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RESEARCH ARTICLE

Identifying the influencing factors and constructing incentive pattern of residents' waste classification behavior using PCA-logistic regression

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Abstract

With the acceleration of urbanization, domestic waste has become one of the most inevitable factors threatening the environment and human health. Waste classification is of great significance and value for improving urban environmental quality and promoting human well-being. Based on the theory of planned behavior, we added external and socio-economic factors to systematically examine how they affect residents' waste classification behavior (WCB). We collected 661 valid data through a questionnaire survey conducted in Jinan, a pilot city for waste classification in China. Key driving factors were identified by combining binary logistic regression and the principal component analysis. The results showed that the elderly, women, and people with higher education are more likely to participate in waste classification. Attitude, collaborative governance, and institutional pressure positively affect WCB, while subjective norm and infrastructure have a negative effect. Knowledge mastery and degree of publicity are positively and significantly related to WCB, but other perceived behavioral control sub-variables negatively affect WCB. Based on the results and status of waste classification in Jinan, we propose the multi-agent linkage governance pattern from various dimensions to explore a powerful guiding incentive that can enhance WCB and provide a reference for waste management policymakers.

Keywords Waste classification behavior · Theory of planned behavior · Binary logistic regression · Principal component analysis · Incentive pattern

Introduction

With the rapid development of the world's economy and urbanization, the amount of municipal solid waste produced has increased dramatically in recent years. According to a World Bank report, the world was estimated to generate solid waste increase by 73% from 2.24 billion tons in 2020 to 3.4 billion tons in 2050 (World Bank 2022). The improper processing of solid waste separation and management, including uncontrolled waste recycling (Lin et al. 2022) and the open burning of waste (Ferronato and Torretta 2019), threatens human health and the environment (Odonkor and Sallar 2021; Hu and He 2022). Especially since the outbreak of the COVID-19 pandemic in 2019, essential public health has faced great challenges. The demand for facemasks, gloves, and personal protective equipment (PPE) kits generates a huge amount of healthcare waste that may contribute to virus contamination, which may also lead to health hazards for trash collection workers and waste management (Ranjbari et al. 2022). The negative impact of solid waste has become a global sustainable development issue. Various sectors of society need to learn to cope with waste pollution and waste management to address global environmental problems (Esmaeilian et al. 2018).

China is facing serious waste disposal and management issues. Its municipal solid waste reached 234.52 million tons by the end of 2020, while the total amount of urban waste is still increasing at an annual rate of 8–10%, and more than two-thirds of the cities face the dilemma of a "waste siege" (Ministry of Housing and Urban–Rural Development of China 2020). In response to the rapid growth in waste generation, the Chinese government has made many attempts to classify waste. As early as 2000, China launched waste

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source-separated collection policies in eight pilot cities (e.g., Beijing, Shanghai, and Guangzhou), collecting municipal solid waste using four different labeled containers (Zhang and Wang 2020). However, the implementation effects in those cities showed a poor performance (Tai et al. 2011). In 2018, Shanghai was selected as the first pilot city for waste classification. Then, 46 key cities were added to the pilot to carry out its implementation, including Jinan, Qingdao, and Taian in Shandong Province. As the second most populated and the third-largest economy in China, Shandong Province has faced severe resource pressure and environmental pollution as a result of prolonged rapid urbanization and prosperous economic development (Chen et al. 2022). In 2020, Shandong also ranked as the third major waste-producing province in China as its waste removal reached 16.74 million tons (National Bureau of Statistics of China 2021). Jinan plays a leading showcase role as the capital of Shandong Province and waste classification pilot city and has implemented a large-scale waste classification policy (Liu et al. 2022). Although residents in Jinan have begun to pay attention to waste classification, many problems hinder them from engaging in waste sorting, including a long-term lack of relevant education and a sound waste classification system. These problems are prevalent in other waste classification pilot cities (Zou et al. 2019). Therefore, a more nuanced understanding of barriers and dilemmas to sorting waste in China is warranted and Jinan city offers an important case to investigate the affecting factors of community residents engaged in waste classification.

Enhancing the effect of waste classification requires a deeper understanding of constraints affecting such behavior. Many scholars tried to focus on the psychological determinants of residents' WCB. From the perspective of individual willingness and behavior, attitude, subjective norm, perceived behavioral control, and intention factors significantly affect WCB (Akulume and Kiwanuka 2016; Zhang et al. 2015, 2022). Some researchers indicate that residents' grasp of classification knowledge contributes to their willingness to participate in waste classification (Zhang et al. 2021). Similarly, perceived difficulty and convenience of waste classification have been proven to play a prominent role in classification intention in recent years (Cudjoe et al. 2020; Cheng et al. 2022). Scholars also consider socio-economic characteristics as key drivers behind the behavioral change in waste classification. Setiawan (2020) found that education level determined the public receptivity regarding waste classification. In addition, age (Pakpour et al. 2014), gender (Shen et al. 2019), and income (Jia et al. 2021) have gradually been confirmed to have an important impact on individuals engaging in waste classifications. Scholars generally use the theory of planned behavior (TPB) and its extended model to investigate the relationship between classification intention and behavior (Wang et al. 2021). Besides, scholars also combine TPB theory and other psychological models (e.g., antecedent-belief-consequence theory and norm activation model) to investigate the influence of internal and external conditions on behavioral intentions and behaviors (Zhang et al. 2021; Goh et al. 2022).

However, classification behavior deviates from intention to some extent in practice. Research points out that residents are often willing to participate in waste classification, while few of them actually act on it (Wang et al. 2020). An increasing number of scholars have begun to focus on the impact of external factors and incentive methods on WCB (Meng et al. 2019; Peng et al. 2021; Wang et al. 2019). Ekere et al. (2009) found that peer influence efficiently explained the probability of waste utilization and separation behavior. Tian et al. (2019) used structural equation modeling and hierarchical regression and found that governments publicizing waste classification knowledge can effectively help implement waste classification in China. Tang et al. (2022) claimed that reward and punishment policies and supporting facilities significantly stimulate and promote WCB, and the implementation of publicity and education activities are conducive to more easily helping residents accept waste classification. Besides, the availability and convenience of infrastructure are also important to interpret and predict WCB (Chen and Gao 2020; Zhang et al. 2019). The study of Rousta et al. (2015) demonstrated that shortening the distance to the drop-off points significantly improved the source sorting of household waste. Wang et al. (2018) confirmed that good facility conditions can significantly promote individuals to separate waste.

Although previous studies have identified some external factors that can influence residents' WCB, there are still many weaknesses and gaps in place. Most of them used a single or several variables to measure the influencing factors, failing to explore in depth the multi-dimensional impact on WCB. In terms of incentive measures, existing research hardly considers the joint governance impact of multiple responsible subjects such as government, communities, and enterprises, making it difficult to establish a long-term incentive mechanism. To avoid the defects of single-perspective research, we considered both the internal factors of the behavior subject and the external environment in the TBP analysis framework and selected 7 factors and 24 sub-variables to better understand the intention-behavior transformation process by binary logistic regression. We discussed the implementation path of waste classification from the perspective of multiple-responsible subjects and constructed a community waste classification and management pattern covering publicity guidance, technical support, and system guarantee. Finally, sensible suggestions for a waste classification system are put forward.

