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Exploring the Pathways to Participation in Household Waste Sorting in Different National Contexts: A Fuzzy-Set QCA Approach

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ABSTRACT With the increasing pace of industrialization and economic growth, the continuous increase in household waste has become a great concern all over the world. Residents' participation in household waste sorting is an effective way to promote the recycling of household waste. How to effectively promote more residents to participate in waste sorting has become an important issue of the government. Previous research mainly used two methods in exploring residents' intention to sort waste: qualitative case studies to explore potential causal descriptions and statistic studies with the structural equation modeling. These researches, however, consider one special case or the net effect of a single factor, which fails to present the comparisons across international contexts and hardly clarifies the complex pathways to residents' participation. In this research, a novel method fsQCA (fuzzy-set qualitative comparative analysis) is applied to explore the pathways both from a macro-level perspective and in different national contexts. Results suggest four different pathways influence residents' participation in waste sorting. In the four pathways, GDP level and source separation system are key causal conditions to influence residents to sort waste, but different configurations of these conditions influence whether residents participate in waste sorting at a high rate. Only when the external conditions and the socio-demographic conditions are combined in a specific form, residents participate in waste sorting at a high rate. At last, the findings provide some exercisable suggestions for decision makers in developing countries to design promotion programs and waste sorting policies.

INDEX TERMS Fuzzy set qualitative comparative analysis, household waste sorting, residents' participation.

I. INTRODUCTION

With the rapid increase in population, fast economic growth and increasing industrialization and urbanization all over the world, the amount of municipal solid waste is surging in many countries. In 2019, the statistical data showed that the stock of municipal solid waste in China had reached 60–70 billion tonnes and some cities such as Beijing were in a ''garbage-surrounded'' situation. The EU produced nearly 250 million tonnes of municipal solid waste per year, 486 kg per capita [1]. These increase in the amount of generated waste also occurred in Japan and USA. The waste that has not been effectively treated will pose great threats to the residents' healthy life and production. How to properly manage solid waste has become an imminent issue for every country. Recycling of previously used materials has been thought as the best method for disposing of solid wastes [2], [3]. However, huge amount of solid waste has not yet been classified, which would hinder waste recycling and produce environmental pollution [4]. As a result, solid waste was landfilled without strict classification or incinerated directly, which threatens the soil and groundwater and pollutes the air. Household solid waste, a major part of municipal solid waste, is inevitably produced by daily activities [5]. Source separation of household waste

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is concerned with sorting waste at home or the recycling facilities, which is an effective method to improve waste management in many countries. Therefore, many measures and policy have been implemented to facilitate sorting waste. Many developed countries such as Japan, EU and USA have formulated systematic laws several years ago and strictly implemented them for years. For instance, Italy has formulated Law Decree 22/1997, called the ''Ronchi Decree'' to fill gaps in legislation on waste management and to transpose the main principles [6]. In China, the first relevant local legislation was published in August 2000 by the People's Congress of Jinan city while it was not until 2011 when Beijing for the first time classified household solid waste into different categories[7]. In fact, many developing countries and some cities in China even have not formulated systematic local regulations and laws. They are still puzzled by a question that much waste has not been sorted yet. Studies have attributed the lack of waste sorting to low household participation[8]. Thus, it is much important for the government to explore the pathways of residents' participation in household waste sorting and promote residents' broad and sustainable participation in waste sorting.

Although there are some existing researches [9]–[12] about the factors influencing residential waste sorting and recycling, a clear explanation about the pathways of residents to participation in waste sorting from the macro-level perspective is still lacking and some exercisable suggestions for decision makers are also lacking. From the perspective of research object, most traditional studies focus on behavioral intention and ignore the intention-behavior gap [13]. From the perspective of theory, many traditional studies [4], [12], [14]–[16] used the Theory of Planned Behavior (TPB) model or TPB-extended model to explore the mechanism of residents' participation, which mainly focus on individual internal psychological factors such as attitude, subjective norms and perceived behavior control. However, few studies have examined the role of external factors on the relationship between intention and behavioral action in recycling [4]. Therefore, there are seldom conclusive results clarifying the interaction between external factors and waste sorting behaviors. From the perspective of related data, most traditional studies [4], [6], [16], [17] conducted survey to collect data from some areas consisted of at most several hundred people. They didn't use the city-level or country-level data to analyze the pathways. To date, no study has systematically identified, compared and explained the pathways of residents to participation in waste sorting across a global set of cases. As a result, their results can only explain the behavior in the community, not the city or country. From the perspective of methodology, researchers [4], [6], [11], [15] who have previously investigated the causal conditions of residents' participation in sorting waste have tended to explain the behavior with two principal analytical strategies. The first is multivariate statistical modeling such as SEM, in which the contribution of a hypothesized causal factor or interaction term on the outcome is estimated, holding all other variables constant. The second strategy is the in-depth case study investigating specific cause-and-effect within specific countries or areas and typically presented in the simple form of qualitative analysis. Case study usually in-depth explains one special case without quantitative methods. Although the statistic studies consider more different cases and causal conditions, these studies focus on examining the net effect of a single or a few factors on the residents' participation. This analysis based on linear relationship ignores the synergistic influence of multiple factors on residents' participation, and thus hardly clarify the behavior. As a result, this has led to insufficient theoretical relation between previous research conclusions, and the fragmentation of research results on residents' participation in waste sorting.

Based on the situation above, this article firstly used data from 23 countries or areas covering developed and developing countries and converted the extent of residents' waste sorting behavior to a fuzzy value. Secondly, this article used a fuzzy-set qualitative comparative analysis (fsQCA) to identify the pathways of residents to participation in waste sorting at a high rate and have a deeper knowledge on our data.

In this paper, the following questions are explored and answered:

(1) What properties does the pathways of residents to participation in waste sorting include?

(2) How many different configurations can lead to residents' participation in waste sorting at a high rate?

(3) What exercisable policies and measures should be taken to decision makers from different countries to encourage residents to participate in waste sorting?

The remainder of this paper is organized as follows. Section 2 provides a brief literature reviews and the conceptual framework. Section 3 introduces research methods and procedures. Section 4 analyzes theoretical results of the fsQCA model and make a discussion. The Managerial implications are put forward in Section 5. The study limitations are presented in Section 6. Conclusions are drawn in Section 7.

