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Research on the Realization Path of Low-carbon Economy Assisted by Waste Classification under the Background of Ecological Civilization

-- Based on the Perspective of Environmental Accounting

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Abstract: Under the strategic guidance of the construction of ecological civilization and the goal of "double carbon", waste classification has become an important link to promote green and low-carbon development, and the evaluation of its environmental and economic benefits has been paid more and more attention. Based on this, this study aims to systematically explore the realization path of waste classification to help low-carbon economy from the perspective of environmental accounting, so as to provide a basis for government policy-making. This study uses the analytic hierarchy process (AHP), focusing on the four dimensions of environmental benefits, economic feasibility, management effectiveness and social sustainability, and sets up three typical paths: policy-driven, technology-incentive-driven and comprehensive cooperation-driven. The results show that the implementation path of comprehensive synergy driving is the optimal solution of waste classification under the current background, especially in terms of environmental benefits and social sustainability. Accordingly, this study puts forward relevant policy recommendations to encourage the government to provide technical empowerment, economic incentives and community co-construction while focusing on policy guidance, so as to carry out diversified collaborative governance.

Keywords: Environmental Accounting, Analytic Hierarchy Process, Waste Classification, Low-carbon Economy.

1. Introduction

1.1. Research Background and Significance

With the development of China's economy, the acceleration of urbanization and the improvement of people's living standards, the amount of garbage produced is increasing day by day. According to relevant statistics, 214 large and medium-sized cities in China produce nearly 190 million tons of domestic waste, and the top 10 cities, led by Shanghai and Beijing, produce 30% of all cities. Under the strategic guidance of the construction of ecological civilization and the goal of "double carbon", garbage classification has changed from a simple health problem to an important link to promote green and low-carbon development. General Secretary once pointed out: "Garbage is a misplaced resource. It is an art to turn garbage into resources and turn decay into magic." This profoundly reveals the core value of waste classification in resource recycling and environmental protection.

At the same time, environmental accounting, as a tool to measure the impact of economic activities on the environment, is gradually being taken seriously. Traditional waste classification evaluation focuses on the final treatment effect, while based on the perspective of environmental accounting, the environmental benefits brought by waste classification can be quantified, so as to more scientifically evaluate its contribution to low-carbon economy. At present, the construction of garbage classification in urban communities is strengthening management, and digital intelligent garbage classification facilities are gradually popularized, which provides technical support for data collection and accounting of environmental accounting.

The significance of this study is to systematically assess the comprehensive performance of waste classification in the four dimensions of environmental benefits, economic feasibility, management efficiency and social sustainability by introducing the accounting framework of environmental accounting. This not only helps to make up for the shortcomings of traditional waste classification research, but also provides a scientific basis for the government to formulate low-carbon economic policies. By exploring the advantages and disadvantages of different paths such as policy-driven, technical incentives and comprehensive synergy, this study aims to provide theoretical support and practical guidance for the construction of an efficient and sustainable waste classification system.

The survey shows that more than 70% of urban residents are willing to classify garbage under the stimulation of red envelopes, and less than 30% of residents are unwilling to classify garbage. Only 22.74% of the people have a better understanding of garbage classification, and 70.42% of the people only know a little about garbage classification. 76.28% of the people think that under the current situation of garbage disposal, it is very necessary to strengthen garbage classification and improve the utilization of recyclable garbage. 25.18% of the people throw away all the garbage directly, 37.16% of the people will put glass, iron and aluminium into the recyclable garbage bin separately, and 53.55% of the people will dispose of harmful garbage such as waste batteries separately. 65.53% of the people are concerned about the follow-up disposal of garbage.