Our study makes the following contributions. First, we extended the TPB to consider the effect of external

incentives and internal characteristics on WCB and use sub-variables to elucidate the influence mechanism from the community scale. Second, we identified driving factors by combining binary logistic regression and principal components analysis (PCA), which enriches research methods for waste classification. Third, based on the status of waste classification and analysis of an incentive pattern from a multi-cognitive perspective, we innovatively proposed the Multi-agent Linkage Governance Pattern for making an effort to promote waste classification policy.

The remainder of this study is organized as follows: "Research hypothesis" presents the theoretical framework and research hypothesis; "Research Methods" describes the research methods and data collections; "Data analysis and results" presents the analysis results; "Discussion and policy suggestions" includes discussions and policy implications; the last section provides conclusions.

Research hypothesis

The TPB was first proposed by Ajzen (1991) to expand on the theory of reasoned action, which assumes that people carry out a specific behavior mediated by their intentions. The factors that affect individuals' behavioral intention can be divided into three categories: attitude, subjective norm, and perceived behavioral control. The attitude toward behavior refers to residents' positive or negative evaluation of a particular behavior's contribution (Razali et al. 2020). A subjective norm relates to the fact that people perceive social pressure from relatives, friends, and other social groups who are important to them thereby performing the expected behaviors. Perceived behavioral control reflects expected barriers in participants' actual behavior. Previous studies have confirmed that TPB not only predicts individual WCB through the intention channel but also can take other influencing factors into account to improve explanatory power according to a specific research context (Fan et al. 2019; Govindan et al. 2022). Based on the actual situation and the implemented policies of waste classification in Jinan, we additionally selected four factors—basic personal information, collaborative governance, infrastructure, and institutional pressure—to initially construct the WCB conceptual hypothesis model (Fig. 1). Moreover, 24 secondary explanatory variables were included to analyze the influencing mechanism.

Basic personal information

The waste classification process involves social and individual dimensions. Socioeconomic factors through residents' basic personal information directly affect individual behavior. Increasingly, research has gradually confirmed that some socioeconomic drivers can significantly affect the tendency of WCB. Afroz et al. (2009) revealed that people who are well educated and have high incomes are more willing to pay for waste management. Adzawla et al. (2019) found that socioeconomic factors such as education, regional location, and per capita income are important in determining a household's waste disposal system. In most households, solid waste management is run by women. More females than males are involved in pro-environmental activities such as waste recycling and classification (López-Bonilla et al. 2020). However, variability in the distribution of

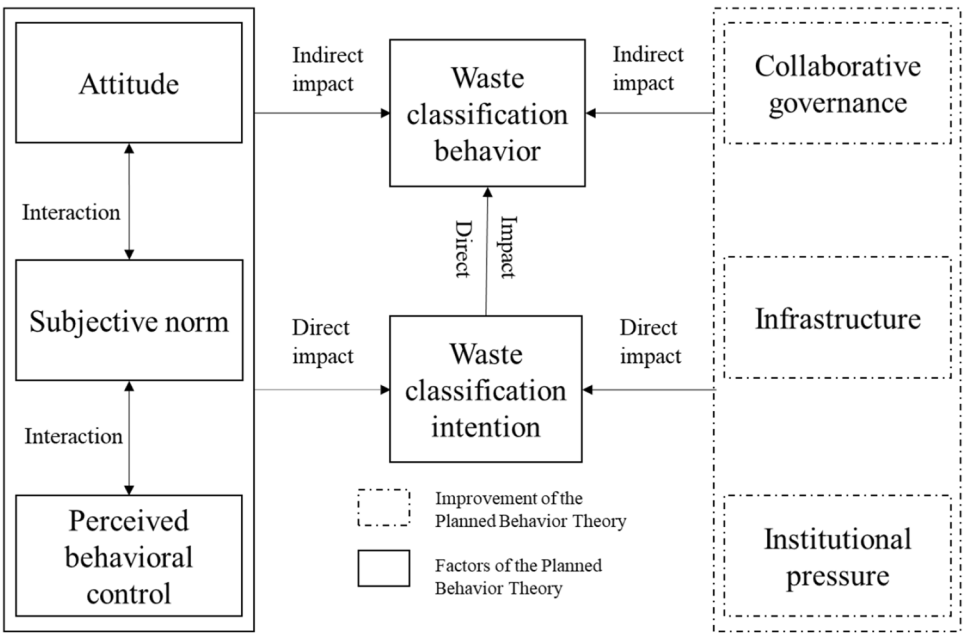

Fig. 1 Conceptual hypothesis model for studying waste classification behavior

respondents can affect the final results. Oskamp et al. (1991) found that education level and gender are not correlated with waste recycling, while people who earn more money were more likely to participate in waste recycling than those who made less.

This study selected gender, age, monthly income, and education level to represent the basic personal information of the respondents and analyzed the relationship between basic personal information and WCB. The proposed hypotheses are as follows:

H1. Residents' basic personal information is related to WCB.
H1a. Women are more likely to be involved in waste classification.
H1b. Seniors are more willing to sort their waste.
H1c. People with higher monthly income and education are easier to be involved in waste classification.

Attitude

Attitudes toward environmental issues directly affect related behaviors (Fu et al. 2020). Residents' concern for the environment positively influences households' participation in recycling (Tonglet et al. 2004b). Attitudes toward waste classification can be expressed as classification awareness, self-efficacy, and environmental responsibility. Efficacy refers to residents' confidence in their ability to use sorting skills to separate different kinds of waste, while environmental responsibility means the mentality of the individual taking the initiative to do something beneficial for the community environment. When residents positively evaluate the beneficial effects of WCB, such as saving resources and improving the community environment, their intention to participate in classification will increase.

This study assumed that classification awareness, self-efficacy, and environmental responsibility positively impact residents involved in waste classification. The hypothesis is as follows:

H2. Attitude toward waste classification positively affects WCB.

Subjective norm

Sociality determines that an individual will consider the thoughts and attitudes of others when deciding to take a specific behavior. Subjective norm refers to an individual's perception of social pressure from the surrounding people or groups to believe that he/she should or should not engage in certain behavior. Residents' trust in waste classification is affected by the attitudes of their neighbors, family, government, and media. Individuals who gain social approval and respect from waste classification will tend to engage in it (Negash et al. 2021). Typically, individuals living in a community that confers great importance to the environment will tend to engage in conservation activities to be consistent with group beliefs and rules. However, communities with a high prevalence of greenness may reduce well-being under the weight of conformity pressure (Binder et al. 2020). To a certain extent, low well-being perception will make residents tired of participating in garbage sorting, thus hindering the formation of a good green environment in the community. In addition, failure to adequately establish waste source-separated collection to support strong moral norms also can lead individuals to believe that their classification behavior will not be susceptible to social pressure (Ma et al. 2018). Thus, subjective norm will not significantly interfere with residents' participation in waste classification.

In this study, three variables, attitude toward others, public pressure, and peer effect, were used to characterize subjective norm. We assume that the attitude of others, public pressure, and peer effect from communities will influence individual participation in waste classification. The hypothesis is as follows:

H3. Subjective norm will not significantly enhance residents' WCB.