II. LITERATURE REVIEWS AND CONCEPTUAL FRAMEWORK

A. CAUSAL CONDITIONS OF RESIDENTS' PARTICIPATION

Several studies have explored the potential factors of residents' participating in household waste sorting. From the micro-level or individual perspective, the factors are usually classified into three aspects such as internal, external and sociodemographic factors [18]. Those factors in each part can directly influence waste sorting behavior and correlate with each other [19] (Figure.1). The internal factors are usually linked with psychological factors such as attitude and beliefs, personal norms, environmental concern and perceived intensity. Attitude and beliefs are defined as person's own perceptions and tendencies of behaviors to waste sorting. Based on the Norm Activation Model (NAM), researchers have identified the personal norm (the feeling of individual moral obligation) as one of internal factors. Nguyen found that an

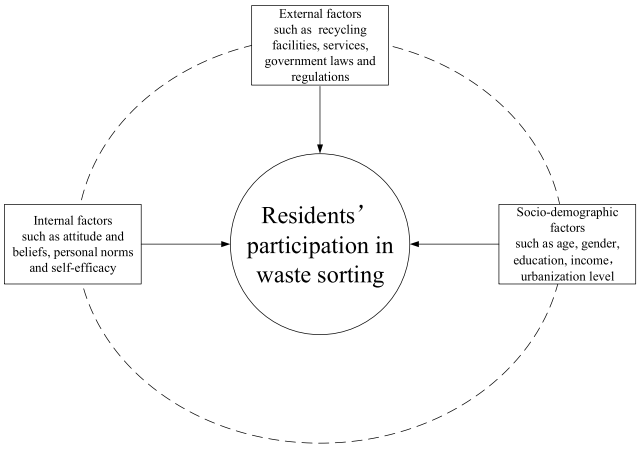

FIGURE 1. Factors that influence residents' participation in waste sorting.

individual sense of social responsibility such as thinking the waste sorting as a good thing for the society contributes to residents' participation in waste separation [20]. Additionally, several papers have analyzed the relationship between the environmental concern and recycling behavior [21]–[24]. Environmental concern is one aspect of an environmental attitude and divided into egoistic, altruistic and biospheric. Tadesse [22] found there is a positive relationship between the environmental concern and the recycling behavior. Aprile [23] showed that as the number of sorting waste increases, the magnitude of the marginal effects of egoistic, altruistic and biospheric concern decreases. Perceived intensity refers to the self-efficacy that people have the self-confidence of individuals in their ability to participate in waste sorting [24]. The external factors are composed of environmental facilities and services, government laws and regulations, and environmental knowledge for residents such as classification methods, recycling channels and how to properly carry out waste classification and recycling [24]. Zhang [4] tested the influence of facilities accessibility and government stimulus on household waste sorting and found that facilities accessibility and government stimulus are directly related to waste sorting behaviors. Wan [25] conducted a survey in Hong Kong and showed that residents followed the government's policy which helped promote the waste separation. Park's research showed that herd behavior effect would drive residents to sort waste[26]. The influential socioeconomic factors such as age, gender, education, income and urbanization also contribute to the waste sorting behavior among the household. Mukherji et al. [27] found that women are more prone to sort and recycle waste because women play a greater role in household activities. However, this result is not conclusive because some articles found no significant differences in residents' participation in waste sorting considering gender [28]. Older adults appear to be willing to recycle because of their frugality and having more time [29]. Past study has stated that age had a significant negative linear relationship with residents' participation [30]. Within the education factors, most literature demonstrate that people who receive more formal education have greater incentive and willingness to sort waste because education can enhance social responsibility and awareness of waste classification [17]. However, Ma found that respondents' educational levels had a significantly negative relationship with waste sorting intention because the respondents with higher education levels may consider more than the environmental values in determining their intention to the municipal solid waste source-separated collection [12]. Park [31] found that education and political affiliation yielded no significant relationship with recycling behaviors. Income has a significant positive relationship with willingness to sort waste [17]. At last, urbanization level is an important factor hindering residents' participation in waste sorting. The dominant barriers in the rural areas are insufficient facilities, a lack of awareness of waste sorting and inconvenience [6]. Besides, recycling infrastructures far from residents' home influence the waste sorting rate of residents.

B. THEORETICAL BACKGROUND

There are several theories to explain and predict residents' participation in household waste sorting. One category is at the micro-level or personal level such as TPB (Theory of Planned Behavior) or A-B-C theory (Attitude-Behavior-Condition). TPB emphasizes that an individual's behavior is influenced by attitude, subjective norm, and perceived behavioral control [32]. Liao [33] incorporated environmental education and knowledge into the TPB model to explain the separation of solid waste (SSW) behavior of 562 high school students. Shen [16] extended the predictive factors of environmental concern and personal moral obligation into the TPB model to explore the factors Influencing young people's intention toward Municipal Solid Waste Sorting. Park [26] combined TPB and NAM model to explain recycling behavior of the consumer. Heidari [34] used the extended TPB and SEM to explain 57% of the variance for behavior toward source separation waste. Botetzagias [35] used the extended TPB to explain the role of moral norms in the context of recycling. Although the TPB can explain some parts of residents' recycling behavior, its model mainly focuses on intrinsic factors and omits other factors. So Guagnano [36] proposed the attitude-behavior-condition theory (A-B-C theory), which states that residents' behavior is determined by the combined effect of residents' attitudes and the crucial factors of external conditions. Hage [37] used the A-B-C theory to explain the recycle behavior in the Sweden and emphasized the importance of external factors. Another category is at macro-level or government level. Three relevant theories such as governance theory, institutional theory and social marketing theory fall into this category. Governance theory emphasizes the interaction between governance market and society. Governance theory has to do with the various perspectives of governance and how they evolve. Governance theory sets some principles such as accountability, control, responsiveness, transparency, public participation, economy, efficiency to a government [38]. Therefore, it is well-suited

to the political areas such as formulating related policies and implementing them. Institutional theory seeks to explain why nations are committed to scientific institutions as well as what forms these take. The central theme is that organizational structures developed in industrialized countries are viewed by policy makers, donors, and other states as signals of progress towards modern institutional development and hence worthy of financial support [39]. Institutional theory emphasizes the process by the structures, including scheme, rules, norms and routines. These two theories usually have been applied in a macro-level analysis to improve the organizational structure of waste recycling programs and evaluate the political system of special laws. Therefore, they are not suitable for the paper which is focused on psychological factors and behavior. Social marketing theory was firstly proposed by Kotler and Roberto, and then expanded by Hornik to explore the causal conditions of recycling behavior. The author attributed the recycling behaviors to four categories: intrinsic incentives, extrinsic incentives, internal facilitators and external facilitators [40]. One type of extrinsic incentive for recycling is social influence. Social influence is a person's concern about how family members and friends would react to not recycling. Other types of extrinsic incentives are laws and monetary rewards which can be regarded as political factors. The intrinsic incentives mean to be the individual's intrinsic motivations to recycling such as personal satisfaction in avoiding waste and being more self-sufficient, the gratification of conserving natural resources; Internal facilitators are those cognitive variables which enable an individual to recycle. These include variables such as awareness of the importance of recycling and knowledge about recycling programs. External facilitators are factors such as time, money, and effort needed to prepare, store, and transport recyclables.

Qualitative comparative analysis (QCA) is a unique analytical method that provides an alternative to conventional methods such as regression-based analysis, clustering approach. Different from symmetric analysis (for instance SEM) which usually considers the accuracy in high values of an antecedent condition indicating high values of an outcome condition and low values of an antecedent condition indicting low values of an outcome condition, QCA is an asymmetric way which considers the causes of a high outcome usually differ substantially from the causes of a low outcome [41]. QCA is a set-theoretic method based on complexity theory to perform a cross-case comparative analysis and uses Boolean algebra to identify configurations that reflect the necessary and sufficient conditions for an outcome condition. The cases represent combinations of causal conditions from which it is then possible to identify one or more pathways explaining a particular outcome [42]. QCA combines the advantages of qualitative and quantitative analysis to compare a limited number of cases and analyze contrarian cases [43]. QCA has attributes of conjunctural causation and equifinality. Conjunctural causation means that a combination of factors rather than a single causal factor yields a particular outcome. The same causal factor may have different effects depending on the context. Equifinality means that an outcome can come from different pathways.