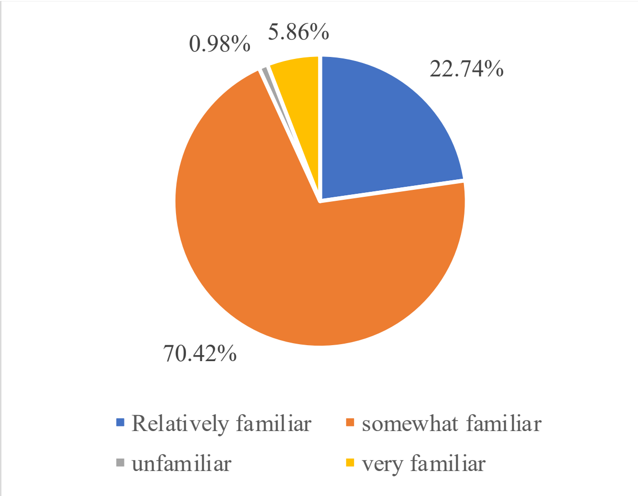

Figure 1. Residents' understanding of garbage classification

1.2. Literature Review

1.2.1. Research Status of Waste Classification at Home and Abroad

Domestic research focuses on policy coordination, technology application and community governance of waste classification. By analyzing 233 policy texts of pilot cities from 2000 to 2020, Ding Jianbiao and Zhang Qianqian (2022) pointed out that the domestic waste classification policy is highly complex, and its synergistic structure covers the macro-framework of "objective-process-result", but there are some limitations such as the fragmentation of policy subjects and the lack of tool synergy. It is necessary to improve efficiency through department linkage, enterprise intervention and social participation [1]. At the technical level, Zhou Fengqi (2020) found that AI technology can reduce human costs and improve efficiency, but the current application is still limited to the collection link, and the operation mode is not mature, so it is necessary to strengthen the research and development of key technologies and the formulation of standards [2], Zhang Xiufang (2021) further discussed the automatic identification technology, and proposed to rely on cloud computing to simplify the system. Promote the intelligent landing of garbage classification [3]. In terms of social participation, Huang Caiyun (2023), taking Y community in Nanjing as an example, reveals the problems of weak residents' awareness and inadequate government services, advocates that multi-governance should be achieved through the coordination of subject positioning, willingness, mechanism and tools [4], and Wu Junmin and Jia Hui (2020) use analytic hierarchy process to prove that residents' awareness and incentives. It is necessary to improve convenience and strengthen family values. In addition [5], Zhang Mao (2023), based on game theory, pointed out that the supervision of garbage classification requires the cooperation of the government, the community and the residents to strengthen the punishment measures and environmental awareness [6].

The experience of waste classification in developed countries provides an important reference for China. Shang Yixuan (2021) reviewed the practices of Japan, Germany, the United States and Singapore, and found that all countries rely on laws and regulations and local characteristic models, such as Japan's emphasis on "proximity principle" and regional balance, Germany's establishment of "dual recycling system" to implement producer responsibility, but there are problems such as waste export orientation [7]. OKUDA I (2007) specifically analyzed the regionalization trend of waste management in Japan, pointing out that under the background of rising costs, the coordination mechanism led by the central government is the key, while the United States relies more on market forces [8]. Nelles M (2016) emphasized that the German Packaging Waste Management Law promoted the development of circular economy, reflecting the effective combination of policy and market [9].

These studies show that garbage classification should be adapted to local conditions and integrate government control and market mechanism. Cui Xiaotong (2015) pointed out from the perspective of social participation that garbage classification requires the cooperation of social organizations, families and other multiple subjects in order to achieve long-term operation [10].

1.2.2. Review

Domestic and foreign studies have shown that waste classification is a complex system engineering that requires the coordination of policy, technology and society. The existing achievements have made remarkable progress in policy coordination mechanism, intelligent technology application, international comparison and reference, but there are three limitations on the whole: first, the research perspective focuses on the qualitative analysis of local links, lacking the systematic quantitative integration of environmental and economic benefits; second, the influence mechanism of residents' behavior motivation, community coordination mechanism and other factors is insufficient; third, the research perspective focuses on the qualitative analysis of local links, lacking the systematic quantitative integration of environmental and economic benefits. Thirdly, it fails to integrate waste classification into the overall framework of low-carbon economy for cost-benefit analysis.

By introducing the perspective of environmental accounting, this study constructs a four-dimensional evaluation model including environmental benefits, economic feasibility, management effectiveness and social sustainability, which effectively makes up for the lack of quantification in traditional research. Future research can continue to establish a long-term monitoring mechanism to monetize indicators such as carbon emission reduction and resource recovery rate of waste classification, explore the docking of big data generated by intelligent devices with environmental accounting system, and build a life cycle assessment framework, so as to promote the transformation of waste classification from end treatment to low-carbon economy.

