indicator screening and analysis are shown in Figure 4. As shown in Fig. 4(a), Fig. 4(b) and Fig. 4(c), Q15 (coefficient of variation: 0.329), Q25 (coefficient of variation: 0.338), Q35 (coefficient of variation: 0.319) and Q45 (coefficient of variation: 0.370) are larger than 0.25, and it is necessary to exclude the above mentioned Q15, Q25, Q35, and Q45, and the remaining 24 second-level indicators are retained.



(a)mean (b)Standard deviation (c)Variation coefficient

Figure 4: The second round of the second round of the analysis of the analysis results

In the same way, the first-level indicators were screened and analysed, and the results of the second round of screening and analysis of the first-level indicators are shown in Figure 5. The data labels in the figure show that the coefficients of variation of all the first-level indicators are less than 0.25 and the average value is greater than 3.5, and all the above first-level indicators are retained.



(a)mean (b)Standard deviation (c)Variation coefficient

Figure 5: The second round of indicators screening analysis results

III. A. 7) Finalisation of the evaluation indicator system

Through the two rounds of evaluation indicator screening mentioned above, the evaluation system of waste classification and resource recovery in housing communities under the low-carbon concept was finally determined, and the evaluation indicator system is shown in Figure 6. The evaluation index system consists of six primary indicators (classification facilities Q1, classification publicity and education Q2, classification effects and benefits Q3, policy management Q4, community participation and co-operation Q5, innovation and continuous improvement Q6) and 24 secondary indicators (number of bins Q11, layout of bins Q12, clarity of classification labelling Q13, maintenance of classification facilities Q14, amount of publicity materials distributed Q21, number of publicity activities Q22, resident participation Q23, popularity of classification index Q24). Q22, participation of residents Q23, popularity of classification index Q24, accuracy of classification Q31, effectiveness of reduction Q32, resource utilisation Q33, efficiency of harmless treatment Q34, improvement of policies and regulations Q41, setting up of management bodies Q42, implementation of management system Q43, supervision Q44, participation of residents Q51, participation of social organisations Q52, cooperation among enterprises Q53 , cross-regional cooperation Q54, technological innovation and application Q61, model innovation exploration Q62, continuous improvement mechanism Q63, and promotion of successful cases Q64) are composed to lay the theoretical foundation for the following weighting analysis and evaluation.

III. B. Numerical analysis of indicator weights

III. B. 1) Weighting analysis of secondary indicators

Based on the weight calculation method in section 2.4 above, the weights of the second-level indicators in the evaluation system are calculated, and the results of the analysis of the weights of the second-level indicators are shown in Fig. 7, where the horizontal axis indicates the second-level indicators, the vertical axis indicates the weights of the corresponding indicators, and the size of the radius of the bubbles indicates the rankings from the largest to the smallest. As shown in Figure 7, Q12 (0.071)>Q54 (0.067)>Q42 (0.064)>Q41 (0.063)>Q53 (0.063)>Q32 (0.061)>Q61 (0.061)>Q22 (0.059)>Q23 (0.058)>Q11 (0.054)>Q63 (0.051)>Q24 (0.050)> Q62(0.048)>Q13(0.046)>Q52(0.039)>Q14(0.036)>Q33(0.023)>Q34(0.019)>Q43(0.017)>Q31(0.015)>Q64(0.014) >Q44(0.010)>Q21(0.008)> Q51(0.006), providing a comprehensive overview of the relationship between the weights and sizes of the secondary indicators.