QCA methods have been applied in a variety of fields, including business behaviors [44], political economy [45], sociology and economic [46]. However, to our best knowledge, no study has employed QCA to evaluate residents' actual waste sorting behavior from the macro-level perspective across developed and developing countries. This method is also well-suited for such an investigation since it is a transdisciplinary research combining the political, sociology knowledge and the causal conditions of such a research can't be explained by an isolated factor. In addition, its sample data size and the case-specific property are well-suited to the QCA method.

C. CONCEPTUAL FRAMEWORK

Based on the social marketing theory, the conceptual framework idea from Xu *et al.* is comprised of external factors (market incentives, government incentives, market facilitators, government facilitators) and socio-demographic factors. The external factors in our conceptual framework correspond to the external incentives and facilitators in the social marketing theory or government incentives and facilitators. According to the literature reviews [15], [17], [24], socio-demographic factors which have significant relations with waste sorting are also considered in this paper. The framework of this paper was mainly built on a mix of abovementioned theories, framework and related findings.

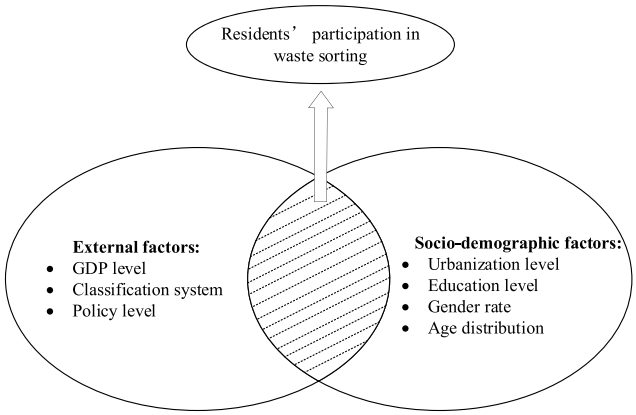

FIGURE 2. Conceptual framework of residents' participation.

The conceptual framework in this paper is shown in Figure. 2. The Wayne graph consists of three variable sets and intersection. It includes an outcome set (residents' participation in waste sorting) and two causal conditions (external factors and socio-demographic factors).

The causal conditions of residents' participation in waste sorting are complex and the impact of changes in individual condition on the residents' participation is also very limited, so the research cannot only consider single condition. For example, the single influence of policy level on residents' participation is limited. Especially, although great success has

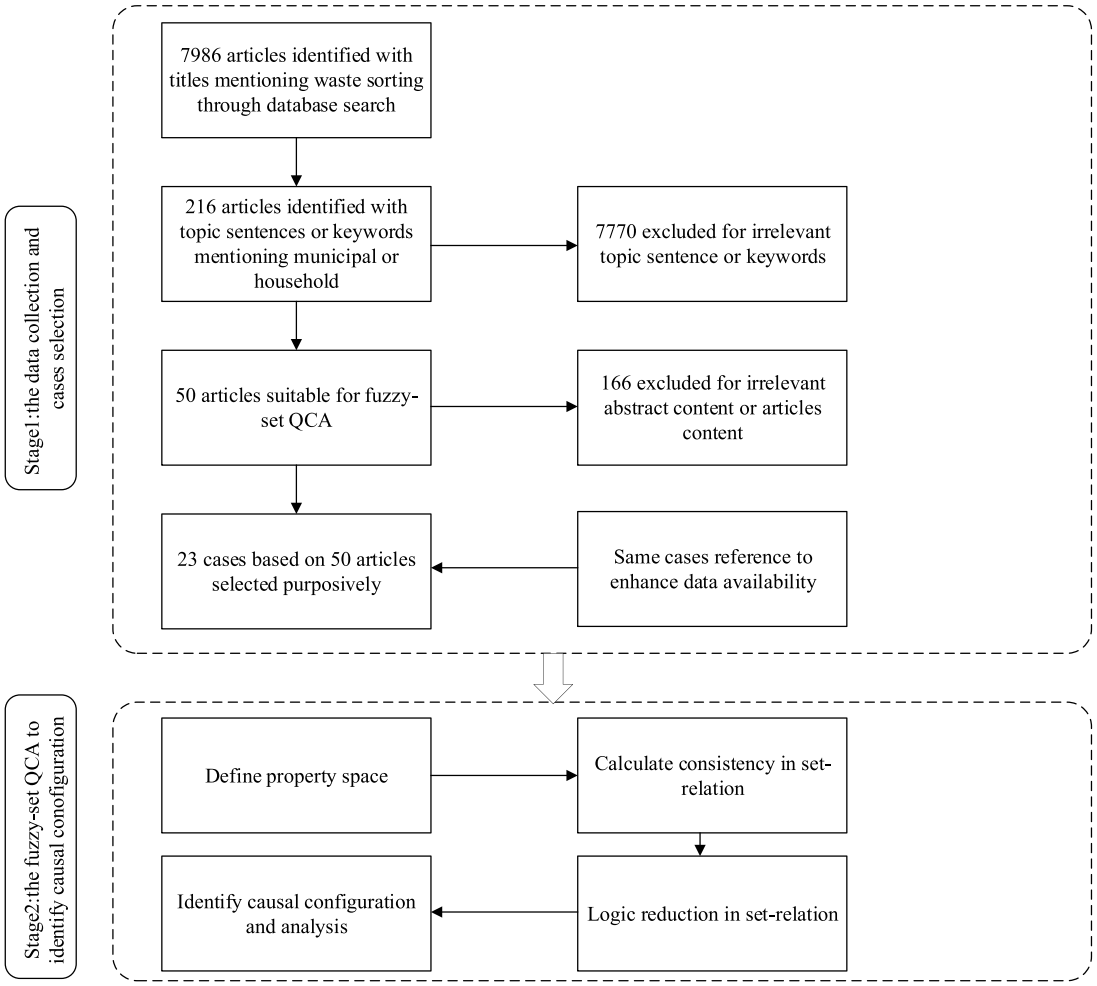

FIGURE 3. Flowchart of the research method.

been achieved in other areas in China only by implementing the strict regulations, the single influence of policy level on waste sorting is limited. In the past short period, the waste-sorting campaign in Shanghai was successful only by the most stringent regulations. However, it is doubtful to maintain the high rate of residents' participation only by the high policy level in a long run. Accordingly, the proposition 1 is made as follows:

1.Only if the external conditions and socio-demographic conditions emerge simultaneously, residents participate in waste sorting at a high rate.

At the meantime, there exists asymmetry in the causal conditions and outcomes. It means that whether the influence of a single causal condition is positive or negative depends not on the main effect of the condition itself on the outcome, but on its configuration with other causal conditions. For example, residents in countries of high GDP level are more likely to participate in waste sorting. However, combined with other causal conditions, residents in countries of low GDP level can still participate in waste sorting at a high rate. As a result, the following two propositions are made:

2.The influence of single causal condition may be negative or positive towards residents' participation, depending on how they combine with other causal conditions.