Perceived behavioral control

Perceived behavioral control represents how easy or difficult an individual perceives to perform a particular behavior. Generally, the more controlled the behavior is, the more likely it is to occur. Behavioral dispositions are also related to the convenience of which individuals perceive pro-environmental behaviors. Perceived convenience, including perceptions of external factors and influence on performing waste classification activities, can improve waste classification capacity (Negash et al. 2021). In previous studies of WCB, the effect of perceived behavioral control had been argued to be either positively significant (Liao et al. 2018) or insignificant (Ghani et al. 2013).

Perceptual behavior control variables can be characterized by personal costs, knowledge mastery, degree of publicity, and difficulty in separating waste. Hence, we propose the next hypothesis:

H4. Perceived behavioral control positively affects WCB.

Collaborative governance

The implementation of garbage classification relies on the joint cooperation between the government, enterprises, and social organizations. Social voluntary organizations are incorporated into the waste classification management

system, which can assist the government in improving community waste classification management. Woldesenbet (2021) highlighted the importance of establishing multi-level and multi-scale waste collaborative governance systems with economic and environmental stakeholders. Diverse stakeholders with prime responsibility and mandates coordinating and supervising with each other are beneficial to establishing effective social governance for waste classification.

Supervision effort was taken as a measure of collaborative governance to analyze the relationship with WCB. Hence, we propose the next hypothesis:

H5. Collaborative governance positively affects WCB.

Infrastructure

Sound infrastructure is the basic guarantee for promoting the implementation of a waste classification system and realizing the harmless treatment of waste. Infrastructure has a strong and positive effect on encouraging classification behavior (Ma et al. 2020). However, this effect is also affected by the subjective perception of accessibility of infrastructure. Residents keen on household waste classification will be restricted by the lack of effective and convenient facilities so they do not take actual action (Zhang et al. 2019). Waste classification facilities take up a lot of time and space, especially complex ones to understand. When residents realize that inconvenient facilities can complicate their lives, their willingness to sort waste diminishes. Even if several classification facilities exist in the community, residents are reluctant to engage in waste classification. The lack of efficient and convenient recovery facilities is an important factor hindering China's waste recycling, which is considered as one of the key environmental constraints obstructing personal intentions to transform a certain recycling behavior (Zhang et al. 2016).

Community infrastructure can be characterized by five aspects: classification label, disposal distance, renewable resource recycling points, transportation, and end-of-pipe treatment. Thus, we formulated the following hypothesis:

H6. Infrastructure negatively affects WCB.

Institutional pressure

Institutional pressure takes advantage of government functions to effectively reduce the amount of garbage clearance and final disposal, thereby effectively recycling important resources in municipal solid waste. Mandatory waste separation policy through mediating effect of attitude indirectly affects the intention of residents to participate in waste classification (Li et al. 2020). In addition to mandatory policies, financial incentives can also motivate households to recycle (Shaw and Maynard 2008). A point reward system can encourage customers to form environmental habits and effectively promote electronic waste recycling management systems (Zhong and Huang 2016).

We divided institutional pressure into four secondary variables: reward and punishment system, credit system, pay-as-you-throw policy, and laws. We assumed that stronger institutional pressures from the government would encourage residents to participate in waste classification. So, the proposed hypothesis is:

H7. Institutional pressure positively affects WCB.

Research methods

Questionnaire design

According to the research hypotheses, the preliminary questionnaire was designed based on the current status of waste classification. To ensure the reliability and validity of the questionnaire, we randomly distributed 82 questionnaires in Jinan, Shandong Province, for a small-scale preliminary investigation. The final questionnaire was revised and re-designed by respondents' feedback. Moreover, the questionnaire adopted the closed-ended survey to improve the investigation efficiency and simplify the data entry process. It consisted of three types of questions: single-choice, multiple-choice, and matrix/rating scale questions. The respondents were required to take at least 5 min to fill it out to ensure that they had enough time to answer the questions rationally and truthfully. The questionnaire's content was divided into three parts: basic personal information, residents' behavior in waste classification, and existing problems and future expectations of waste classification. Basic personal information included permanent residence, gender, age, monthly income, and education level. The second part of the questionnaire was divided into six categories: (1) attitude, (2) subject norm, (3) perceptual behavior control, (4) collaborative governance, (5) infrastructure, and (6) institutional pressure, totally including 20 variables. In this part, measurement indexes were designed by the 5-point Likert Scale. The five options to each question were arranged in order (from low to high) by values (points 1–5): "completely disagree," "relatively disagree," "uncertain," "relatively agree," and "strongly agree". Questions of the third part aimed to identify the existing problems in the waste classification process.

Data collection

As the capital of Shandong Province, Jinan was already included in the first batch of 46 waste classification pilot

cities in 2018. Considering the typicality of the study area, Jinan was selected for this study to analyze the behavior mechanism of residents' waste classification and propose key policy recommendations for governments. Waste classification data of residents were collected through online and offline questionnaires. We first selected seven communities respectively located in Shizhong District, Lixia District, Tianqiao District, Huaiyin District, Licheng District, Zhangqiu District, and Changqing District of Jinan to conduct the questionnaire survey. Then, a total of 830 questionnaires were distributed based on random sampling, 168 of which were distributed online and the remaining 662 by in-person interviews in each community. In the data collection process, some questionnaires were eliminated for incomplete and invalid filling, so 661 valid questionnaires were obtained with a response rate of 79.64%. We obtained 133 valid responses online and 528 offline, with a response rate of 79.17% and 79.76%, respectively.

PCA-logistic regression model

The binary logistic regression model can explore the relationship between multiple independent variables and a categorical dependent variable, which is widely used in medicine and sociology (Boateng and Abaye 2019). Unlike linear regression, the predicted dependent variable in binary logistic regression has a binary outcome (Tu 1996). We took the WCB as the dependent variable and 24 influencing factors of WCB as the explanatory variables to establish the influence factors model. First, assume that the probability of residents' engagement in waste classification is p $(0 < p < 1)$, and that the probability of not participating in waste classification is $1 - p$. The binary logistic regression model can be expressed as

$$Logit\left(\frac{P}{1-P}\right) = \alpha + \sum\nolimits_{i=1}^{m} \beta_i x_i \tag{1}$$

In this model, β_i is regarded as the logistic regression coefficient of the independent variable. m is the total number of variables and the range i is an integer between 1 and m. α is a constant.

Considering the existent correlation between 20 secondary explanatory variables excluding four basic personal information variables, PCA was adopted to eliminate the effect of multicollinearity among sub-variables to avoid severe estimation bias. PCA is a useful model for reducing the dimensionality of large data sets, which not only improves interpretability but also minimizes information loss at the same time (Jolliffe and Cadima 2016). To avoid multicollinearity and retain as much variance as possible in the original dataset, we adapted the PCA method with varimax rotation to analyze the six influencing dimensions of attitude, subjective norm, perceived behavioral control, collaborative governance, infrastructure, and institutional pressure. First, we used the normalization approach for data pretreatment, calculated as

$$\widetilde{x}_{ij} = \frac{x_{ij} - \bar{x}_j}{S_j}, (1, 2, \cdots, n; j = 1, 2, \cdots, m) \tag{2}$$

$$\bar{x}_j = \frac{1}{n}\sum_{i=1}^{n} x_{ij}, (i = 1, 2, \cdots, n; j = 1, 2, \cdots .m) \tag{3}$$

$$S_j = \frac{1}{n-1}\sum_{i=2}^{n} \left(x_{ij} - \bar{x}_j\right)^2, (i = 1, 2, \cdots, n; j = 1, 2, \cdots, m) \tag{4}$$

where n is the number of samples and m is the number of variables. x_{ij} represents the value of the j-th variable for the i-th sample. $\widetilde{x}_{ij}$ is the normalized data. $\bar{x}_j$ and S_j stands for the mean and standard deviation of the j-th variable, respectively.

