Engagement factors for household waste sorting in Ecuador: Improving perceived convenience and environmental attitudes enhances waste sorting capacity

Negash, Y. T., Sarmiento, L. S., Tseng, M-L., Lim, M. & Ali, M. H.

Original citation & hyperlink:
Negash, YT, Sarmiento, LS, Tseng , M-L, Lim, M & Ali, MH 2021, 'Engagement factors for household waste sorting in Ecuador: Improving perceived convenience and environmental attitudes enhances waste sorting capacity', Resources, Conservation and Recycling, vol. 175, 105893.
https://dx.doi.org/10.1016/j.resconrec.2021.105893

DOI 10.1016/j.resconrec.2021.105893
ISSN 0921-3449
ESSN 1879-0658

Publisher: Elsevier

Engagement factors for household waste sorting in Ecuador: Improving perceived convenience and environmental attitudes enhances waste sorting capacity

Authors

Yeneneh Tamirat Negash
- Department of Business Administration, Asia University, Taiwan
- Institute of Innovation and Circular Economy, Asia University, Taiwan

Email: yeneneh@asia.edu.tw; yenuta@gmail.com

Liria Salome Calahorrano Sarmiento
- Institute of Innovation and Circular Economy, Asia University, Taiwan

Email: liria.calahorrano@gmail.com

Ming-Lang Tseng (Corresponding author)
- Institute of Innovation and Circular Economy, Asia University, Taiwan
- Department of Medical Research, China Medical University Hospital, China Medical University, Taiwan

Email: Tsengminglang@gmail.com; tsengminglang@asia.edu.tw

Ming K. Lim
- College of Mechanical Engineering, Chongqing University, China
- Faculty Research Centre for Business in Society, Coventry University, United Kingdom

Email: ac2912@coventry.ac.uk

Mohd Helmi Ali
- UKM Graduate School of Business, Universiti Kebangsaan Malaysia, 43600 UKM Bangi, Selangor, Malaysia
- Faculty of Economics and Management, Universiti Kebangsaan Malaysia, 43600 UKM Bangi, Selangor, Malaysia.

E-mail: mohdhelmiali@ukm.edu.my

Engagement factors for household waste sorting in Ecuador: Improving perceived convenience and environmental attitudes enhances waste sorting capacity

Abstract

This study contributes to developing a set of engagement factors to address waste mishandling and enhances waste sorting intention in households. Prior studies do not specify a set of factors to mobilize and empower households toward better waste sorting engagement. In addition, in Ecuador, waste separation rates are low, and household waste sorting reduces the separation efforts at collection facilities to increase the recycling efficiency for sustainable plastic waste management strategies. This study adopted the theory of planned behavior to understand waste sorting engagement factors, and the factors are described in qualitative information and linguistic preferences. Hence, this study applied the fuzzy Delphi method to screen out the less important attributes and fuzzy decision-making trial and evaluation laboratory to visualize the interrelationships among attributes. This study finds that waste sorting capacity is driven by environmental attitudes, perceived convenience, social norms and economic drivers. The results also indicated that households' environmental attitudes, perceived convenience and economic drivers are causal factors that drive waste sorting engagement. For practitioners, separation knowledge, willingness to participate, pro-environmental decisions, and social responsibility arrangements are the driving criteria for improving waste sorting engagement and reducing and eliminating pollution. Theoretical and practical implications are discussed.

Keywords: waste sorting engagement; theory of planned behavior; fuzzy Delphi method; fuzzy decision-making trial and evaluation laboratory

Engagement factors for household waste sorting in Ecuador: Improving perceived convenience and environmental attitudes enhances waste sorting capacity

1. Introduction

In Ecuador, waste generation in urban areas accounts for 70% of total national waste production, and 84.7% of the waste is a mixture of materials that requires considerable effort to classify and that mostly goes directly to landfills (INEC, 2020). Household solid waste accounts for a significant proportion of urban solid waste, and the amount is growing every year (Wang et al., 2018; INEC, 2020). In sustainable plastic waste management strategies, household waste separation is central; it reduces separation efforts at collection facilities and increases recycling efficiency (Meng et al., 2018; Knickmeyer, 2020). However, recycling efficiency is affected by waste sorting behaviors (Meng et al., 2018; Araee et al., 2020; Pendersen and Manhice, 2020). For instance, 34.4% of households throw away plastic bags and bottles in Ecuador's coastal region, causing the deaths of seabirds and marine creatures and influencing human well-being (Moreira et al., 2021). Waste sorting at the household level is recommended to reduce the stress related to municipal waste management. However, engagement factors for household waste sorting in Ecuador have not been clarified. Waste separation rates are low, and additional efforts are required in collection facilities to separate waste and recyclable material (Meng et al., 2018; Knickmeyer, 2020). Meng et al. (2019) noted that waste management ineffectiveness is caused by residents' weak engagement in identifying and classifying waste into compost, glass, paper, metal, and plastic. Developing waste sorting engagement (WSE) enables sustainable resource recovery, reduces landfill space, and increases recycling rates (Fan et al., 2019; Wang et al., 2020). This study aims to develop a WSE model to clarify the attributes and improve Ecuador's waste management ineffectiveness.