3.There are several different configurations that can lead to residents' participation in waste sorting, and some of causal conditions included in each configuration may be the same.

III. RESEARCH METHODS

In this section, the sources of data are explained and proper cases are selected firstly. Then, basic concept and arithmetic operations of the fuzzy-set qualitative comparative methods are introduced. Finally, we explain how the data is analyzed and identify causal configurations of residents' participation in waste sorting. The flowchart of the method is presented in Figure.3.

A. DATA COLLECTION

This study gathers survey data and causal conditions from an academic and grey literature and online database and then forms the final eligible cases. The data searching procedure consists of four steps: 1) search initial key words such as the

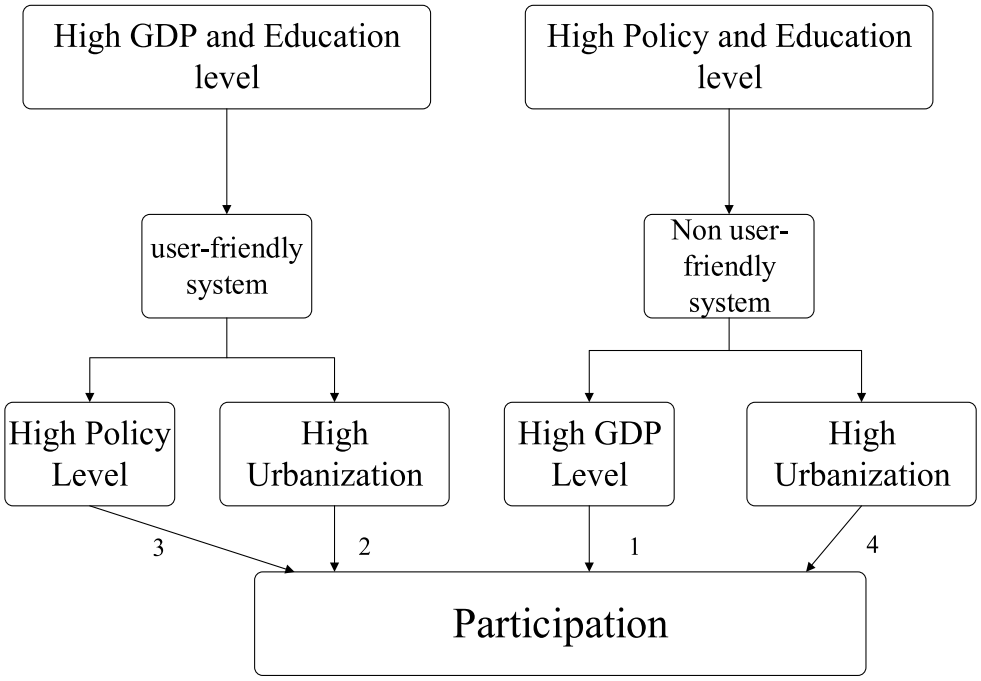

FIGURE 4. Causal pathways to residents' participation in waste sorting.

name of a country, waste sorting in the scientific databases to locate several papers; 2) remove duplicate articles; 3) review related article in-depth, extract data concerning residents' participation in waste sorting, and remove articles, which are not focused on behavior. 4) search related waste sorting policy and implementation level in each country from articles or websites and find some sociodemographic data from the government database. Data from 2008 to 2019 for 11 years mainly are collected from those articles, UN database and database of China Statistics Bureau. In the end, this paper purposefully selects 23 countries or areas for analysis (a suitable sample size for fsQCA). Cases are selected purposefully to include the greatest variety of outcomes and causal conditions as possible. In this way, case selection maximizes the range of outcomes and causal conditions like GDP per capita, waste sorting category, education level, and so on. The literature reviews concerning the causal conditions and the residents' participation in waste sorting are exhibited in table 1.

B. FUZZY-SET QUALITATIVE COMPARATIVE ANALYSIS (FSQCA)

FsQCA applies the fuzzy-set method by using fuzzy scale (continuous from full non-membership (0) to full membership (1) or discrete number) than on a binary scale (crisp-set qualitative comparative analysis) in a set of cases that share a hypothesized causal condition. Thus, fsQCA is more powerful to explain case-specific details. Using fsQCA, researchers can explore complex causal patterns among different causal or independent variables by studying a small number of cases. By considering causal configurations, fsQCA does not analyze how two or more independent variables affect an outcome, but rather explores all possible configurations of variables. In order to explore the residents' behavior, four steps are followed:

1) DEFINING THE PROPERTY SPACE

The first procedure for fsQCA is to define the property space, where all configurations of causal conditions are identified. Since the property space delimits potential explanations of the outcome, the causal conditions should be chosen carefully and referred to in extant theoretical knowledge. According to the selected literature and related theory, five causal conditions positive related with the residents' participation in waste sorting are selected to meet our standard.

a: EXTERNAL CONDITIONS

1. GDP level measures the degree of country's wealth and the extent to which recycling infrastructure has been put into use. A country with higher GDP level usually deploys more recyclable bins in neighborhood areas, which makes it convenient for residents to sort waste. A study in the European Union shows that residents in economically stronger countries are more likely to participate in waste sorting [50].

2. Classification system includes two aspects: classification category and practical maneuverability. For example, the classification standard household solid waste in Shanghai is divided into four categories such as recyclable, hazardous, wet and dry waste [11]. However, the classification standard in Japan is more complicated. It is not necessary to sort waste as fine as possible since the suitable classification system depends on economy and environment [70].

TABLE 1. Selected cases in the comparative study.

Country	Attributes description	Case Reference
Shanghai, China	Residents' participation, urbanization, source classification method, classification system, policy	[47] [48]
Sweden	Residents' participation, urbanization, classification system, policy	[6] [19] [48] [49] [50]
Beijing, China	Residents' participation, urbanization, source classification method, classification system, policy	[6] [24] [48] [51]
Shanghai, China	Residents' participation, urbanization, source classification method, classification system, policy	[6] [24] [48] [51]
Guilin, China (2008)	Residents' participation, urbanization, source classification method, classification system, policy	[6] [24] [48] [51]
USA	Residents' participation, policy	[48] [52]
Japan	Residents' participation, classification system, policy	[48] [53]
Romania	Residents' participation, classification system, policy	[48] [50] [54] [55]
Bulgaria	Residents' participation, classification system, policy	[48] 50] [56]
Czech Republic	Residents' participation, classification system, policy	[48] [50] [57]
Italy	Residents' participation, classification system, policy	[23] [50] [58]
Estonia	Residents' participation, classification system, policy	[48] [50] [59]
Croatia	Residents' participation, classification system, policy	[48] [50] [60]
Cyprus	Residents' participation, classification system, policy	[48] [50] [61]
Latvia	Residents' participation, classification system, policy	[48] [50] [62]
Hungary	Residents' participation, classification system, policy	[48] [50] [63]
Austria	Residents' participation, classification system, policy	[48] [50]
Poland	Residents' participation, classification system, policy	[48] [50] [64]
Portugal	Residents' participation, classification system, policy	[48] [50] [65]
Slovenia	Residents' participation, classification system, policy	[48] [50] [66]
Slovakia	Residents' participation, classification system, policy	[48] [50] [67]
Bangladesh	Residents' participation, classification system, policy	[17] [68]
Kenya	Residents' participation, classification system, policy	[69]

Practical maneuverability means that the waste classification system can provide a user-friendly tool for waste generators, recyclers and environmental managers. A good waste classification system is the foundation and precondition for efficient waste management [48]. And the classification category should well match with its practical maneuverability and other social-demographic factors [70].