Second, calculate the correlation matrix among the variables and it can be formed as $R = (r_{ij})_{m\times m}$:

$$r_{ij} = \frac{\sum_{k=1}^{n} \widetilde{x}_{ki} \cdot \widetilde{x}_{kj}}{n-1}, (i, j = 1, 2, \cdots, m) \tag{5}$$

where $r_{ii} = 1, r_{ij} = r_{ji}.r_{ij}$ represents the correlation coefficient between the i-th variable and the j-th variable.

Then, calculate the eigenvalues of the correlation matrix R, denoted by $\lambda_1 \geq \lambda_2 \geq \cdots \geq \lambda_m \geq 0$, and the corresponding eigenvectors $u_1, u_2, \ldots, u_m$, where $u_j = (u_{1j}, u_{2j}, \ldots, u_{nj})^T$. The i-th principal component can be expressed as

$$F_i = u_{1i}\widetilde{x}_1 + u_{2i}\widetilde{x}_2 + \cdots + u_{ni}\widetilde{x}_j (j = 1, 2, \cdots, m) \tag{6}$$

After dimensionality reduction by PCA, the WCB model was established to analyze the mechanism of residents' WCB based on binary logistic regression. It is defined as follows:

$$WCB = \alpha_0 + \alpha_1 x_{gender} + \alpha_2 x_{age} + \alpha_3 x_{income} + \alpha_4 x_{education} + \sum_{i=1}^{k} \beta_i F_i, (1,2, \cdots, k) \tag{7}$$

where k represents the number of principal components and α_0 is a constant. α_{1-4} and β_i stand for the coefficient of variables.

The regression coefficients of principal components only consider the comprehensive impact of the driving factors. After performing the logistic regression, we further predicted and identified how each variable influences residents' WCB. According to the previous studies (Dong and Bollen 2015; Dai et al. 2021; Gan et al. 2022), we reverse PCA back to the original variables and reconstruct

the influence coefficient of sub-variables. Since principal components are essentially linear combinations of the original variables, we replaced the principal components in the WCB influencing factor model with the original variables (that is, we added formula 6 to formula 7) to obtain the influence coefficients of each sub-variable. The prediction model can be expressed as

$$WCB = \alpha_0 + \alpha_1 x_{gender} + \alpha_2 x_{age} + \alpha_3 x_{income} + \alpha_4 x_{education} + \sum_{i=1}^{k} \sum_{j=1}^{m} \beta_i u_{ji} \widetilde{x}_j \quad (8)$$

Data analysis and results

Descriptive statistics analysis

The socio-demographic profile of the respondents is shown in Table 1. Among the total participants, the number of women was a little more than men, with a ratio of 51.73:48.27. In terms of age distribution, most respondents were less than 30 years old, accounting for 65.46%, while other age groups were more evenly distributed. The monthly income of respondents was concentrated between RMB 1500 and 8000, accounting for 74.29% of the total, which fits the characteristic range of the average monthly salary of RMB 4117 in Jinan and is well represented. From the perspective of education level, the percentage of postgraduate and above was 14.04%, the university degree was 42.69%, and the senior high school degree accounted for 23.61%, making a total of over 80%. It is indicated that most of the respondents have a high education level, which also ensures the accuracy of the questionnaire results.

Reliability and validity analysis

When a measurement scale is involved in research, Cronbach's alpha coefficient has been considered as one of the most important and pervasive statistics used to test the reliability of the scale (Taber 2018). Before handling the results, we used the IBM SPSS Statistics 22.0 software to test the reliability of the questionnaire. The Cronbach's alpha coefficients of different survey methods were all greater than 0.7, indicating the questionnaire items were highly reliable. In addition, the validity test was used to evaluate the accuracy of the target object of a questionnaire. We also measured the sampling adequacy by SPSS and followed the steps: analysis-dimensionality reduction-factor analysis. Before applying the PCA, the Kaiser–Meyer–Olkin (KMO) measure of sampling adequacy and Bartlett's test were first performed on 20 variables for a preliminary test. The KMO measure ranges between 0 and 1; the closer it is to 1, the easier it is to accept the factor model. The result showed that the KMO statistical values of the online, offline, and overall questionnaires were 0.887, 0.844, and 0.892, respectively, indicating that all the questionnaires passed the validity test and fulfilled the conditions for factor analysis. The variables were strongly correlated and appropriate for PCA. Meanwhile, Bartlett's coefficients of different survey methods were all significant at the 1% level, rejecting the null hypothesis that there is no correlation among variables, further confirming the results of the KMO measure (Table 2).

Table 1 Socio-demographic profile of the respondents

Variables	Demographics	Frequency	Percentage (%)
Gender	Male	319	48.27
	Female	342	51.73
Age	Under 18	190	28.76
	18–30	243	36.70
	31–45	84	12.77
	46–60	73	11.06
	61 or above	71	10.71
Monthly income (RMB)	Under 1500	118	17.86
	1500–3000	136	20.60
	3000–5000	195	29.47
	5000–8000	160	24.22
	80,000 or above	52	7.85
Education level	Junior high school or below	130	19.65
	Senior high school	156	23.61
	Graduate	282	42.69
	Postgraduate or above	93	14.05

Table 2 Reliability and validity tests

Survey method	Cronbach's α	KMO	Bartlett's test of sphericity		
			Approx. chi-square	*df*	Sig
Online	0.872	0.887	7749.456	351	0.000
Offline	0.869	0.844	2318.020	351	0.000
Overall	0.867	0.892	9881.706	351	0.000

Results of logistic regression

The data were analyzed by the IBM SPSS Statistics 22.0 software in three main steps. First, PCA method is used to reduce the dimension of primal data. Second, we regarded gender, age, education level, and monthly income as categorical variables, and the principal components as continuous variables. All the categorical and continuous variables were taken into consideration to explore the influence mechanism of WCB by logistic regression. Third, according to logistic regression results, coefficients of 20 explanatory variables were obtained by bringing the coefficients of four principal components into the principal component analysis equation.

Four principal components were extracted based on the condition that the eigenvalue was greater than 1 and their cumulative variance contribution reached 67.55% (> 50%), indicating that the four extracted principal components explained 67.55% of the information from 20 explanatory variables. The 20 explanatory variables were then transformed into four principal component factors by the weighted evaluation method (Table 3). According to the distribution of high loadings in this matrix, the first principal component includes four variables: reward and punishment system (x_1), credit system (x_2), pay-as-you-throw policy (x_3), and laws (x_4), which are all sub-variables of institutional pressure. The second principal component consists of attitude of others (x_8), public pressure (x_9), personal costs (x_{10}), difficulty in separating waste (x_{11}), peer effects (x_{12}), disposal distance (x_{13}), renewable resource recycling points (x_{14}), and supervision effort (x_{15}). These sub-variables can be divided into two categories: one is the classification cognition formed by public opinion and pressure from the external environment or suffering benefit losses, and the other is the construction of external public infrastructure. The third principal component includes classification awareness (x_{16}), knowledge mastery (x_{17}), and degree of publicity (x_{18}). The last principal component also has two parts: infrastructure and self-social cognition, involving end-of-pipe treatment (x_5), transportation (x_6), classification label (x_7), self-efficacy (x_{19}), and environmental responsibility (x_{20}).