Increasing WSE provides a sustainable strategy to reduce waste and reuse and recycle materials (3 Rs) (Li et al., 2017; Wang et al., 2018; Tseng et al., 2021). Proper household waste classification reduces municipal waste and environmental pollution by 30%-40% (Zhang et al., 2018; Wang et al., 2020). Prior studies have focused on identifying and describing the attributes affecting WSE (Varotto and Spagnolli, 2017; Chen and Gao, 2020). Nevertheless, Schanes et al. (2018) argued that even if households have a high intention to improve their waste sorting, this intention often does not translate into action due to economic and knowledge attributes influencing WSE. The gap between intentions and actual waste sorting should consider cognitive and contextual attributes. Meng et al. (2019) indicated a lack of research on the economic and knowledge attributes influencing a person's WSE. Limited progress in waste sorting has been made, and knowledge gaps still exist, particularly concerning understanding the engagement factors that bridge intentions and actual waste sorting behavior (Gholizadeh and Tajdin 2019). In addition, Chen and Gao (2020) argued that inappropriate sorting in recycling facilities or sorting performed by informal collection channels damages the environment. This study uses WSE to address the gap between intentions and actual waste sorting behavior.

Improving WSE requires a deeper understanding of behavioral components: environmental attitudes, social norms, and perceived convenience (Passafaro and Livi, 2017; Li et al., 2019; Pei, 2019). Households intend to engage in waste separation when they evaluate it positively, experience social pressure to perform it, and believe that they have the means and opportunities to do so (Xu et al., 2018; Li et al., 2019; Knickmeyer, 2020). Attitudes, perceived control, and subjective norms are listed in the theory of planned behavior (TPB) (Wang et al. 2018, Zhang et al., 2019). The TPB considers the relationships between personal, social influence, and control issues to explain intentions (Ajzen, 1991; Wang et al., 2020). Previous studies have used TPB attributes to analyze WSEs based on residents' environmental attitudes, community behavior, collection channels, and government policies (Xu et al., 2017; Fan et al., 2019; Liu et al., 2019; Wang et al., 2020a). However, the TPB has limitations, particularly regarding the correlation between intentions and actual waste sorting behavior (Zhang et al., 2016; Razali et al., 2020). While the TPB considers social norms, it does not consider the economic factors that may influence a person to engage in waste sorting (Xu et al., 2018; Sujata et al., 2019; Shan et al., 2020). Sociodemographic conditions play a role in the intervention of economic drivers, particularly in low- and middle-income households. Moreover, due to different polymer compositions, the plastic in household waste is heterogeneous and contaminated by the products it contains (Ragaert et al., 2017; Eriksen et al., 2019). WSE requires knowledge about the materials and their pollutants to enhance waste sorting capacity. A study considering the TPB and additional attributes is required to reveal household WSE and to address the gap between intentions and actual waste sorting behavior. Hence, this study argues that environmental attitudes, perceived convenience, social norms, economic drivers, and waste sorting capacity define WSE. This study integrates the TPB, economic factors, and waste sorting capacity into a hierarchical framework to determine each factor's importance and increase the waste sorting of households through WSE indicators.

WSE involves qualitative attributes and uncertainties because of experts' linguistic preferences for the attributes. The uncertainties are challenging to capture effectively with formal models and methods, making it difficult to gain insights into WSE (Tseng et al., 2019; Negash et al., 2021). The combination of fuzzy set theory with the Delphi method and fuzzy decision-making trial and evaluation laboratory (FDEMATEL) transforms linguistic preferences into triangular fuzzy numbers (TFNs), normalizes subjective responses, and reduces bias and uncertainty (Tsai et al., 2020). The attributes should be integrated into a hierarchical model to elucidate their complex interrelationships, enrich the engagement model, and improve waste sorting capacity. However, fewer studies address WSE based on the interrelationships of its attributes, and prior studies have neglected linguistic fuzziness (Zhang et al., 2016; Zhang et al., 2019). In this context, the fuzzy Delphi method (FDM) validates and filters important household WSE criteria based on linguistic preferences, and the FDEMATEL visualizes the complex interrelationship among them (Tseng et al., 2018; Negash et al., 2021). This study combines fuzzy set theory with the Delphi method and FDEMATEL to determine the most relevant attributes and their interactions that affect WSE. These proposed methods allow the inclusion of expert opinions, offer a list of valid criteria and determine the relationships of the attributes of WSE. The objectives of this study are as follows:

- To validate a set of WSE attributes based on qualitative information
- To develop a causal model under uncertainties
- To determine WSE criteria to increase residents' WSE in the Ecuadoran context

This study contributes to addressing the gap between intentions and actual waste sorting behavior by (1) providing a set of WSE attributes in a hierarchical structure, including environmental attitudes, perceived convenience, social norms and interactions, economic drivers, and waste sorting capacity, (2) presenting the causal relationships among the attributes, and (3) identifying mail criteria for managerial applications in public campaigns and education systems. Thus, decision-makers can refer to this study to increase the WSE of low- and middle-income households in Ecuador.

This paper is organized as follows. Section 2 presents a literature review. Section 3 discusses the proposed method. Section 4 shows the results. The managerial and theoretical implications are discussed in Section 5. Finally, Section 6 presents the conclusion, limitations and future studies.

2. Literature Review

This section discusses the literature on WSE. In addition, the proposed method and measured attributes are presented.