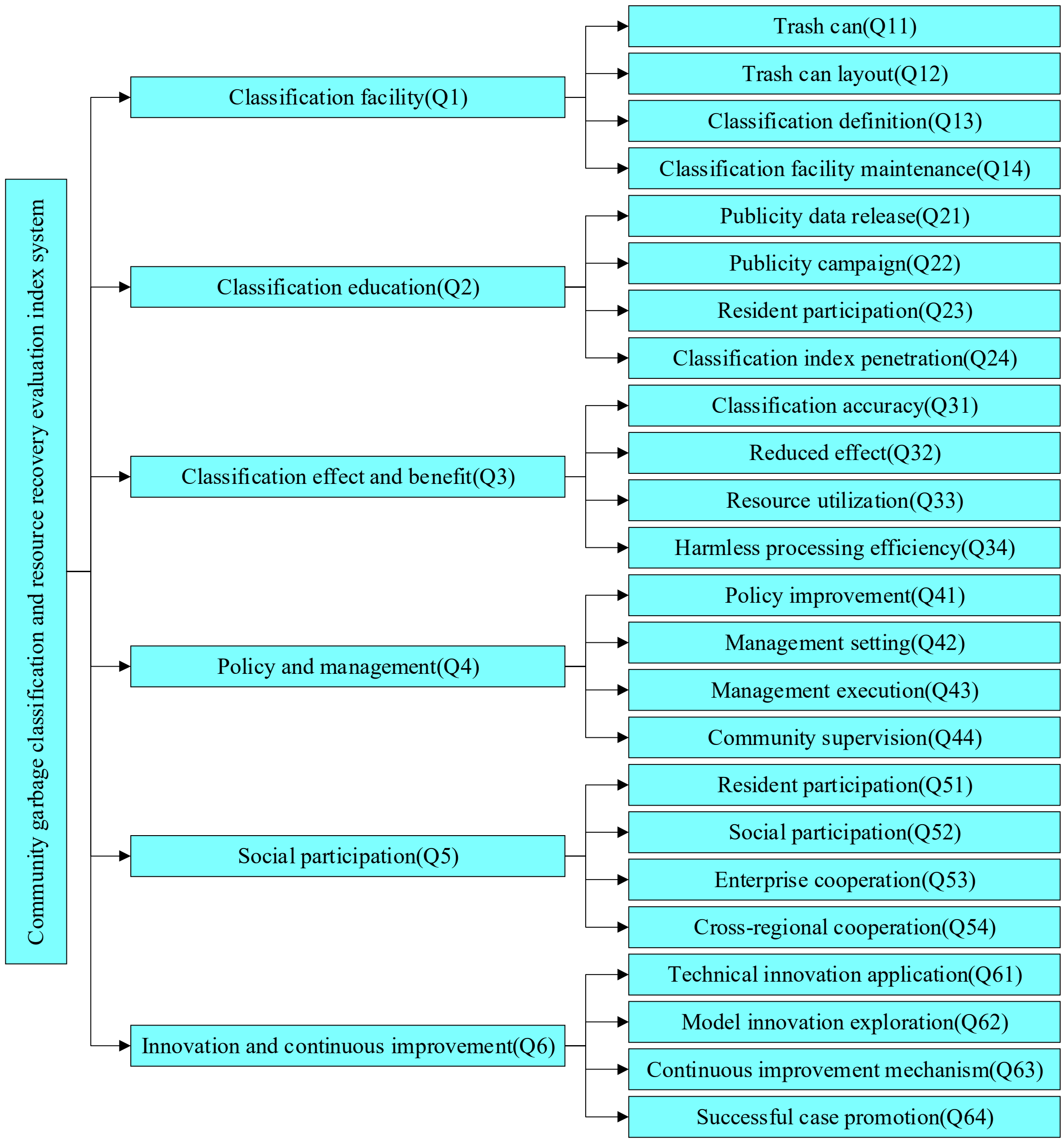


Figure 6: Evaluation index system

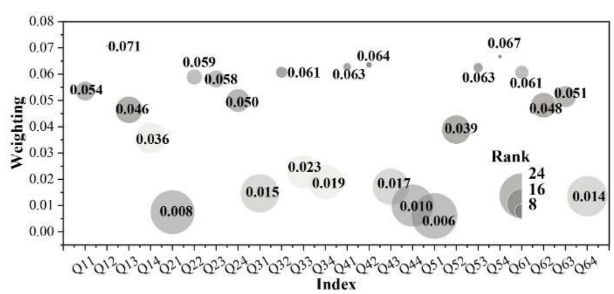


Figure 7: Second grade index weight analysis results

III. B. 2) Analysis of the weights of tier-1 indicators

The same method was used to calculate the weights of the first-level indicators in the evaluation system, and the results of the analysis of the weights of the first-level indicators are shown in Fig. 8. Q1 (0.206) > Q2 (0.175) > Q5 (0.174) > Q6 (0.174) > Q4 (0.154) > Q3 (0.117), which results in the first-level weights of the indicators, and provides the data support for the analysis work below.