3. Policy level is defined as government laws or facilitators. Government laws concerning waste sorting impose monetary rewards or penalties for householders who carry out good or bad performance in waste separation. Government facilitators are defined as campaign encouraging waste sorting. A survey in Hangzhou, China shows that government policy has a positive association with recycling behavior [10].

b: SOCIO-DEMOGRAPHIC CONDITIONS

1. Urbanization level is defined by the percentage of populations who live in the city. A study in China showed that due to the uneven distribution of separation facility and inconvenience, household waste separation and collection is low in rural areas [28]. Another reason is that the wet and the dry waste is collected every day while the harmful and glasses in the rural areas are collected by the public janitor monthly. In the urban areas, recycling station are usually within walking distance from household, which make it convenient for residents to participate in waste sorting. A survey in South Africa showed that waste bins that were provided by municipalities were used for waste disposal by 43.36% of urban households as compared to 1.54% for those from rural households [71].

2. Education level can be measured by literacy across different countries since some less developed countries don't have specific and detailed education information. A survey in Liberia shows that the percentage of the residents with high literacy(88%) participating in waste sorting is much higher than that of the residents with relative low literacy(80%) [72]. Another criterion is to measure the average schooling year of a nation. Education level is directly related with residents' intrinsic factors such as awareness of environmental protection. With a longer schooling year, an increase in knowledge will increase their attitude toward environmental protect. In addition, they may be likely to learn more waste sorting technique as their schooling year increases. A survey of 378 ordinary residents in the Taiyuan City of China showed that public education has a significant positive effect on the willingness of urban residents to classify household waste [51].

3. Gender rate measures the proportion of the female population. Most literature demonstrate that female members tend to be more involved in household work than males and thus more willing to participate in the household waste sorting [29].

4. Age or age distribution of municipalities' inhabitant is often is described as mean or median age or the percentage of people in particular age groups. Sidique [28] found a positive correlation between waste sorting rate and age because waste sorting is very time-consuming, old people have much spare time and don't consider the distance to the recycling bins. Studies in the United States showed that there is a statistically significant relationship between age and source separation,

old people over 65 years are more likely to separate urban waste [73]. A survey in Thailand showed that the older residents tend to sort waste by themselves, whereas the younger residents let waste management services to do the separation [74].

2) SET-MEMBERSHIP MEASURES

Calibration in fsQCA study is very challenging since distinct and operationalizable anchor points for fuzzy set calibration is lacking[75]. The first method for calibration is the direct calibration which is used for quantitative data. In this way, each causal condition is represented on a continuous scale between 0 and 1. However, quantitative data cannot simply be normalized values between 0 and 1. To perform direct calibration, the research must specify three breakpoint values: full membership (fuzzy score = 0.95), full non-membership (fuzzy score = 0.05) and the crossover point (equal to a 0.5 score). These points should be anchored in external criteria and theoretical and case knowledge [76]. The second method for calibrating fsQCA data is indirect calibration. This can be done for either quantitative or qualitative data by creating groupings of cases. To calibrate qualitative data the researcher develops a list of operationalized measures for each of the conditions and outcomes [77]. Then, qualitative anchors are defined for full membership and non-membership in the set and the case data are evaluated based on these operationalized definitions. Three-value fuzzy set, four-value fuzzy set and six-value fuzzy set are often applied in the indirect calibration. Ideally, the research should make use of the external criteria to get the direct calibration. however, in practice, scholars have often been confronted with theory and substantive knowledge not being available. Hence, no clear indicators were available on where to set the thresholds (such as the 0.5 anchor). For this paper, we use the indirect calibration to convert data to fuzzy-sets since some causal conditions are qualitative and exact anchor of these conditions is difficult to obtain. According to the data distribution and the types of causal conditions, we learn from the literature [43] to apply the four-value fuzzy set to the calibration. While three-value set is a rudimentary fuzzy set, the four-value scheme is especially useful in situations where researchers have a substantial amount of information about cases, but the nature of the evidence is not identical across cases [42]. Causal conditions and original outcome data are converted to fuzzy-set scores by coding each case according to the table 2 and table 3. Scores are assigned using the indirect method of calibration: a value of 1 is assigned to cases showing full membership, 0 is assigned for full non-membership, and scores of 0.67 and 0.33 are assigned for partial membership. The cross-over point remains fixed at 0.5.

Table 4 reports the fuzzy set membership scores for causal conditions and residents' participation in waste sorting. In total, 12 of the 23 cases have full participation in waste sorting (score 1). 5 of the 23 cases have partial participation in waste sorting (score 0.67); 2 cases have hardly participation in waste sorting (score 0.33); and 4 cases have non-participation in waste sorting (score 0).

Table 5 shows standard deviations, and correlations of the membership scores for all variables included in the Table 4.

TABLE 2. A fuzzy score of residents' participations in waste sorting.

Definition	Score	Description
residents' participation	1.0	Participation rate ≥ 95%, residents' full participation in waste sorting
	0.67	65% ≤ Participation rate < 95%, residents' partial participation in waste sorting
	0.33	35% ≤ Participation rate < 65%, residents' hardly participation in waste sorting
	0.0	Participation rate < 35%, residents' non-participation in waste sorting

TABLE 3. A fuzzy score of causal conditions in waste sorting.

Definition	Score	Description
GDP level	1.0	The level of the Developed country (GDP per capita ≥ 20,000 dollars)
	0.67	The level of the medi-level Developed country (15,000 ≤ GDP per capita < 20,000 dollars)
	0.33	The level of the Developing country (6,000 ≤ GDP per capita < 15,000 dollars)
	0.0	The level of the Least developing country (GDP per capita < 6,000 dollars)
Urbanization level	1.0	Complete urbanization, percent of urban population ≥ 80%
	0.67	Mature urbanized, 60% ≤ percent of urban population < 80%
	0.33	Medi-level urbanized, 40% ≤ Participation rate < 60%
	0.0	Low urbanized, Participation rate < 40%
Education level	1.0	Mean schooling year ≥ 12, high education level
	0.67	9 ≤ Mean schooling year < 12, relative high education level
	0.33	7 ≤ Mean schooling year < 9, medium education level
	0	Mean schooling year < 7, low education level
Source separation system[a]	1.0	Simple classification and user-friendly collection system
	0.67	Common classification and user-friendly waste collection system
	0.33	Common classification and Common collection system
	0.0	Elaborate classification and professional collection system
Policy level	1.0	Systematic law and strict implementation
	0.67	Systematic law and casual implementation
	0.33	Systematic law and hardly implementation
	0.0	No Systematic law

[a] Source separation system includes two parts. One is different classification category and the other is its practical maneuverability. We define the classification of simple recyclable and non-recyclable as a simple method, classification into 3-8 distinct patterns as a common method, classification into 8 or more distinct patterns as an elaborate method. Furthermore, we use the standard measure of practical maneuverability defined by Wen[48] and define the system of US and China as a common practical system, the system of Japan as a professional system, the system of EU and others as a user-friendly system

TABLE 4. Membership scores for the residents' participation in waste sorting and cauSal conditions.