2.1 Waste sorting engagement

Household waste sorting requires a set of skills, including identifying potential waste material (plastic, paper, clothes, and organic waste), followed by correctly identifying the container for each category and performing proper waste treatment (Passafaro and Livi, 2017; Shan et al., 2020). Leeabai et al. (2019) argued that municipalities have attempted to implement waste sorting at the source without success due to low engagement. Chen and Gao (2020) highlighted that waste management's success depends on residents' engagement in classification activities. However, Zhang et al. (2019) found that improper classification hinders the efficiency and benefits of the waste management process. Governments aiming to mitigate these problems have implemented environmental policies to increase waste separation collection without much success (Li et al., 2017; Wang et al., 2018). Compared to less dense areas, urban areas with large quantities of solid waste significantly underperform (Wang et al., 2018; Knickmeyer, 2020). Efficient waste management systems depend on residents' performance in waste sorting activities.

Increasing WSE reduces the negative environmental impacts related to improper waste disposition, landfills, and unrecovered materials. Despite the benefits and importance of WSE, it has had limited success in alleviating pollution, with low recycling rates (Fan et al., 2019; Shan et al., 2020; Tseng et al., 2021). Meng et al. (2019) noted that waste management ineffectiveness is caused by residents' weak engagement in identifying and classifying waste into compost, glass, paper, metal, and plastic. Prior studies have focused on the psychological perspective and individual perceptions to understand WSE (Passafaro and Livi, 2017; Xu et al., 2017; Fan et al., 2019). Many studies have examined sociodemographic and economic attributes corresponding to environmental behaviors such as waste sorting (Wang et al., 2018; Xu et al., 2018; Pei, 2019). External attributes such as location convenience, facility accessibility, and public education influence WSE (Leeabai et al., 2019; Liu et al., 2019). Plastic recycling efficiency is affected by WSE and waste separation quality; an exogenous material may damage machines and pollute newly recycled material (Meng et al., 2018; Pendersen and Manhice, 2020). Increasing household WSE mitigates the effect of growing plastic and urban waste production. Hence, stakeholders aiming to achieve better recycling efficiency and material recovery must understand the engagement factors that affect waste separation in households.

2.2 Waste sorting engagement factors

WSE is personal and related to environmental attitudes, including a willingness to sort, ecological concerns, perceived moral obligation, and sustainability attitude (Liu et al., 2019; Zhang et al., 2019; Shan et al., 2020). Social norms reflect that individuals are likely to be involved in waste separation activity if the surrounding people are involved (Fan et al. 2019; Sujata et al., 2019; Knickmeyer, 2020). Control indicates that an intention to participate in waste separation is contingent on the individual's perception over the convenience of the factors that facilitate or interfere with WSEs (Lee et al., 2017; Fan et al., 2019; Shan et al. 2020). The TPB determines an individual's intention as a function of attitudes, social norms, and perceived behavioral control (Ajzen, 1991; Z. Wang et al., 2020). Despite its importance, the TPB lacks the economic and knowledge factors that may influence WSE (Sujata et al., 2019; Shan et al., 2020; Wang et al., 2020). Additional factors can be integrated into the TPB for its improvement. Prior studies have complemented the TPB with new factors (Xu et al., 2017; Sujata et al., 2019; Shan et al., 2020). Other theories that explain WSE include the theory of engagement with enthusiasm, social interaction, active participation and residents' willingness to sort waste (Liu et al., 2019; Meng et al., 2019; Wang et al., 2020a). This study extends this research by including economic drivers and waste sorting capacity to understand and improve residents' WSE. Hence, five factors, i.e., environmental attitudes, perceived convenience, social norms and interactions, economic drivers, and waste sorting capacity, are integrated to explain the gap between intentions and behavior.

Environmental attitudes represent residents' position toward waste sorting and recycling (Meng et al., 2019). This study defines environmental attitudes as the psychological and moral position toward waste sorting activities. Previous studies have correlated environmental attitudes and WSE. Zhang et al. (2019) noted the positive correlation between personal attitudes and behavioral intentions, which is positively associated with WSE. Attitudes guarantee individuals' long-term sustainability intentions and make it easier for community members to achieve WSE goals. Sujata et al. (2019) found that attitudes and self-efficacy are better predictors of recycling behavior through their direct effect on recycling intentions. In addition, Liu et al. (2019) reported residents' attitudes toward waste sorting, conscientious personality, and willingness to classify household waste. Thus, attitudes are a prerequisite for achieving better recycling efficiency and material recovery, making environmental attitudes an important factor affecting WSE. Shan et al. (2020) found a positive correlation between attitude recycling efficiency, material recovery, and better WSE. However, the effect of attitudes toward WSEs is expected to vary from one household to another and among communities. Indeed, Knickmeyer (2020) remarked that social behaviors could vary between urban areas and be affected by local factors, including economic and knowledge attributes. Environmental attitudes affect WSE through behavioral intentions.

Perceived convenience involves individual perceptions of external factors and their effect on performing waste sorting activities (Xu et al., 2017). Varotto and Spagnolli (2017) explained that in waste separation activities, convenience is achieved by appearance and proximity and that it is necessary to achieve a recycling culture. Perceived convenience provides the basis for WSE. Sujata et al. (2019) noted that increased consumption and a change in lifestyle create uncertainty and make it inconvenient to engage in waste sorting activities. Nevertheless, the lack of convenient recycling facilities discourages residents from WSE. For instance, Knickmeyer (2020) noted that the continuous changes in the specifications of materials and the incompatible systems adopted by communities in different areas make waste sorting a complex and inconvenient task for residents, thus hindering WSE. Previous studies have shown that contextual factors, including infrastructural convenience, affect WSE (Lee et al., 2017; Fan et al., 2019). Increasing convenience is a factor in improving social norms and perceptions of control, which, in turn, lead to WSE. Shan et al. (2020) noted that convenience affects perceived effort, which is a factor in the risk, attitudes, norms, and self-regulation approach. Hence, perceived convenience is a factor that influences WSE and involves personal opinions concerning resources and the ease or difficulty of performing an action.