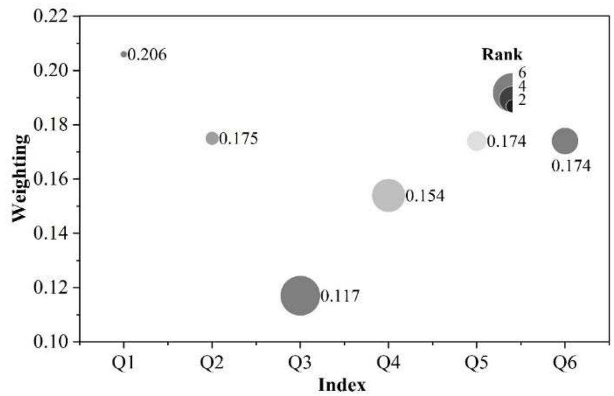


Figure 8: The results of the first level index weight analysis

III. C. Fuzzy integrated evaluation analysis

III. C. 1) Development of a rubric

Selecting a community as a research sample, according to the evaluation index of waste classification and resource recovery in housing communities under the low-carbon concept, the rubric set is divided into five grades, which are excellent, good, average, pass, and poor, corresponding to V1, V2, V3, V4, and V5, and this paper adopts the expert consultation method to obtain the data of the fuzzy comprehensive evaluation method, and invites 20 as experts to evaluate and score them. Integrating the expert scoring data, the results are summarised in the table, and Table 6 shows the summary of expert scoring. It can be seen that most of the experts gave excellent and good, in order to further quantify the results of the evaluation and analysis, the next construction of the affiliation matrix.

Table 6: Experts score

Secondary indicator	Excellence	Good	General	Passing	Difference
Q11	4	7	3	3	3
Q12	6	9	3	0	2
Q13	6	9	1	1	3
Q14	4	6	4	2	4
Q21	2	9	4	3	2
Q22	5	6	2	3	4
Q23	5	5	2	4	4
Q24	6	7	2	2	3
Q31	4	8	2	4	2
Q32	6	5	2	3	4
Q33	6	7	2	1	4
Q34	5	6	3	1	5
Q41	5	5	5	2	3
Q42	5	5	5	2	3
Q43	5	5	3	2	5
Q44	3	8	5	1	3
Q51	3	9	3	0	5
Q52	4	8	3	1	4
Q53	4	6	5	2	3
Q54	6	8	1	1	4
Q61	3	9	4	0	4
Q62	6	9	4	1	0
Q63	4	9	5	1	1
Q64	6	5	5	4	0

III. C. 2) Constructing the affiliation matrix

According to formula (18), the evaluation results of housing waste classification and resource recovery under the low-carbon concept are calculated, and the comprehensive evaluation results are shown in Figure 9. Through the data in Fig. 9, its comprehensive evaluation results are:

$$W \cdot R_{m*n} = \left(w_1, w_2, w_3 \cdots, w_m\right) \begin{pmatrix} r_{11} & r_{12} & r_{13} & \cdots & r_{1n} \\ r_{21} & r_{22} & r_{23} & \cdots & r_{2n} \\ r_{31} & r_{32} & r_{33} & \cdots & r_{3n} \\ r_{41} & r_{42} & r_{43} & \cdots & r_{4n} \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ r_{m1} & r_m 2 & r_{m3} & \cdots & r_{mn} \end{pmatrix}$$

$$= \left[4.946, 6.984, 3.188, 1.775, 3.106\right]$$

Finally, based on the principle of maximum affiliation, the evaluation results of waste classification and resource recovery in a housing community under the low-carbon concept are good, and the data reflect 6.984, although the waste classification and resource recovery in a community can meet the requirements of the current low-carbon concept, but in order to further enhance the community's low-carbon quality and green and sustainable development, the follow-up will be based on the results of the analysis, and put forward corresponding optimisation strategies.