According to the established PCA-logistic regression model, the regression coefficient was estimated using the IBM SPSS Statistics 22.0 software. In Table 4, the regression results show that gender, age, and education level significantly influenced residents' WCB ($P < 0.001$), while the monthly income had insignificant effects on residents' WCB

Table 3 Rotated component matrix of principal components

Variables	Symbols	Principal components			
		1	2	3	4
Reward and punishment system	x_1	0.195	−0.051	0.052	−0.105
Credit system	x_2	0.285	−0.154	0.055	−0.107
Pay-as-you-throw policy	x_3	0.272	−0.139	0.050	−0.117
Laws	x_4	0.305	−0.181	0.049	−0.106
End-of-pipe treatment	x_5	0.117	−0.005	−0.111	0.148
Transportation	x_6	0.096	0.019	−0.092	0.127
Classification label	x_7	0.081	0.009	−0.083	0.184
Attitude of others	x_8	−0.207	0.332	0.016	0.034
Public pressure	x_9	−0.133	0.282	0.067	−0.098
Personal costs	x_{10}	−0.085	0.216	0.060	−0.046
Difficulty in separating waste	x_{11}	−0.026	0.157	−0.043	0.040
Peer effects	x_{12}	−0.044	0.186	−0.017	0.005
Disposal distance	x_{13}	−0.023	0.170	−0.014	0.003
Renewable resource recycling points	x_{14}	0.006	0.130	−0.025	0.056
Supervision effort	x_{15}	0.046	0.078	0.055	−0.004
Classification awareness	x_{16}	−0.053	0.048	0.305	0.073
Knowledge mastery	x_{17}	0.003	0.023	0.445	−0.153
Degree of publicity	x_{18}	0.050	−0.017	0.445	−0.173
Self-efficacy	x_{19}	−0.047	0.003	−0.125	0.558
Environmental responsibility	x_{20}	−0.037	−0.005	−0.003	0.464

Table 4 Results of binary logistic regression

Variables	B	S.F	Wald	*df*	Sig	Exp (B)
Gender	−0.80	0.41	3.88	2.00	0.04**	2.23
Age	0.84	0.28	9.12	4.00	0.00***	2.32
Monthly income	0.15	0.18	0.69	5.00	0.41	1.16
Education level	1.40	0.48	8.44	4.00	0.00***	4.12
First principal component	0.13	0.04	8.93	1.00	0.00***	0.88
Second principal component	-0.27	0.07	14.92	1.00	0.00***	0.76
Third principal component	1.28	0.11	124.42	1.00	0.00***	3.59
Forth principal component	0.17	0.10	3.25	1.00	0.07*	1.19
_cons	16.16	1.73	0.001	1.00	1.00	1.50

***, **, and * denote significance levels of 1%, 5%, and 10%, respectively

with both *P* values greater than 0.1. Only three principal components had significant effects at the 1% level with a *P* value below 0.001. The coefficient of the fourth principal component significantly impacted WCB at the 5% level ($P=0.07$). Specifically, education level and the third principal component had the highest coefficients at 1.40 and 1.28, respectively. Education and publicity can internalize waste classification knowledge into sorting awareness and ability, which helps residents to establish environmental consciousness and cultivate classification habits. In addition, the second principal component coefficient was negative, preliminarily indicating that social pressure, personal cost, and undeveloped infrastructure inhibit residents from engaging in waste classification.

The absolute value of the regression coefficient directly reflects the influence degree of the explanatory variable on the explained variable. A negative value indicates that the influencing factor has a hindering effect on WCB, while a positive value implies that this driver can promote WCB to some extent. Based on PCA and the results above, the coefficients of the influencing factors of WCB are shown in Table 5.

Basic personal information

According to basic personal information, gender negatively impacted residents' participation in waste classification ($\beta=-0.800$), demonstrating that the proportion of women engaged in waste sorting is higher than that of men under the intra-household labor division mode where most Chinese women are in charge of housework. Conversely, age and education level had positive effects on WCB with a high coefficient of 0.840 and 1.400, respectively. The results indicate that residents are more willing to participate in waste classification with age and those who possess a higher education level are more likely to receive comprehensive propaganda and education on waste classification, thereby more actively involved in classification.

Attitude

Enhancing and cultivating residents' awareness of waste classification can be useful to improve waste management effectiveness (Baul et al. 2021). The results show classification awareness was necessary to strengthen WCB ($\beta=0.383$). The positive effects of self-efficacy and environmental responsibility on WCB were significant (both $\beta=0.072$), indicating that individuals who internalize waste management as their responsibility and obligation can be motivated to sort domestic waste. Therefore, the stronger the classification willingness and self-efficacy of residents is, the stronger the positive relationship between behavioral attitude and WCB will be.

Subjective norm

Subjective norm refers to the influence of external factors (i.e., families, relatives, friends, community neighbors) on the decision-making of residents' waste classification through social pressure. The total effect of subjective norm on the WCB was significant. The results manifest that attitude of others ($\beta=-0.090$) and public pressure ($\beta=-0.025$) were negatively associated with WCB, confirming that the current public opinion environment hinders residents' engagement in waste classification. Peer effects negatively affected WCB ($\beta=-0.077$), which demonstrates that the current group behavior tendency fails to positively guide residents' behavior decision-making in Jinan. The results show that the majority of residents in Jinan believe that subjective norm cannot change and intervene in their behavior to engage in waste classification. The community in Jinan has not yet formed a strong social atmosphere that is conducive to waste classification, in which normative function has not been fully exerted. When a community does not establish a good classification environment, subjective norm fails to make a positive effect on WCB and residents tend to be reluctant to separate the

Table 5 Binary logistic regression coefficient

Variable type	Sub-variable	Coefficient (β)
Basic personal information	Gender	−0.800
	Age	0.840
	Monthly income	0.150
	Education level	1.400
Attitude	Classification awareness	0.383
	Self-efficacy	0.072
	Environmental responsibility	0.072
Subjective norm	Attitude of others	−0.090
	Public pressure	−0.025
	Peer effects	−0.077
Perceived behavioral control	Personal costs	−0.001
	Knowledge mastery	0.538
	Degree of publicity	0.543
	Difficulty in separating waste	−0.094
Collaborative governance	Supervision effort	0.055
Infrastructure	Classification label	−0.089
	Disposal distance	−0.023
	Renewable resource recycling points	−0.057
	Transportation	−0.089
	End-of-pipe treatment	−0.100
Institutional pressure	Reward and punishment system	0.087
	Credit system	0.131
	Pay-as-you-throw policy	0.117
	Laws	0.134

domestic waste because it is time consuming and labor intensive.