Social norms reflect the social pressure that influences a particular behavior, expressing the approval or disapproval of others and linking pride or shame to WSE (Lindbeck, 1997; Meng et al., 2019). The influence of social norms on WSE is evident when residents see other individuals participating in waste separation and recycling activities. Passafaro and Livi (2017) reported that social norms correlate with perceived recycling skills, basic sorting skills, and attitudes and significantly affect household practice. However, the literature on the effect of social norms on WSE is limited, and previous studies differ regarding their findings of the impact of a social norm on the intention to perform waste sorting. For instance, Sujata et al. (2019) determined that social norms predict waste sorting behavior; however, they observed that social norms are weak predictors compared to factors related to attitudes and self-efficacy. Fan et al. (2019) determined that social norms significantly affect waste sorting intentions, affecting WSE. Knickmeyer (2020) noted that social norms are critical for recycling behavior and culture and are enhanced by adequate waste classification infrastructure. In addition, social norms are psychological factors, and their influence depends on personality traits, which make some individuals more likely to be influenced by them than others (Varotto and Spagnolli, 2017; Chen and Gao, 2020). Thus, the impact of social norms on household waste sorting capacity requires further investigation.

Previous studies have proven the effect of economic incentives on pro-environmental behavior (Yuan et al., 2016; Xu et al., 2018; Pei et al., 2019). Households' WSE reduces the time and money spent by waste management facilities to verify the correct waste type and reclassify landfill material. Low-quality waste separation and mixed waste require an extra recycling process, increasing costs (Leeabai et al., 2019). Economic incentives are necessary for WSE. Economic schemes such as pay-as-you-throw have been implemented to reduce the waste collected by municipal systems and to enforce WSE (Grazhdani, 2016; Schanes et al., 2018). Economic factors are effective in encouraging household waste separation and enhance WSE. Fan et al. (2019) demonstrated that economic incentives such as perceived costs and benefits influence waste sorting intentions, suggesting the implementation of waste charges, taxes, or penalties to induce WSE. Chen and Gao (2020) mentioned that economic profits influence residents to be involved in waste separation activities, which is critical for WSE. However, the lack of economic incentives leads to low recycling rates in urban areas. Indeed, Xu et al. (2018) noted that most waste separation activities are voluntary and have low efficiency without a reward. WSE failed due to the lack of economic incentives. In sum, economic punishments and rewards are public policies for regulating WSE.

Residents with knowledge about pollution, environmental issues, and possible solutions and actions to mitigate problems related to waste are more likely to engage in waste sorting activities and accept formal collectors (Li et al., 2017; Wang et al., 2020a). Knowledge about waste classification and awareness of consequences boosts the willingness to participate in waste sorting activities and contributes to strategies designed to enhance WSE. Schanes et al. (2018) noted that the lack of knowledge about the environmental and social consequences of waste explains the ignorance about the impact of wasteful behavior. Meng et al. (2019) found that publicity and education that provide knowledge about recycling and waste classification enhance waste sorting capacity. Zhang et al. (2019) found that awareness of consequences determines personal attitudes, correlates with ascribed responsibility, and indirectly affects waste sorting intentions. Fan et al. (2020) acknowledged the effect of residents' perception of adverse consequences on WSE. Waste sorting capacity is among the determinants of residents' commitment, which influences WSE. Wang et al. (2020) reported that residents showing a waste sorting capacity adopted green behavior such as recycling and chose appropriate recyclers with qualified disassembly. However, Pedersen and Manhice (2020) found that over 30% of their participants showed mistrust in the waste management system. Therefore, waste sorting capacity contributes to WSE, and explaining its relationship with other factors is necessary to fully understand its effects on households.

2.2 Proposed method

Prior studies have used various methods to understand WSE, such as observations, interviews, evolutionary game models, and structural equation modeling (Pedersen and Manhice, 2020; Wang et al., 2020). Passafaro and Livi (2017) used a structural equation model to determine the relationship between motivational, behavioral and dispositional factors and perceived and actual recycling skills. Using structural equation modeling, Fan et al. (2019) reported that environmental motivations and habitual attributes influence WSE. Pei (2019) applied partial least squares structural equation modeling to test community and neighborhood attachment effects on waste recycling intentions. Chen and Gao (2020) used a multiagent-based simulation to simulate residents' decision-making behavior during the waste sorting process and determined the effect of utility parameters on waste separation.

This study combines fuzzy set theory with the Delphi method and FDEMATEL to determine the most relevant attributes and their interactions that affect WSE. Fuzzy set theory has been applied to transform respondents' linguistic preferences into quantitative values, considering the variability in the responses and the uncertainty among preferences (Chen et al., 2019; Feng and Ma, 2020). Fuzzy set theory is merged with the Delphi method to obtain a set of weighted criteria through expert evaluation (Gholizadeh and Tajdin, 2019; Negash et al., 2021). Bui et al. (2020) used the FDM to identify sustainable solid waste management barriers, considering the ambiguity in linguistic preferences and the challenging interpretability of respondents' perceptions. Tsai et al. (2020) employed the FDM to exclude invalid criteria for integrated solid waste management. Negash et al. (2021) reported that using the FDM reduces respondents' uncertainty and increases reliability and validity, filtering criteria for subsequent use. The FDM aids in filtering the most reliable and valuable criteria for WSE, achieving agreement among respondents' perceptions, and reducing uncertainty and ambiguity in linguistic responses.