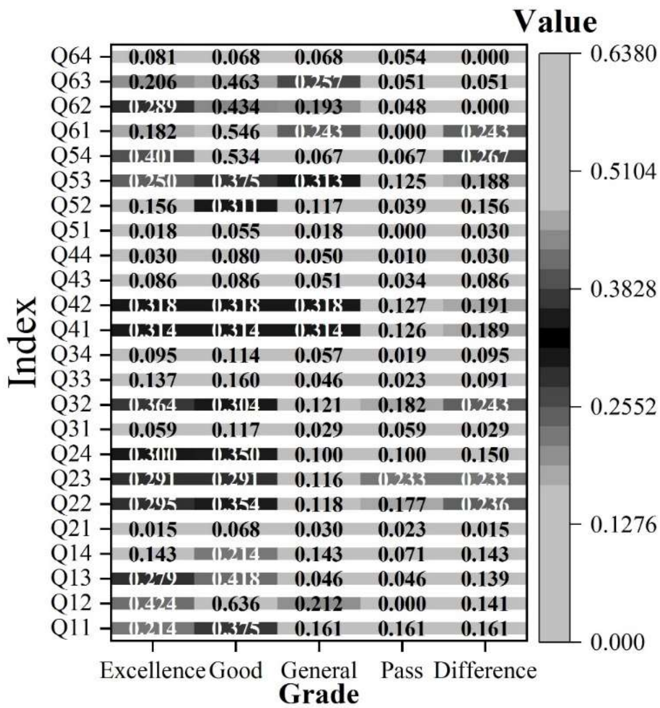


Figure 9: Comprehensive evaluation results

IV. Conclusions and recommendations

IV. A. Conclusion

This paper synthesises the Delphi method, entropy weight method and fuzzy evaluation algorithm to jointly explore the construction of a waste classification and resource recovery system for housing communities in the context of green and low carbon. The research results of this paper are shown as follows:

(1) In the second round of indicator screening process, secondary indicators Q15 (coefficient of variation: 0.329), Q25 (coefficient of variation: 0.338), Q35 (coefficient of variation: 0.319), Q45 (coefficient of variation: 0.370) are greater than 0.25, and four of them are excluded from the treatment, while the coefficients of variation of the primary indicators are all less than 0.25, and the average value is greater than 3.5, and primary indicators are all retained to finalise the evaluation index system.

(2) In the process of weight analysis of evaluation indexes, the top five weights of secondary indexes are Q12(0.071)>Q54(0.067)>Q42(0.064)>Q41(0.063), and the top five weights of primary indexes are: Q1(0.206)>Q2(0.175)>Q5(0.174)>Q6(0.174)> Q4(0.154)>Q3(0.117), which not only demonstrates the distribution

of the weights of the first-level indicators, but also provides data support for the subsequent fuzzy comprehensive evaluation analysis.

(3) Finally, based on the principle of maximum affiliation, the evaluation result of rubbish classification and resource recovery in a housing community under the low-carbon concept is good, and its data reflects 6.984, which to a certain extent reflects that there are still some problems in the construction of rubbish classification and resource recovery in a certain community, and puts forward optimisation strategies and suggestions in this regard.

IV. B. Recommendations

IV. B. 1) Improvement of relevant laws on waste separation and recycling

Under the concept of green, low-carbon and sustainable development, formulating a waste separation and recycling policy from a legal point of view and promoting the formation of a recycling-oriented society is the basis for realising Beijing's waste separation and recycling policy. According to foreign experience in rubbish disposal, especially in Japan and Germany, before dealing with the problem of urban living rubbish and forming a rubbish resource recycling system, a set of rubbish disposal law system will be formulated to clarify the responsibilities related to rubbish generation and to constrain the behaviours of the main bodies of each process of rubbish disposal. And if we want to promote the construction of community waste classification and resource recycling system, it is even more necessary to form a series of legal system to ensure its effective operation.

IV. B. 2) Improvement of the community life management system

In view of the characteristics of the community living rubbish management and recycling resource management, which are managed by many departments and branches, the rubbish recycling and utilisation should be managed in a unified way, so as to minimise the intersection of rights between various departments, in order to reduce the transaction cost of the rubbish management and to improve the efficiency of the implementation of rubbish disposal. At the same time, we can learn from Germany's binary management model, and set up a third-party management organisation between the community and the government, and take back part of the authority of rubbish management, so that the third-party management. The third party management organisation can carry out integrated operation for some kinds of rubbish from front-end collection to terminal treatment and reuse, and the government department is responsible for the supervision. This not only avoids the phenomenon of the unity of government and enterprise in the community waste management system of the past few days, but also centralises the management of the whole process of waste disposal, improves efficiency and is more in line with the concepts of low-carbon living and sustainable development.

IV. B. 3) Strengthening education and awareness-raising

Various means of publicity and the media have been used to vigorously publicise to the public the ways and significance of waste separation and recycling, and corresponding basic courses and education have been added to raise the awareness of sustainable development and the concept of low-carbon living. Not only should residents be made aware of the ways of separate collection of domestic waste, they should also be made to understand the ways of disposal of domestic waste and the significance of recycling of resources.

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