Perceived behavioral control

Table 3 indicates that the total effect of perceived behavioral control on the WCB was significantly positive. However, it shows that perceived behavioral control can negatively affect WCB through personal costs ($\beta = -0.001$). From the perspective of cost–benefit, residents are bothered by or even resist sorting waste when they perceive it may interfere with personal interest and waste their time, whereas the influence coefficient of personal costs on the WCB of Jinan residents was lower than other variables. The effect of difficulty in separating waste ($\beta = -0.094$) was consistent with personal costs, which played a negative role in waste classification. In addition, knowledge mastery and degree of publicity had significantly positive effects on WCB with high relevance ($\beta = 0.538$; $\beta = 0.543$). As part of our investigation, we discovered that only 35.22% of residents believed they mastered the relevant knowledge of waste classification, and 37.20% expressed they often received waste classification publicity. The results further confirm that the lack of education and publicity is one of the obstacles that residents find difficult to sort waste.

Collaborative governance

The results affirm that supervision effort positively affects WBC ($\beta = 0.055$), indicating that enforcing the supervision of domestic waste can effectively enhance the probability of residents' classification behavior. According to the result of questionnaires and interviews, communities have not yet established a perfect supervision system in Jinan, and carrying out waste classification efforts mostly depend on the consciousness of residents.

Infrastructure

The total effect of infrastructure on the WCB was significantly negative. Specifically, the coefficients of classification label, disposal distance, renewable resource recycling points, transportation, and end-of-pipe treatment were −0.089, −0.023, −0.057, −0.089, and −0.100, respectively. In addition, according to the survey, Jinan's classification infrastructure is still insufficient. These results indicate that the inconvenient infrastructure limits the residents' waste classification behavior.

Institutional pressure

In terms of institutional pressure, the total effect and all variables positively affected WBC, confirming that institutional pressure from relevant government departments can positively reinforce waste classification. The credit system (β = 0.131) encourages WCB by linking waste classification ratings to credit preferential policies, facilitating a virtuous household waste cycle. The reward and punishment system (β = 0.087) and laws (β = 0.134) equitably allocate the rights and obligations to waste management and guarantee that residents adequately classify waste. Pay-as-you-throw policy (β = 0.117) can effectively improve the usage efficiency of recyclable waste and reduce waste generated at the source (i.e., the household).

The influence mechanisms of residents' WCB are summarized in Fig. 2. It shows that H1, H2, H5, and H7 hold, which means that attitude, collaborative governance, and institutional pressure all positively affect WCB. The elderly, women, and highly educated people are more willing to engage in waste classification. For H3 and H6, the logistic regression coefficients of subjective norm and infrastructure variables were all negative, indicating that they all have a negative effect on WBC. For H4, perceived behavioral control is indeed related to WBC; however, only knowledge mastery and the degree of publicity play a positive role, with personal costs and difficulty in separating waste playing a negative effect.

Discussion and policy suggestions

Discussions

According to this analysis, the elderly, women, and people with higher education are more likely to engage in waste classification. It confirms that basic personal information has explanatory power for WCB (Han et al. 2019). Influenced by traditional Chinese social customs, the elderly and women are the main bearers of household waste classification and recycling. In comparison, highly educated people are more likely to be exposed to information about waste classification and, thus, their intentions and behavior can be influenced more easily. Considering monthly income, we found that it is insignificantly related to WCB. This result might be attributed to the waste classification background in China. Before the pilot was proposed in Jinan in 2018, community residents had little command of waste classification. The potential impact of monthly income cannot be demonstrated in the short term. Moreover, the total effect of attitude, subjective norm, and perceived behavioral control are positive, indicating that these factors can enhance WCB (Liu et al. 2019). However, two secondary variables of

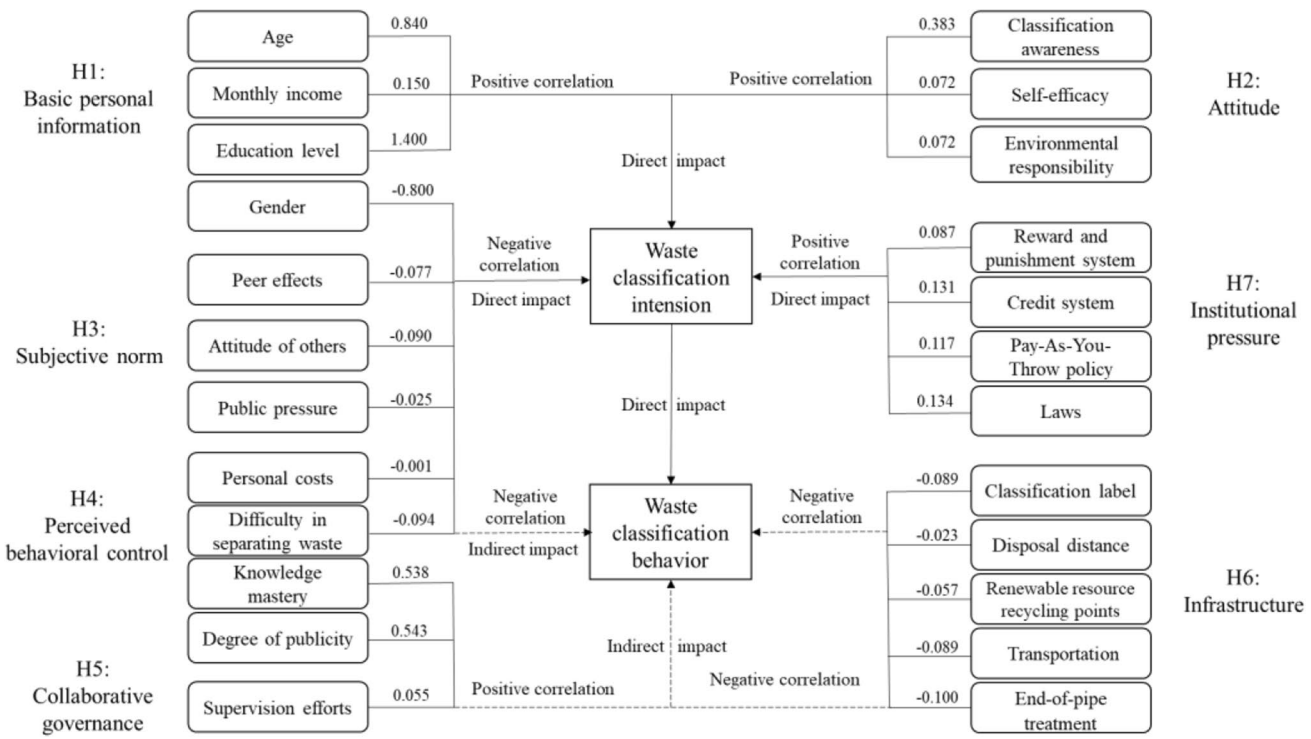

Fig. 2 Mechanism of residents' waste classification behavior

perceived behavioral control—personal costs and difficulty in separating waste—negatively affect WCB. The influence coefficient of personal costs is lower than 0.005, which is relatively negligible. The higher the costs residents perceive, the less willing they are to sort waste. Besides, individuals may reduce the frequency of waste sorting when feeling difficulty in understanding the classification process. We further confirm that improving collaborative governance can enhance residents involved in waste classification. However, there is a research gap in the relationship between this factor and WCB. In addition, institutional pressure has a significant effect on WCB. Chen and Gao (2020) also observed that economic and policy incentives like subsidies are an important factor affecting residents' WCB. Some scholars confirmed that infrastructure is significantly correlated with WCB (Leeabai et al. 2019; Peng et al. 2021). In the case of Jinan, infrastructure negatively affects and significantly hinders WCB. Our investigation found that classification, recycling bins, and other facilities in Jinan communities are insufficient, and their spatial layout is inconvenient. Convenience and availability of facilities can strengthen recycling attitudes that determine an individual's recycling and WCB (Tonglet et al. 2004a).