Country	GDP level	Urbanization level	Education level	Source Separation System	Policy level	Participation
Czech Republic	0.67	0.67	1	0.33	0.67	1
Estonia	0.67	0.67	1	0.33	0.67	1
Croatia	0.33	0.33	0.67	0.33	0.67	1
Italy	1	0.67	0.67	0.67	1	1
Cyprus	1	0.67	1	1	0.33	0.67
Latvia	0.67	0.67	1	0.67	0.67	0.67
Hungary	0.33	0.67	1	0.33	1	1
Austria	1	0.33	0.67	0.67	1	1
Poland	0.33	0.67	1	0.33	0.67	1
Portugal	1	0.67	0.33	0.67	1	1
Romania	0.33	0.33	0.67	0.33	0.67	0.67
Slovenia	1	0.33	0.67	0.67	1	1
Slovakia	0.67	0.33	1	0.33	0.67	1
Sweden	1	1	1	0.67	1	1
Shanghai(2013), China	0.67	1	0.67	0.33	0.67	0.33
Japan	1	1	1	0	1	1
USA	1	1	1	0.33	0.67	0.67
Bangladesh	0	0	0	1	0	0
Kenya	0	0	0	1	0	0
Beijing, China	0.33	1	0.67	1	0.33	0.33
Shanghai(2008), China	0.33	1	0.67	1	0.33	0
Guilin, China	0	0	0.33	1	0.33	0
Bulgaria	0.67	0.67	0.67	1	0.33	0.67

TABLE 5. Means, Standard Deviations, and Pairwise Correlations of Variables (Fuzzy-Set Scores).

	Means	Standard Deviation	GDP	Urbanization	Education	System	Policy
GDP	0.61	0.35	1				
Urbanization	0.59	0.33	0.51*	1			
Education	0.73	0.31	0.53	0.63**	1		
System	0.61	0.31	-0.30**	-0.28	0.58**	1	
Policy	0.64	0.31	0.69**	0.36	0.53**	-0.63**	1

note: *p<0.01 **p<0.05

As a result, the five conditions (GDP level, urbanization level, education level, source separation system and policy level) meet the standard criteria (standard deviation is not less than 0.3 and correlation score is less than 0.7) for use in the fsQCA. The other factors were excluded because of missing data.

3) CONSISTENCY IN SET RELATIONS

The next task in applying fsQCA is to evaluate which configurations of causal conditions act as sufficient conditions for residents' participation in waste sorting. It requires a cross-case comparison of memberships between the causal conditions and the residents' participation in waste sorting. For fuzzy sets, the assessment of consistency is a bit more complex because causal conditions and outcomes have partial memberships. According to set theory, a consistent subset relation with fuzzy measures emerges when membership scores in a given causal set of attributes are consistently less than or equal to the membership scores in the outcome set[78]. The consistency measure in this case is thus calculated as the sum of the consistent, or membership scores in a causal set, divided by the sum of all the membership scores

TABLE 6. Analysis of conditions for necessity consistency and coverage.

Condition	Necessity Consistency	Necessity Coverage
GDP Level	0.791	0.905
Urbanization Level	0.688	0.805
Education Level	0.876	0.840
Separation System	0.541	0.619
Policy Level	0.854	0.932

that pertain to that causal set:

$$Consistency(X_i \leq Y_i) = \sum_i [\min(X_i; Y_i)] / \sum_i (X_i) \quad (1)$$

To avoid deterministic solutions, detecting a subset relation does not require that all cases are included in the final pathways. Instead, based on the concept of quasi-sufficiency (Ragin takes the proportion of cases in X that fall within the boundaries of Y as a measure of the consistency of these data with sufficiency. The imperfect subset relations that most of cases in X fall within the boundaries of Y are described with quasi-sufficiency. A consistency of the order of 0.8 is usually taken as large enough in the literature to support a claim of quasi-sufficiency.), when the consistency measure of a configuration statistically exceeds a minimum threshold, the configuration will be considered as a sufficient pathway in which a few inconsistent cases are allowed because of random error [79]. We set the consistency threshold of 0.8 in this article. In order to mitigate the potential effect of measurement and coding errors, configurations including more than one case are finally analyzed to get the results [80]. The results of necessity analysis are exhibited in Table 6. According to the value of necessity consistency shown in Table 6, no condition exceeds the consistency score threshold of 0.9, indicating none of these cases is considered essential. In addition, the necessity level of the education level is close to 0.9, meaning the education level is approximate to the necessary conditions for the residents' participation in waste sorting. As a result, these five conditions should remain in the final analysis.

4) LOGIC REDUCTION

The final task in applying QCA is to prune the sufficient configurations by eliminating redundant elements. While consistency is a measure of the significance of a subset relationship, coverage is a measure of its relevance and reflects the share of consistent memberships as a proportion of total memberships in the outcome set [78]. It is similar to the R-square value usually exiting in regression methods [81]. Coverage enables the assessment of the empirical importance of sufficient configurations with the following principle:

$$Coverage(X_i \leq Y_i) = \sum_i [\min(X_i; Y_i)] / \sum_i (Y_i) \quad (2)$$

where X_i means to be the causal conditions, Y_i means to be residents' participation in waste sorting. The reduction procedure includes an important step related to the treatment of "remainders," which are configurations with an insufficient number of best-fit cases in the sample because now existing sample can't cover all possible situations [82].

IV. RESULTS AND DISCUSSION

Firstly, we use fsQCA (version 3.0) to analyze converted date (table 4) and then get edited truth table (table 7) by setting consistency to be more than 0.8 and the minimum number of the coverage to be more than one case. Secondly, we conduct a sufficiency analysis and then get the complex solution -four causal pathways (figure 3) leading to residents' actual participation in waste sorting, with a coverage score of 0.731 and consistency score of 0.946 (table 8). The result (see it in appendix) reports raw and unique coverage scores. Raw coverage indicates the extent of overlap of the size of the configuration set while unique coverage indicates the extent of overlapping explanations by partitioning the raw coverage [83]. These indicators explain the extent of empirical relevance of configuration statements. After the logic reduction, the parsimonious causal conditions are high GDP level with coverage score of 0.791 and consistency score of 0.905 and non-user-friendly source separation system with coverage score of 0.541 and consistency score of 0.962. Finally, according to the complex solution and parsimonious solution, we conclude the core conditions and the peripheral conditions. Core conditions are the ones with a strong causal relation with the outcome (usually the parsimonious solution), peripheral elements are those with a weaker one.