FDEMATEL explains the causal effects and interrelationships of attributes. Tseng et al. (2019) used FDEMATEL to visualize the effect and causal groups among a set of criteria and factors based on graph theory. Feng and Ma (2020) used FDEMATEL to create a causal diagram to determine the relationships of the factors assessed by expert responses based on linguistic descriptions. Chen et al. (2019) mentioned that applying FDEMATEL helps address vagueness in the responses of decision-makers and reduces the complexity of decision analysis. Tsai et al. (2020) applied FDEMATEL to investigate the interrelationships among criteria and factors, considering experts' linguistic preferences for sustainable solid waste management. FDEMATEL employs fuzzy set theory to convert judgments into crisp values; afterward, it analyzes the relationships among factors based on the previous responses. FDEMATEL identifies the important and driving attributes among a set of linguistic preferences, fuzzy set theory normalizes the expert responses, and FDEMATEL draws a map based on driving power and dependence (Tseng et al., 2018; Bui et al., 2020). This study uses FDEMATEL to determine the relationships among factors and to identify the most important drivers in the set of criteria analyzed.

2.3 Proposed measures

This study performed a content analysis on five different factors of WSEs: environmental attitudes, perceived convenience, social norms and interactions, economic drivers, and waste sorting capacity. As shown in Appendix 1, the initial set includes 51 criteria that were proposed from the literature analysis. This section discusses the 23 criteria validated after FDM analysis.

The environmental attitudes factor considers residents' psychological and moral perception of waste sorting. It includes the sorting willingness (C1) to participate in waste sorting activities (Liu et al., 2019; Wang et al., 2020a). Pro-environmental attitude (C2) affects decision-making to protect the environment (Chen and Gao, 2020; Shan et al., 2020). Social responsibility (C3) considers waste separation to be a civic duty and a moral obligation (Liu et al., 2019; Meng et al., 2019). Hence, environmental attitudes must be considered to evaluate WSE. Perceived convenience involves the perception of difficulty in performing waste sorting activities and achieving a certain level of engagement among residents. Criteria related to the subjective perception of the convenience and ease of classifying waste, such as the time spent (C4), house storage space (C5), abundant rubbish bins (C6), the perception of the complexity of waste sorting (C7), recycling facility accessibility (C8), and facility appearance (C9), including visual cues, prompt WSE (Passafaro and Livi, 2017; Leeabai et al., 2019). Furthermore, information that facilitates the classification and recycling process and trash bin arrangements (C10) reduces the waste separation effort (Zhang et al., 2019). Consequently, the criteria for evaluating perceived convenience must be considered to understand and perform waste sorting.

Social norms and interactions consider the social pressure to perform WSE, as links with individuals who surround residents influence residents' behaviors. Therefore, waste separation performed by family (C11) and waste separation performed by friends and colleagues (C12) concern the closest individuals and their effect on WSE (Xu et al., 2017; Liu et al., 2019; Chen and Gao, 2020). In the interconnected world, relationships with other residents have changed because of social networks online and social media. Thus, social media influence (C13) concerns interest in WSE due to posts on social networks such as Facebook, WhatsApp, and Twitter (Sujata et al., 2019). Previous studies show that WSE is enhanced by the sense of belonging to the community and the sense of being protected by the community, including neighborhood ties (C14) and community attachment (C15), which evaluates the bond between place and person (Crociata et al., 2016; Pei, 2019). Waste cosorting (16) is waste sorting in a group, as social beings and engagement are gained and maintained when waste sorting is performed as a group (Wang et al., 2020). Accordingly, the criteria related to social norms contribute to WSE and are necessary to maintain WSE over time.

Economic drivers concern the reward and punishment approach and involve economic benefits for residents, such as cost savings (C17) and taxes or payments such as waste disposal fees (C18) charged to residents (Meng et al., 2018; Meng et al., 2019). Ultimately, determining waste sorting capacity involves an evaluation of the positive or negative effects of economic and environmental activities. Some individuals are unaware of the environmental cost of materials and pollutants (C19), defined as the pollution caused by economic activities. This study involves the pollution cost incurred by inappropriate dismantling in recycling facilities or dismantling performed by informal collection channels damaging the environment (Chen and Gao, 2020). A positive effect of waste sorting behaviors is environmental pollution reduction (C20), decreasing volume of plastic and other waste, increasing recycling, and protecting the oceans and life on Earth. Evaluating the effects of waste sorting requires prior knowledge. Environmental literacy (C21) provides knowledge about pollution and environmental issues and possible solutions and actions to mitigate the problems related to waste, and separation knowledge (C22) supports correct waste classification (Xu et al., 2017; Q. Wang et al., 2020). Finally, recycled consumption (C23) considers the positive effect of the acquisition and consumption of recycled material (Sujata et al., 2019). Consequently, the proposed factors and criteria are used to estimate WSE.

3. Method

This section details the methodology used, including the analytical steps.

3.1 Fuzzy Delphi method

The FDM converts respondents' judgments into TFNs (Table 1) to examine their agreement and screen out unimportant criteria (Tseng et al., 2018; Negash et al., 2021). The TFN value of criterion α assessed by the b^{th} respondent is given as $j = (x_{\alpha b}; y_{\alpha b}; z_{\alpha b}), \alpha = 1, 2, 3, \dots, n; b = 1, 2, \dots, m.$ The steps this study followed to implement the FDM are listed below.