The relationships between driving factors and residents' WCB are shown in Fig. 3. At its core, residents' waste sorting is the process of converting waste classification knowledge into classification behavior driven by classification intention. In our study, institutional pressures, publicity and education, infrastructure, and collaborative governance were identified as four important external conditions that stimulate classification motivation and improve classification ability. From a government perspective, institutional pressure can promote residents to sort waste, including enforcing classification and incentive rewards. This enforcing classification mainly relies on laws and sets corresponding penalties to form a self-regulating mechanism for residents to participate in waste classification, while incentive rewards create some enthusiasm among residents for waste classification, which, to some extent, converts classification intention into behavior. Whether it is to motivate residents to sort waste or to implement enforcement policies, the goal is to transition the public from an "inaction" state to an "action" state by cultivating classification awareness. However, while the majority of residents in Jinan have a certain awareness of waste classification, they still fail to form a classification habit. The reason is that they have little command of the current classification norms and methods and feel that waste classification is onerous and has a high personal cost. The survey results show that the overall identification rate of waste categories among residents in Jinan is only 7.22%. Therefore, education and publicity play an important role in improving classification knowledge (Knickmeyer 2020), and our study confirmed it through regression analysis. We find that education and publicity levels were positively related to

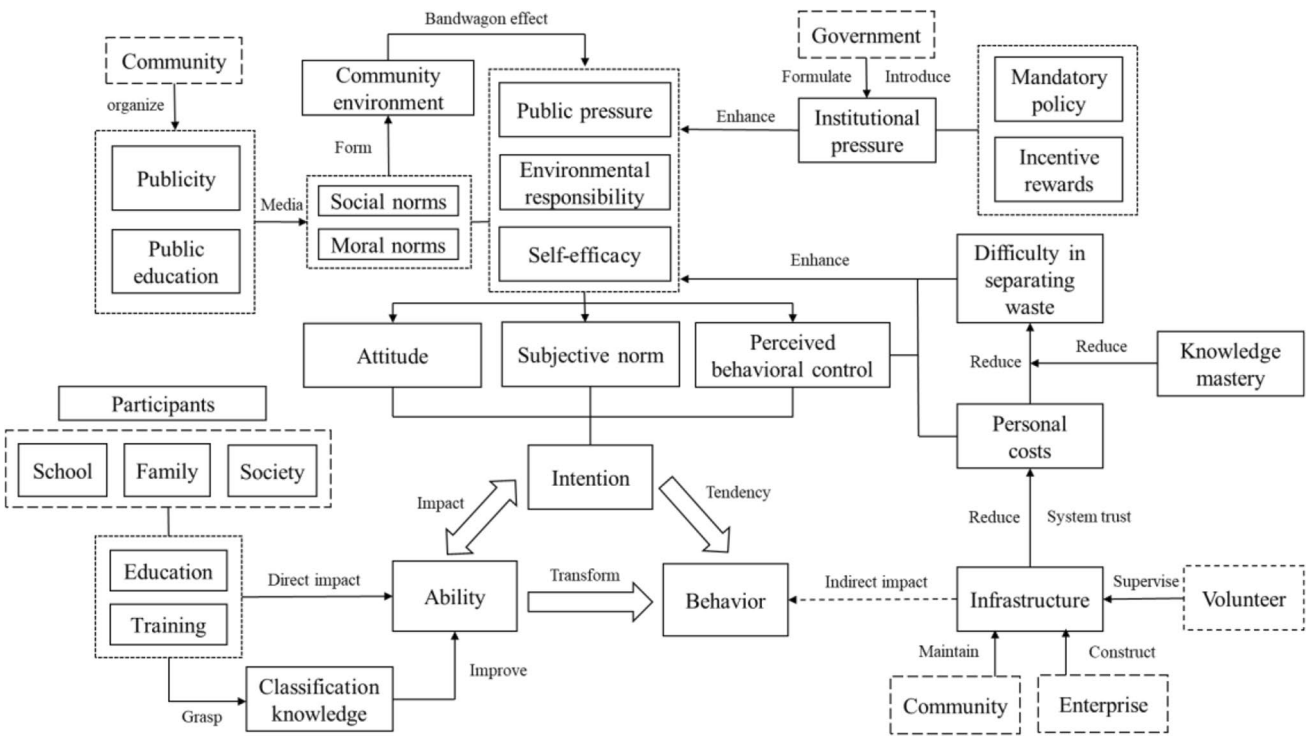

Fig. 3 Relationships between driving factors and residents' WCB

WCB. Education and publicity not only improve residents' ability to sort waste by themselves but also can effectively involve other residents in waste classification efforts through public pressure and the bandwagon effect, thereby forming an improved common environmental and classification ethos. Good community management can easily help individuals to build confidence and abilities to sort waste (Hu et al. 2021). In the process of social advocacy and education, residents gain more knowledge and enhance self-efficacy and mutual supervision of waste classification. Moreover, infrastructure is an important component of garbage collection and disposal has a negative effect on WCB in the study results. It stems from residents distrusting poorly developed facilities and disposal systems. Residents often believe that even after careful sorting, household waste ends up mixed and transported together, which will take a lot of effort and increase the personal cost. According to our survey, most communities in Jinan are only equipped with standard 50-L green trash cans and lack smart trash cans, four-labeled containers, and renewable resource recycling points. Hence, improving sorting facilities and strengthening supervision at waste disposal points are critical for residents to participate in waste classification (Govindan et al. 2022). In terms of collaborative governance, individuals, businesses, and NGOs voluntarily participating in public services play an important role in the waste sorting process (Lu and Sidortsov 2019). This kind of voluntary behavior can promote the formation of residents' classification habits and reduce the cost of maintaining and building infrastructure and is also conducive to the promotion of waste classification policies.

Policy suggestions

According to the analysis of the WCB mechanism, residents engaging in waste classification are affected by various factors of public, society, and individuals. Therefore, it is necessary to comprehensively consider the links and stakeholders in various factors when constructing the guidance and incentive mechanism for WCB. We investigated the current governance model of waste classification in Jinan and found that the local government and community residents are the main responsible subjects involved in waste classification. However, adopting an only-government-led model to manage waste classification puts too much pressure on the government. In addition, both residents as the behavior subjects and markets that play the role of resource allocation lack the enthusiasm to engage in waste classification. These blocks make it difficult for collaborative governance to form cohesion. To resolve the dilemma of residents' participation in waste sorting, it is essential to establish the relevant institutional system of multi-agent joint management of waste classification. In addition, there is a serious deviation between the waste classification willingness and the actual behavior of residents in Jinan communities. The survey results show that while 96.83% of the respondents are willing to sort waste, only 21.3% have actually done it. According to the regression results, the incentive of external factors is an important connection point to realizing the transformation of residents' internal intention into classification behavior. Based on the above discussion, we explore the powerful guiding incentives to enhance residents' participation in waste classification from the perspective of community governance. The multi-agent linkage governance pattern is innovatively proposed covering three levels of publicity guidance, technical support, and system guarantee (Fig. 4), and its specific strategies are divided into the following three dimensions.