Pathway 1 includes low GDP level, non-user-friendly system, high education level, systematic laws and strict implementation. This pathway explains the mechanism of residents' high-level participation in the countries such as Croatia, Hungary, Poland, Romania. Pathway 2 includes high GDP level, user-friendly system, high education level, systematic laws and strict implementation. This pathway explains the mechanism of residents' high-level participation in the countries such as Italy, Latvia, Austria, Slovenia, Sweden. Pathway 3 includes high urbanization level, user-friendly system, high education level, high GDP level. This pathway explains the mechanism of residents' high-level participation in the countries such as Italy, Cyprus, Latvia, Sweden, Bulgaria. Pathway 4 includes high urbanization level, non-user-friendly system, high education level, systematic laws and strict implementation. This pathway explains the mechanism of residents' high-level participation in the countries such as Japan, Czech Republic, Estonia, Hungary, Poland, Shanghai, USA.

A. THE VERIFICATION OF THE PROPOSITION 1

In the pathways 1 and 4, the policy level and education level are the key conditions that constitute the sufficient condition for residents' participation in waste sorting. In the pathways 2 and 3, the GDP level and education level are key conditions that constitute the sufficient conditions for residents' participation in waste sorting. It means that the external conditions and socio-demographic conditions must interact together to

TABLE 7. The edited truth table.

Policy level	Separation system	Education level	Urbanization level	GDP level	Number	Participation	Raw consistency	PRI consistency	SYM consistency
1	0	1	0	0	2	1	1	1	1
1	0	1	1	0	2	1	1	1	1
1	1	1	0	1	2	1	1	1	1
1	1	1	1	1	3	1	0.9547	0.9337	0.9337
1	0	1	1	1	5	1	0.9535	0.9432	0.9432
0	1	1	1	1	2	1	0.9336	0.8759	0.8759
0	1	1	1	0	2	0	0.7657	0.6203	0.6203
0	1	0	0	0	3	0	0.2705	0.11	0.11

TABLE 8. Combinations of conditions of sufficiency.

conditions	Causal pathways			
	1	2	3	4
Policy level	●	●		●
Separation system	⊗	●	●	⊗
GDP level	⊗	●	●	
Urbanization level			●	●
Education level	●	●	●	●
Raw coverage	0.270456	0.477202	0.477202	0.477826
Unique coverage	0.0424736	0.0424736	0.0424736	0.126171
Consistency	1	0.958595	0.958595	0.957447
Cases covered	Croatia, Hungary, Poland, Romania	Italy, Latvia, Austria, Slovenia, Sweden	Italy, Cyprus, Latvia, Sweden, Bulgaria	Japan, Czech Republic, Estonia, Hungary, Poland, Shanghai, USA
Overall consistency	0.730793			
Overall coverage	0.945837			

Note: Frequency threshold=2, consistency threshold=0.8. Solid circle(● or ●) refers to the high level of the causal condition. Circles with a cross (⊗ or ⊗) refers to the low level of the causal condition. The large circle represents core condition, the small circle represents peripheral condition, and blank spaces indicate the condition is redundant for achieving the outcome.

result in residents' participation in waste sorting at a high rate. The proposition 1 has been confirmed. This result corresponds to QCA's idea of dealing with complex problems. The influence of single condition on residents' participation is very limited. The residents' participation is the result of conditions interacting together.

B. THE VERIFICATION OF THE PROPOSITION 2

According to the table 8, the causal condition of GDP level exists in the pathways 1,2 and 3. In addition, the coverage of the pathway 2 and 3 is close to 50%. The GDP level can be regarded as a key condition for driving residents to participate in waste sorting, but the existence of this condition alone is not enough to generate the high-level participation. In the pathways 4, whether the GDP level appears will not affect the residents' participation. At the meantime, the GDP level in pathway 1 is low, but the GDP level in pathway 2 and 3 is relatively high. It means the high GDP level will promote residents' participation, but the low GDP level may also promote residents' participation when combining with other causal conditions. The proposition 2 has been confirmed.

C. THE VERIFICATION OF THE PROPOSITION 3

After in-depth analysis of the findings in table 8, we will compare and explain the mechanism of different pathways and provide some exercisable suggestions for decision makers in different countries or areas.

1. 'Mature' mode for waste sorting. The pathway 2 and 3 fall into this category. Most of these countries are much developed EU countries such as Sweden, Italy, Latvia. Residents have a great knowledge of waste sorting and environmental protection (intrinsic factors). The classification mode is not complex and thus easy to master. From the view of hierarchy, the collection system has clear and multi-level hierarchies. From the point of practical maneuverability, the collection system is much more intelligent and easier-to-use. The government also enact systematic laws, strictly implement laws to drive people to sort waste, which makes it convenient for people to sort waste (extrinsic factors). So, residents in these developed countries are more likely to sort waste since they have a strong economy and the recycling infrastructure are more developed. The recycling infrastructure and the convenience of the separation system enable people to sort waste easily.

2.'high policy level+ high urbanization level+ non-user-friendly system' mode for waste sorting. The pathway 4 falls into this category. Most residents of these countries live in city and get access to the recycling facilities and recyclable bins much easily. Because of a relative high population density and systematic laws and strict implementation, the herd effects of active participation spread in the neighborhood much fast and promote more and more residents to participate in waste sorting. The GDP level of these countries is also not low. In fact, the hierarchy of the USA's system is fuzzy while Japan's waste classification system requires a certain degree of professional knowledge about the chemical and physical characteristics of the waste. However, due to sufficient awareness programs, operator's obligation for separate waste sanitation, plentiful bins to separate collection, this non-user-friendly system doesn't significantly hinder residents' participation in waste sorting. The relative high education level enables residents to master such a little complex system gradually. These typical countries are Japan, Czech Republic, Shanghai, USA.

3.'high policy level+ low GDP level+ non-user-friendly system' mode for waste sorting. The pathway 1 falls into this category. These typical countries are Croatia, Hungary, Poland, Romania. They are the newest EU members which don't have the required ability to fully meet the standard of EU[56]. Due to the low GDP level, they lack better recycling facilities and enough recyclable bins in the areas. In addition, poor regions of these countries whose economic and environmental interests are often in conflict may be less supportive of policy. However, their small population and areas facilitate the country's centralization, which make residents strictly implement the laws. So, residents' high-level participation in waste sorting is mainly attributed to these countries' strict policy and public education for environmental awareness. This mode is much different from the mode of China and USA. Sufficiency consistency scores for each pathway exceed the threshold of 0.8 and make it sufficient for achieving residents' participation in waste sorting. As is known, some causal conditions in these pathways are the same.

Based on the finding above, the third proposition has been fully confirmed. There are three modes that lead to residents' participation in waste sorting.

In further analysis, we find there are some nuances in the policy and education. From the perspective of education, in the USA and Japan, the education about how to sort and the policy about increased tariffs if the waste is not separated rightly influence residents' participation in waste sorting positively. However, the similar policy is less acceptable and less effective in promoting waste sorting behavior in the EU. And people in the EU don't prefer to know how to separate waste. It is the moral of protecting the environment and user-friendly system that drive them to sort waste at a high rate. From the perspective of policy, Shanghai took a top-down approach when enacting new decree, in which citizen and societies play a less important role in shaping local environmental regulation. EU countries took a bottom-up approach when enacting policies.