2. Methods and Materials

2.1. Model Construction

In order to select a better implementation scheme of waste classification, the study used the analytic hierarchy process (AHP) to evaluate. The criterion layer study mainly delineated four influencing factors: environmental benefits, economic feasibility, management efficiency and social sustainability. The includes the policy-compulsory-driven scheme, the technology-incentive-driven scheme, and the comprehensive cooperation-driven scheme. Specifically, the environmental benefits are more focused on the carbon emission reduction effect and resource recycling rate of the path. Economic feasibility is based on an environmental accounting perspective, assessing the cost-effectiveness and long-term financial sustainability of the path. Management effectiveness focuses on evaluating the implementation efficiency, operability and stability of the path. Social sustainability is the ability of an assessment pathway to promote public participation, acceptance, and long-term behavioral change. The policy-compulsory-driven scheme is a path dominated by administrative orders, regulatory constraints and punitive measures, while the technology-incentive-driven scheme is a path dominated by technical and economic incentives such as intelligent classification facilities and points reward platforms. The comprehensive synergy driven scheme combines the advantages of the former two, focusing on the synergy path of policy guidance, technology empowerment, economic incentives and community co-construction.

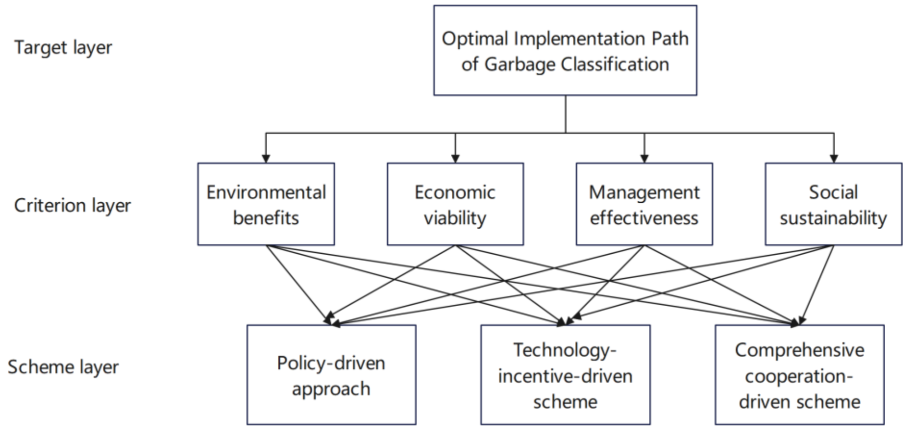

Figure 2. AHP hierarchy division

2.2. Data Sources

After the establishment of the distribution mode hierarchy structure model, we should compare the relative importance of each factor in the same level to the previous level, and use the judgment value to show the importance degree of each factor, so as to form a judgment matrix. In the project, the research invites 15 experts from the fields of environmental science, public management and economics to score. An assignment agreed upon by many experts was obtained, and the comparison scale used is shown in Table 1.

Table 1. Comparison Scale

Scale value	Meaning
1	The two factors are equally important.
3	Comparing the two factors, the former is slightly more important than latter
5	Comparing the two factors, the former is obviously more important than latter.
7	Comparing the two factors, the former is more important than latter.
9	Comparing the two factors, the former is more important than latter.
2, 4, 6, 8	The scale value corresponding to the intermediate state is judged
Countdown	An important indicator of the contrast between the two factors, the inverse comparison

The n-order comparison judgment matrix A can be obtained by judging every two elements in the matrix one by one according to the scale in the above table.

$$A_{n\times n} = \begin{bmatrix} a_{11} & a_{12} & a_{1..} & a_{1n} \\ a_{21} & a_{22} & a_{2..} & a_{2n} \\ a_{..} & a_{..} & a_{..} & a_{..} \\ a_{n1} & a_{n2} & a_{n..} & a_{nn} \end{bmatrix} \quad (1)$$