First, adopt a multi-guidance pattern to translate residents' classification willingness into practical actions. Based on the government's financial support, the community should be equipped with the infrastructure for waste classification collection and transportation. Residents' waste disposal in the community should be merged and regularly monitored. To overcome the disadvantages of manual sorting, the Internet of Things and big data can be used to collect and process information, analyze data, and monitor waste flow. In addition, there should be a waste classification publicity campaign and education mechanism that integrates households, schools, and communities to improve residents' classification awareness. Communities and schools should hold lectures that systematically popularize waste classification standards and operation flow and help to overcome its fragmented acceptance. Besides, the community should organize parent–child activities to strengthen the connection between families and work together to promote waste classification. The sustainable operation of the guidance mechanism also depends on external environmental factors. Various community activities should be held to enhance residents' sense of responsibility and belonging in the process of promoting community integration, thereby forming a joint force of community governance to gradually regulate residents' behavior.

Second, use multi-dimensional incentives to apply external driving forces to waste classification. Through the alliance of communities, volunteers, and property management, link volunteer service with multiple social fields to realize the full potential of external incentives. Form the credit system of volunteer service time, which is related points to the extracurricular activities in primary and the graduation requirements of universities. Moreover, volunteer associations and insurance companies establish an insurance points mode, so that residents can obtain medical insurance, pension insurance, and other security. Residents can exchange pension funds after the age of 60 with their annual voluntary activities and accumulated points. Cooperation agreement between the government and credit reporting agencies to integrate waste classification

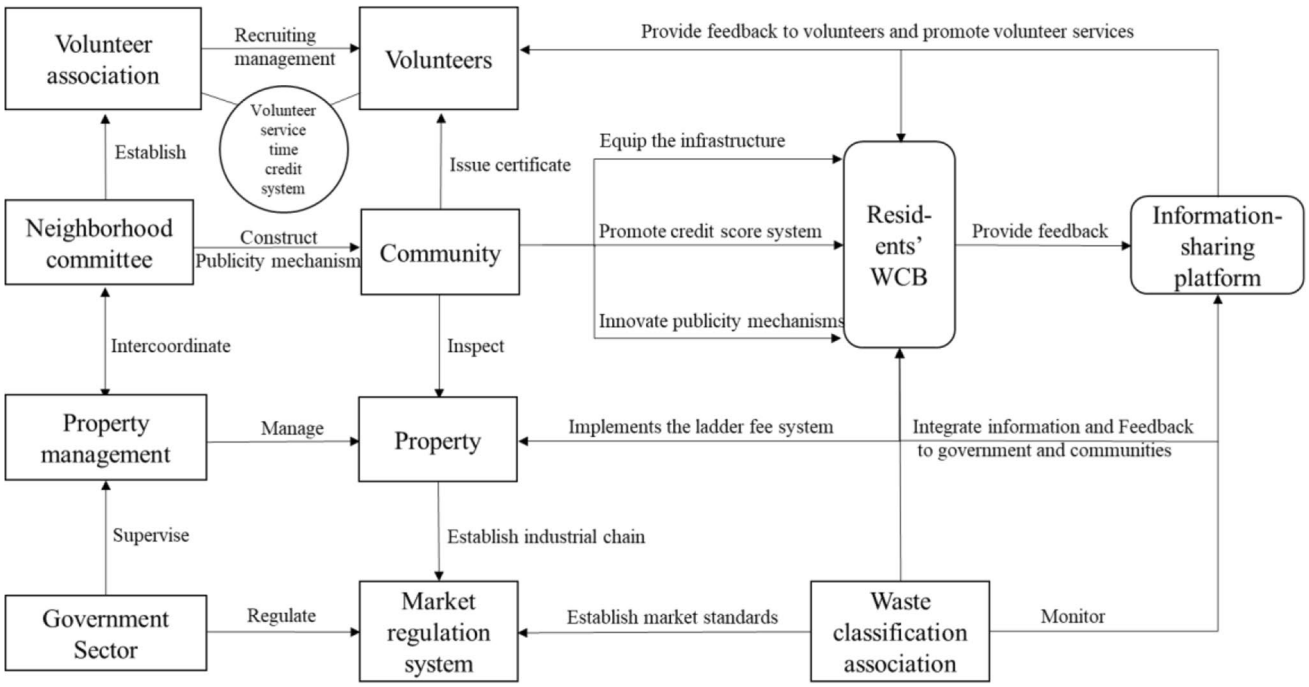

Fig. 4 The multi-agent linkage governance pattern

into the credit reporting system and adopt appropriate incentives and penalties for residents with different credit ratings. Based on the credit score and the length of time of volunteers, society sets up the level of domestic waste disposal fees and implements the ladder fee system to improve residents' engagement through community management.

Third, enhance the multi-layer supervision system to ensure the operation of the guidance and incentive mechanism. On the one hand, introduce the market regulation system to construct long-term operations contributing to the marketization and economic construction of waste classification. The market can achieve the purpose of recycling and reducing waste by adjusting the supply and demand of waste classification. Enterprises assist waste management and classification with the economic market to turn the waste disposal process into a complete industrial system. On the other hand, construct various information-sharing platforms to provide residents with channels for opinions and suggestions. These platforms can integrate information and timely feedback to government and communities to promote waste classification and management work and help form a new grassroots social governance pattern of co-construction, co-governance, and sharing.

Conclusions

Waste classification is an important component of urban ecological civilization construction. Exploring the WCB and its driving forces is conducive to green and sustainable development. We selected seven communities in Jinan City of China and collected 661 valid questionnaires to analyze the current issue and influence mechanism of WCB. Based on previous research and the current situation in Jinan, we further extended the TPB and took internal factors and the external environment into consideration. Incorporating seven influencing factors and their secondary variables into the theoretical framework, we combined PCA and binary logistic regression to analyze the questionnaire's data. The main findings are summarized as follows.

The elder, women, and people with higher education are easier to engage in waste classification, while the monthly income insignificantly affected residents' WCB. Meanwhile, attitude, collaborative governance, and institutional pressure have a significantly positive effect on residents to classify household waste. However, subjective norm and infrastructure negatively affect this behavior. Two secondary variables—knowledge mastery and degree of publicity in perceived behavioral control factor—have a positive effect on WCB while other variables negatively influence WCB. Based on these results, we constructed the multi-agent linkage governance pattern to help transform residents' intentions into classification behavior with the combination of multi-stakeholders and external incentives.

This study identified the key factors affecting WCB and established an effective incentive mechanism, which provided a strong guarantee for implementing waste classification policies in Jinan. In future works, we will consider conducting comprehensive and comparative studies on different

types of cities from time scales and spatial dimensions based on this research, to further enrich our theoretical and policy framework. In addition, we will explore effective paths for establishing a dynamic tracking and feedback system to regularly evaluate the implementation performance of existing classification policies, and eliminate policies that impede the timely processing of waste classification and management. The final outcome will be a more replicable and popular waste classification management pattern with Chinese characteristics.

Author contribution All authors contributed to the study conception and design. Investigation and material preparation were performed by MQ, DZ, and ZW. Methodology and software were performed by RZ and MQ. The first draft of the manuscript was written by RZ, MQ, DZ, and ZW. Writing—review and editing were performed by YW, YC, and RZ. Supervision and funding acquisition were performed by YC. All authors read and approved the final manuscript.

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Data availability The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Conflict of interest The authors declare no competing interests.

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