D. ROBUSTNESS TEST

In order to ensure the stability of the findings, the robustness test includes three aspects: (1) After the single necessary causal condition is removed, the configurations remain unchanged. Since no necessary causal condition exists in this paper, we don't check this point. (2) Robustness is tested by adjusting the consistency value. When the consistency is set as 0.85 and other factors remain unchanged, the four pathways remain unchanged. When the consistency is set as 0.9 and other factors remain unchanged, the four pathways still remain unchanged. (3) Robustness is tested by adjusting the frequency threshold. When the frequency threshold is increased from 2 to 3, the pathway 1 and 4 are missing. The pathway 2 and 3 still exists. Therefore, the main configurations obtained by fsQCA analysis in this paper are credible and robust.

V. MANAGERIAL IMPLICATIONS

Nowadays, many residents from some developing countries or areas are reluctant to participate in waste sorting. To this day, Guilin and Kenya has had no formal household waste sorting legislations or any kind. Even some countries with a relative high residents' participation in still can enhance some aspects to promote more residents to participate in waste sorting. The findings of this article provide specific management suggestions for decision makers to design promotion programs and waste sorting policies as follows:

(1) The government should raise awareness and strengthen management of residents' participation in waste sorting. Administrative departments should pay attention to the synergistic influence of external conditions and socio-demographic conditions. On one hand, government firstly should build more recycling facilities and deploy more recyclable bins in the community. Secondly, different countries should enact related policies considering the urbanization level and other conditions. On the other hand, lectures can be held in communities to not only improve residents' environmental protection consciousness but also popularize waste sorting standards and skills, thereby minimizing the difficulties involved in waste sorting.

(2) Different countries should take different measures to improve residents' participation rate. As for Japan and USA, they can improve their separation system to further increase residents' participation rate. As for Croatia and Romania, they should build more recycling infrastructure and bins in the urban areas and learn more from the standard separation system and policy of the developed countries in EU. Through the analysis, we find the failure of participation in waste sorting in Shanghai(2013) mainly be attributed to the casual implementation of the policy. So, the imminent step for enhancing residents' participation is to strengthen the policy implementation in Shanghai. As for countries or

areas with low GDP level and urbanization level like western areas in China, it is much effective to build a user-friendly classification system such as waste sorting vehicles with automatic waste sorting or even a binary classification mode to promote residents' participation in waste sorting, which in turn will enhance the environment protection awareness. For some cities in the coastal areas in China, it is proper to imitate the waste sorting model and experience of Shanghai with some changes in policy and separation system considering the local recycling industry.

VI. STUDY LIMITATIONS

Our analysis uses the data from the present published case study or the database from the government sites, and is therefore prone to the positivist fallacy that some inexact pathways have been identified. In addition, some causal conditions such as gender rate and age in the data can't be collected in great detail, so these conditions are excluded in the analysis. Future study should include more cases and more causal conditions to conduct analysis of residents' participation in waste sorting.

Our study is based on complex causality and uses specific cases instead of variables to establish causal pathways leading to a particular outcome. Due to the limited cases and purposeful selected causal conditions, comparisons from a strict analytical standpoint may not be meaningful; And the QCA findings' empirical validity is not superior to the findings obtained through other methods. The contribution of our study here is to use fsQCA method and compare limited cases to make a better understanding of data and put forward some meaningful suggestions.

VII. CONCLUSION

In this paper, a comparative analysis method based on fuzzy sets is used to study the residents' participation in waste sorting and the results show the complexity and diversity. This paper has identified four pathways of the residents' participation in waste sorting through the empirical research, and systematically analyzed the mechanism of configurations of external conditions and socio-demographic conditions. The article draws the following three conclusions:

(1) Only if the external conditions and socio-demographic conditions emerge simultaneously, residents participate in waste sorting at a high rate. The influence of single condition on residents' participation is very limited. Especially, although great success has been achieved in other areas in China only by implementing the strict regulations, the influence of policy level on waste sorting is limited. In the past short period, the waste-sorting campaign in Shanghai was successful only by the most stringent regulations. However, it is difficult to maintain the high rate of residents' participation only by high policy level in a long run. The government should shift away from just emphasizing command-and-control measures and pay more attention to raise residents' awareness of protecting environment. The residents' participation is the result of conditions interacting together.

(2) The influence of single causal condition may be negative or positive towards residents' participation, depending on how they combine with other causal conditions. The core condition (parsimonious solution), the high GDP level, will promote residents' participation, but the low GDP level may also promote residents' participation when combining with other causal conditions. Firstly, the conflicts between economic and environmental interests are less likely to happen in the richer area. Secondly, richer regions from inland China provide and maintain more developed disposal infrastructures for residents to sort waste at fixed times of a day. Thirdly, President Xi said that mountains and clear water are equal to mountains of gold and silver. Making effort to develop green economy is conducive to increasing the GDP level and the high GDP level will stimulate the green economy in return. Fourthly, if the local government uses the ''low GDP'' mode, residents in the poorer regions can still participate in waste sorting at a high rate. The component of waste in these areas are relatively simple and residents are scattered. Different from the current China mode, the local government firstly dispatches the waste sorting vehicles instead of stationary bins to sort waste preliminary and then uses waste sorting equipment to sort waste furtherly. The dynamic waste collection vehicles can also promote residents to strictly implement the regulations. This mode is well suited to small counties and cities in China.

(3) There are several different configurations that can lead to residents' participation in waste sorting, and some of causal conditions included in each configuration may be the same. Residents' participation is the result of three different modes- 'Mature' mode, 'high policy level+ high urbanization level+ non-user-friendly system' mode, and 'high policy level+ low GDP level+ non-user-friendly system' mode.

On this basis, government can take different measures according to different conditions and improve residents' participation rate.

APPENDIX

Literature review search terms:

Academic databases searched included Science Citation Index Expanded, Social Science Citation Index, Conference Proceedings Citation Index – Science, Conference Proceedings Citation Index- Social Science & Humanities, Book Citation Index– Science, Book Citation Index– Social Sciences & Humanities. Practitioner databases searched included World Bank websites. The year range from 1995 to 2020.

Example search terms were: (1) TI = ((waste sorting OR waste recycling OR waste classification OR waste sorter OR source-separated OR waste separation OR waste management)) (2) TI = ((waste sorting OR waste recycling OR waste classification OR waste sorter OR source-separated OR waste separation OR waste management)) AND TS = (municipal OR household) AND (participation OR participate)

fs/QCA software output (Ragin and Davey, Univ of Arizona, version 3.0):

Model: Participation = f(Policy level, System, Education level, Urbanization, GDP)
Algorithm: Quine-McCluskey
True: 1
Don't Care: -

--- COMPLEX SOLUTION ---
frequency cutoff: 2.000000
consistency cutoff: 0.933602
Assumptions:

	raw coverage	unique coverage	consistency
Policy level*~ System * Education level *~GDP	0.270456	0.0424736	1
Policy level* System *Education level * GDP	0.477202	0.0424736	0.958595
System*Education level* Urbanization * GDP	0.477202	0.0424736	0.958595
Policy level*~System*Education level*Urbanization	0.477826	0.126171	0.957447

solution coverage: 0.730793
solution consistency: 0.945837

--- PARSIMONIOUS SOLUTION ---
Assumptions:

	raw coverage	unique coverage	consistency
GDP	0.79138	0.334791	0.905
~System	0.541536	0.0849469	0.962264

solution coverage: 0.876327
solution consistency: 0.913411

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