Merging the expert matrix, using the geometric mean method to ensure consistency check, m experts (m = 1, 2... K) the formed scoring matrix is multiplied by bits and then raised to the power of m to obtain a unique integrated matrix $\overline{A}$The formula is as follows:

$$\overline{A} = (\prod_{k=1}^{m} a_{ij}^{k})^{\frac{1}{m}} \quad (2)$$

Calculate that relative weight of the unique integrated matrix

The most commonly used method to calculate the maximum eigenvector of the paired comparison matrix is the sum-product method and the square root method. In this paper, the sum-product method is used. The specific calculation steps of the sum-product method are as follows:

(1) obtain a unique integration matrix $\overline{A}$

(2) Set the matrix $\overline{A} = (a_{ij})_{n\times n}$Each column vector is normalized to obtain $B = (b_{ij})_{n\times n}$

$$b_{ij} = \frac{a_{ij}}{\sum_{i=1}^{n} a_{ij}} \quad (3)$$

(3) Add the row vectors of the normalized matrix B

$$M_i = \sum_{j=1}^{n} b_{ij} \quad (4)$$

(4) Put the vector $M = \begin{bmatrix} M1 \\ M2 \\ \dots \\ M_n \end{bmatrix}$Normalization is performed

$$W_i = \frac{M_i}{\sum_{i=1}^{n} M_i} \quad (5)$$

An eigenvector is obtain $W_i = \begin{bmatrix} W1 \\ W2 \\ \dots \\ W_n \end{bmatrix}$

(5) Calculate the largest eigenvalue λ_{max}

$$\lambda_{max} = \frac{1}{n} \sum_{i=1}^{n} \frac{[AW]_i}{W_i} \quad (6)$$

(6) Consistency test of judgment matrix

① Calculate the consistency index

$$CI = \frac{\lambda_{max} - n}{(n-1)} \quad (7)$$

② Calculate the consistency ratio

$$CR = \frac{CI}{RI} = \frac{\lambda_{max} - n}{(n-1)RI} \quad (8)$$

RI is a random index, and the specific values are shown in Table *.

Table 2. Average random consistency index RI value of judgment matrix

Matrix order	1	2	3	4	5	6	7	8	9	10	11	12
RI	0	0	0.52	0.89	1.12	1.26	1.36	1.41	1.46	1.49	1.52	1.54

3. Results and Discussion

3.1. Calculation Results

Based on the calculation results of each indicator judgment integration matrix and weight, the weights of indicators at all levels are summarized in the following table:

Table 3. Weight Summary

Target layer	Criterion layer	Relative weight	Scheme layer	Relative weight	Comprehensive weight
Optimal Implementation Path of Garbage Classification	Environmental benefits	0.272	Policy compulsion driven scheme	0.2532	0.0689
			Technology incentive-driven solutions	0.2992	0.0814
			Integrated Synergy-Driven Solution	0.4476	0.1217
	Economic viability	0.2556	Policy compulsion driven scheme	0.2186	0.0559
			Technology incentive-driven solutions	0.4063	0.1039
			Integrated Synergy-Driven Solution	0.3752	0.0959
	Management effectiveness	0.2255	Policy compulsion driven scheme	0.3187	0.0719
			Technology incentive-driven solutions	0.2769	0.0624
			Integrated Synergy-Driven Solution	0.4044	0.0912
	Social sustainability	0.2469	Policy compulsion driven scheme	0.28	0.0691
			Technology incentive-driven solutions	0.227	0.056
			Integrated Synergy-Driven Solution	0.493	0.1217

Table 4. Proportion of scheme layer

	Proportion of three scheme layers
Policy-driven approach	0.2658
technology incentive driven solution	0.3037
Integrated Synergistic Driven Solution	0.4305

3.2. Result Analysis

From the above results, it can be seen that the third scheme, namely the comprehensive collaborative driving scheme, is better. The weight of the comprehensive synergy driven scheme is 0. 4305, which is the highest, indicating that this path is the best choice to promote waste classification and achieve low-carbon economy. This shows that a single administrative order or market means is difficult to solve the complex problem of garbage treatment, and it must rely on the joint governance of the government, enterprises, communities and residents. In addition, the weight of technical incentive is 0.3037, which is greater than weight of policy mandatory 0.2658, indicating that technical means play a significant role in improving management efficiency and resource recovery rate. The application of intelligent sorting, digital supervision and other technologies can effectively reduce the cost of environmental management and enhance the environmental benefits of environmental accounting. Although the weight of policy compulsion is low, it is still the basic guarantee. In the early stage of garbage classification, mandatory policies and regulations are necessary, but with the maturity of the system, we can no longer rely solely on this means to achieve benefits.