The geometric mean aggregation method is used to determine the weight of element b (j_b) as follows:

$$j_b = \{x_b = min(x_{\alpha b}), y_b = (\textstyle\prod_1^n y_{\alpha b})^{1/n}, \text{and } z_b = max(z_{\alpha b})\} \quad (1)$$

Afterward, Equation (2) is utilized to determine the upper and lower bounds.

$$u_b = z_b - \alpha\,(z_b - y_b), l_b = x_b - \alpha(y_b - yx_b), b = 1, 2, 3, \dots, m \quad (2)$$

where α captures the negative and positive perceptions of the experts, ranging from 0 to 1; under ordinary circumstances, $\alpha = 0.50$ is commonly selected.

Finally, the criteria weight (D_b) is calculated using Equation (3).

$$D_b = \int(u_b, l_b) = \delta[u_b + (1 - \delta)l_b] \quad (3)$$

where δ indicates the degree to which an expert was positive and establishes an equilibrium across expert opinions. The threshold value γ, where $\gamma = \sum_{\alpha=1}^{n}(D_b/n)$, allows criteria to be screened. When $D_b > \gamma$, the criterion is accepted, and when $D_b < \gamma$, the criterion is rejected.

(Insert Table 1 here)

3.2 FDEMATEL

FDEMATEL investigates the interrelationships among attributes considering experts' linguistic preferences. The steps this study followed to implement FDEMATEL are listed below.

Normalization: For a group of *n* respondents, $\tilde{z}_{ij}^{f}$ represents the fuzzy weight of the *i^th^* attribute affecting the *j^th^* attribute assessed by the *f^th^* member.

$$S = \left(s\tilde{z}_{1ij}^{f}, s\tilde{z}_{2ij}^{f}, s\tilde{z}_{3ij}^{f}\right) = \left(z_{1ij}^{f} - minz_{1ij}^{f}\right)/\Delta_{min}^{max}, \left(z_{2ij}^{f} - minz_{2ij}^{f}\right)/\Delta_{min}^{max}, \left(z_{3ij}^{f} - minz_{ij}^{f}\right)/\Delta_{min}^{max}, \quad (4)$$

where $\Delta_{min}^{max} = max\, z_{3ij}^{f} - minz_{1ij}^{f}$.

Compute the left (*lt*) and right (*rt*) normalized values (Equation (5)) and the total normalized crisp value (Equation (6)).

$$\left(slt_{ij}^{f} + srt_{ij}^{f}\right) = \left(sz_{2ij}^{f}/\left(1 + sz_{2ij}^{f} - sz_{1ij}^{f}\right), sz_{3ij}^{f}/\left(1 + sz_{3ij}^{f} - sz_{2ij}^{f}\right)\right) \quad (5)$$

$$s_{ij}^{f} = \left[slt_{ij}^{f}\left(1 - slt_{ij}^{f}\right) + \left(srt_{ij}^{f}\right)^{2}\right]/\left(1 - slt_{ij}^{f} + srt_{ij}^{f}\right) \quad (6)$$

Aggregate the subjective judgments of *n* assessors, and calculate the synthetic values.

$$\tilde{z}_{ij}^{f} = \frac{1}{f}\left(\tilde{z}_{ij}^{1} + \tilde{z}_{ij}^{2} + \tilde{z}_{ij}^{3} + \cdots + \tilde{z}_{ij}^{f}\right) \quad (7)$$

Obtain an initial direct relationship matrix, where $[\tilde{z}_{ij}^{f}]_{n\times n}$ and z_{ij} indicate the degree to which criterion *i* affects criterion *j*. Standardize the initial direct relationship matrix.

$$Y = \omega \times Z \quad (8)$$

where$\omega = \frac{1}{\max_{1\le i\le f} \sum_{j=1}^{f} \tilde{z}_{ij}^{f}}$

Obtain the total relationship matrix.

$$X = \lim_{f\to\infty} (Y + Y^{2} + \cdots + Y^{f})^{n} = Y(I - Y)^{-1} \quad (9)$$

Map a causal diagram; an influential relationship map is generated by the values of (D + R, D - R). The x-axis (D + R) represents "prominence" and shows importance. The y-axis (D - R) represents "relationship" and sorts criteria into cause and effect groups. If (D - R) is negative, the criteria are in the effect group, and when (D - R) is positive, it is in the causal group.

$$D = \left[\sum_{i-1}^{n} Y_{ij}\right]_{n\times n} = [Y_i]_{n\times 1} \quad (10)$$

$$R = \left[\sum_{j-1}^{n} Y_{ij}\right]_{n\times n} = [Y_i]_{1\times n} \quad (11)$$

3.3 Analytical steps

This study is based on 17 Ecuadorian experts who participate in waste sorting activities. The experts were selected based on their experience, knowledge, and involvement in waste sorting and recycling activities and activism (profile in Table 2). The analytical steps are as follows:

1. A systematic literature review was performed to identify probable WSE attributes, which were used as the initial set for FDM assessment.
2. The FDM questionnaire was formed, and interviews were conducted with 17 experts in Ecuador who shared their opinions in linguistic terms. The FDM was applied to remove insignificant criteria by applying Equations (1)-(3).