From the weight of a single index, the weight of environmental benefits is the highest, which is consistent with the goal of low-carbon economy. It shows that carbon emission reduction and resource recovery rate are the first consideration in the path selection, and if the path cannot bring significant environmental improvement, the value will also be reduced. The weight of economic sustainability is second only to environmental benefits. It shows that environmental accounting emphasizes the input-output ratio. The analysis shows that although waste classification requires early investment, the economic value generated by resource utilization can support the sustainability of the path.

The analysis shows that in the context of ecological civilization, the realization of low-carbon economy of waste classification cannot rely solely on government mandatory policies, but should build a comprehensive system of government guidance, technology empowerment, market operation and public participation, which embodies the value co-creation advocated by environmental accounting.

4. Conclusion

4.1. Research Conclusion

Based on the analytic hierarchy process (AHP), this study constructs a path evaluation model for the realization of low-carbon economy assisted by waste classification, and draws the following conclusions through analysis:

(1) Among the three realization paths of policy-driven, technological incentives and comprehensive synergy, the comprehensive synergy path has the highest weight. This result shows that it is difficult to achieve long-term governance by relying solely on administrative orders or technical means, and it is necessary to build a synergistic mechanism of multi-governance among government, enterprises, communities and residents.

(2) Environmental benefit is the core driving force. Criterion layer analysis shows that environmental benefit is the key factor affecting path selection, which verifies the core value of waste classification in the construction of ecological civilization, and achieves carbon reduction at the source through end treatment.

(3) Economic feasibility is the guarantee. The results show that the sustainable operation of waste classification system can not be separated from economic support. Only when the environmental benefits can cover or partially cover the environmental costs, the path is feasible.

4.2. Countermeasures and Suggestions

Based on the above conclusions, this paper puts forward the following countermeasures and suggestions for the government to optimize the waste classification system and promote the development of low-carbon economy:

(1) Promoting multiple collaborative governance

The government needs to change from "manager" to "service provider" and "coordinator", establish a cross-sectoral linkage mechanism, and integrate the resources of urban management, environmental protection, commerce and other departments. Encourage social capital to participate in the construction and operation of waste classification facilities, reduce government financial pressure and improve operational efficiency through PPP model. Establish a community grid management system, give full play to the supervision and guidance role of property management, industry committees and volunteers, and enhance the participation of residents.

(2) Increase investment in science and technology

Intelligent garbage sorting boxes are popularized in the community, and residents are encouraged to classify correctly by means of points exchange and real-time feedback. Build a digital platform, use big data and Internet of Things technology to establish a traceability system for the whole process of garbage classification, realize the digital management of the whole chain from delivery, collection, transportation to disposal, and reduce human errors.

(3) Improve the policy system

We will improve laws and regulations, refine the regulations on rewards and punishments for waste classification, impose severe penalties on mixed transportation, and set up special subsidies to reward advanced communities and enterprises. Establish a carbon inclusive mechanism, explore the incorporation of waste classification and reduction into personal carbon accounts, so that residents' environmental protection behavior can form a positive incentive.

4.3. Research Deficiency and Prospect

This study is mainly based on expert scoring and some public data, lacking the support of large-scale and long-term field monitoring data, which may lead to some subjective bias in the weight results. In addition, the price index system mainly focuses on the macro level, and the soft indicators such as residents' psychological factors at the micro level are not considered enough. Future research can further monetize the environmental benefits of waste classification, build a more accurate cost-benefit analysis framework, and provide a more intuitive economic basis for government decision-making.

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