3. The FDEMATEL questionnaire was developed based on the FDM results, and interviews were conducted with the same experts. Equations (4)-(7) were used to perform the defuzzification process.
4. Equation (8) was used to determine the normalized direct relationship matrix. Then, the total interrelationship matrix was computed using Equation (9).
5. The (D+R) horizontal axis values and the (D-R) vertical axis values were determined by applying Equation (10) and Equation (11). These values were used to generate a cause-effect interrelationship diagram of the attributes. The graph is divided into 4 quadrants: the attributes in quadrant 1 are identified as “driving attributes,” which have a greater causal impact and higher importance; the attributes in quadrant 2 are termed “voluntary attributes,” which have a greater causal effect but lower importance; those located in quadrant 3 represent “independent attributes,” which have both weak causal effects and low importance; and those in quadrant 4 are called “core attributes,” which have weak causality but higher importance.

(Insert Table 2 here)

4. Results

This section provides an overview of the situation in Ecuador, explains the relationships among WSE factors and identifies the critical criteria for assessing WSE in Ecuador.

4.1 Case background

In 2018, Ecuador disposed of 4.6 million tons of solid waste; 45% was disposed of in landfills, 35% was disposed of in emerging landfills, and 20% was thrown into open dumps, gullies, and rivers. To achieve sustainable development, waste generation is a concern. Landfills and disposal places are located in impoverished indigenous communities, increasing social, ecological, and health impacts (Solíz and Yépez, 2019). Waste generation in urban areas accounts for 70% of total national waste production, with a per person waste generation of 0.75 kg/day. Ecuador has four different regions: the insular, coastal, Andean, and Amazonian regions. The insular region, represented by the Galapagos Islands, separates 100% of waste at the source. However, the continental part differs, with 48.9% and 48.7% of waste being separated in the Andean and Amazonian regions, respectively, and only 3.6% of waste being separated in the coastal region. The waste collection was measured as differentiated and nondifferentiated; 15.3% of waste collected was classified and sorted; however, 84.7% was a mixture of materials requiring a further separation process and mostly going directly to landfills (INEC, 2020). It is necessary to increase waste separation at the source to reduce the impact of waste on the environment and poor communities. In Ecuador, waste management demands a shift in focus from waste separation at landfills and municipal facilities to separation at the source through policies, campaigns, and environmental education.

The evidence of achievement in the insular region is an indicator of Ecuador’s potential to classify waste. However, the amount of waste separation in continental Ecuador is low, and incentives and campaigns are required to achieve success. Pincay et al. (2018) analyzed consumer engagement in coastal regions and found that plastic recycling is part of a cognitive attitude. Moreira et al. (2021) studied coastal regions and found that 70.1% of respondents believe that waste separation in their houses is essential, 39.8% have the intention to separate, 84.3% are unaware of the existence of waste separation facilities, and 34.4% still throw away plastic bags and bottles. Waste separation is performed by 1,500 recyclers in the national network of Ecuador's recycler associates; however, it is estimated that 20,000 recyclers work at the national level (Solíz and Yépez, 2019). Nevertheless, the actual amount of separated waste is still low. Understanding WSE attributes increases waste separation at the source and improves the legal framework and conditions of informal recyclers.

4.2 Analytical results

The analytical steps in Section 3.3 are followed to obtain the analytical results.

1. Fifty-one criteria for WSE were collected from prior studies (Appendix 1). The criteria set was analyzed by expert linguistic judgments (Table 1), the linguistic judgments were transformed into TFNs, and two rounds of FDM assessment were conducted (Appendix 2 and Appendix 3). The FDM results show that 23 criteria were over the threshold value of 0.4189, as shown in Table 3.
   (Insert Table 3 here)
2. Twenty-three validated criteria resulting from the FDM analysis were organized into five factors and used to formulate the FDEMATEL questionnaire. Interviews were conducted to assess the interrelationships among factors, and the experts' answers were converted into TFNs using linguistic scales, as shown in Table 1. For illustration, the relationship matrix and defuzzied values from one respondent are shown in Appendix 4. The crisp values were averaged and integrated into a direction matrix and finally normalized into a total direction relationship matrix in Table 4; accordingly, the effect and cause groups were formed using ($\alpha+\beta$) and ($\alpha-\beta$), as shown in Table 5.
   (Insert Table 4 and Table 5 here)
3. Figure 1 represents the relationships among factors: environmental attitudes (A1), perceived convenience (A2), social norms and interactions (A3), and economic drivers (A4) are direct causes of waste sorting capacity (A5). Additionally, perceived convenience influences environmental attitudes. In particular, the empirical results indicate that to improve WSE, municipalities should focus on perceived convenience (A2) and environmental attitudes (A1). Hence, personal attitudes and perceived convenience have a better effect on waste sorting capacity. Social norms and interactions and economic factors have a weak effect.
   (Insert Figure 1 here)
4. Step 2 is repeated to assess the interrelationships among the criteria. For illustration, the fuzzy matrix assessment from one expert opinion is shown in Appendix 5, and the crisp value matrix of the expert is shown in Appendix 6. Table 6 provides the total interrelationship matrix of criteria; the (D+R) horizontal axis values and the (D-R) vertical axis values are determined, as given in Table 7.
   (Insert Tables 6 and Table 7 here)
5. Figure 2 shows the dependence and driving power graph, which classifies the criteria into four quadrants of different power levels, thereby structuring the criteria into levels and groups. The results show that separation knowledge (C22), pro-environmental attitude (C2), sorting willingness (C1), social responsibility (C3), and trash bin arrangements (C10) are the most important criteria driving WSE.

(Insert Figure 2 here)

5. Implications

This section presents the theoretical and managerial implications for WSE.

5.1 Theoretical implications

This study enriches the literature by providing theoretical insights into improving WSE and filling the gap between intentions and actual waste sorting behavior. It constructs a causal hierarchical framework for assessing WSE based on five factors and finds that perceived convenience (A2), environmental attitudes (A1) and economic drivers (A4) are causal factors that drive WSE. The results also indicate that perceived convenience and environmental attitudes strongly influence waste sorting capacity. Economic drivers have a medium influence, and social norms and interactions have a weak influence on waste sorting capacity. Although the TPB considers the two causal factors found in this study, i.e., perceived convenience and environmental attitudes, it nevertheless does not consider the economic factors influencing WSE. The TPB must integrate economic drivers to obtain better insights and outcomes into WSE. Economic factors that influence a person to engage in waste sorting can be integrated into the TPB to improve the understanding of WSE (Xu et al., 2018; Sujata et al., 2019; Shan et al., 2020).

Perceived convenience (A2) affects waste sorting capacity (A5) and possesses the highest driving power among the proposed factors driving WSE. Perceived convenience is related to the difficulty of performing an action based on one's surroundings and the action's conditions. In particular, perceived convenience is shown to have a better effect on waste sorting capacity. Previous studies have demonstrated that perceived convenience improves waste separation and collection; however, no relationship between convenience and attitudes has been shown (Xu et al., 2017; Leeabai et al., 2019; Zhang et al., 2019). Therefore, perceived convenience mitigates frustration when the conditions are not ideal for certain actions. Perceived inconvenience creates friction among actors and hinders WSE; however, perceived convenience encourages WSE (Knickmeyer, 2020). Satisfactory conditions in waste collection facilities will reduce the conflict between the intention to sort waste and the effort spent sorting waste, thereby increasing WSE. Perceived convenience also involves the visual cues given by the environment to adequately classify waste; these cues support knowledge acquisition and instruction, increasing waste sorting capacity. Hence, the perception of usability and understanding the difficulty of using the waste collection system will enhance waste management effectiveness by improving residents' engagement in identifying and classifying waste.

In addition, this study finds a driving relationship between environmental attitudes (A1) and waste sorting capacity (A5). Previous authors have shown the correlation between these two factors of WSE, as environmental attitudes influence waste sorting intentions and therefore WSE. However, such attitudes have not been ascribed to causing waste sorting capacity; in fact, personal attitudes have been considered an effect of waste sorting capacity (Passafaro and Livi, 2017; Zhang et al., 2019). Considering that the moral or psychological position toward waste sorting creates a predisposition and willingness to participate in waste sorting, regarding interest in these activities, knowledge acquisition is the first step toward engagement. Environmental attitudes are the predisposition to protect the environment and undertake pro-environmental activities and obligations. Knowledge is important for correctly performing pro-environmental activities. Environmental attitudes cause people to search for the proper way to dispose of waste and to understand the consequences of the activities related to the recycling process. The direct relationship between these two factors is considered a new approach to increasing WSE, addressing citizens' environmental position toward our planet, and creating interest in and a moral obligation to participate in waste sorting activities. Public campaigns and pro-environmental awareness-raising communication are necessary to improve waste recycling and protection (Zhang et al., 2019; Knickmeyer, 2020). Hence, the attitude toward the current situation, consequences, and actions to mitigate the individual's impact on the environment is key to WSE.

Economic drivers (A4) impact WSE and waste sorting capacity. As the economic situation is important to families, savings and cost reduction help alleviate economic pressure. Taxes and charges make individuals understand the reason for payment. Previous research has acknowledged the importance of taxes and subsidies to waste sorting intentions, commitment, and behavior (Fan et al., 2019; Chen and Gao, 2020). Some individuals have seen the possibility of selling recyclable materials to increase household income; other individuals have reduced their consumption through the correct classification and reuse of materials, particularly plastic, such as plastic bags. To perform an economic activity, individuals understand and learn about the classification system to obtain the correct material and sell it to gain petty cash. Similarly, to reduce costs, individuals become involved in understanding and performing the actions necessary to save money; currently, accessibility to information creates awareness. Sociodemographic conditions also play a role in the intervention of economic drivers, and this study involves a population of low- and middle-income families.

Social norms and interactions (A3) affect waste sorting capacity. Social interactions facilitate knowledge transmission through group activities and unspoken behaviors, thus creating awareness of the environment and waste sorting activities. Social learning occurs by observing the conduct of others or through direct experience in a social learning system. Individuals practicing waste sorting behavior are more likely to influence others to sort waste and share knowledge about correct waste disposal methods and actions to facilitate recycling activities as well as reasons to sort waste. Some authors have suggested including policies and public campaigns by the government to create waste sorting capacity (Meng et al., 2019; Q. Wang et al., 2020). However, cultural and contextual factors seem to affect WSE awareness, and increasing people's awareness may require a long-term effort; in some cases, the results are not evident (Varotto and Spagnilli, 2017; Li et al., 2019). Similarly, children learn about waste sorting actions and consequences by observing their parents, and parental behavior is translated into recycling and WSE (Crociata et al., 2016; Liu et al., 2019; Knickmeyer, 2020). Ensuring there are individuals who sort waste and who lead campaigns in small communities will influence WSE in society.

5.2 Managerial implications

This study provides criteria that can engage, mobilize, and empower households toward better WSE. Separation knowledge (C22) is related to understanding the correct way to perform waste separation. In Ecuador, only 15.3% of waste collected was classified and sorted; public or private campaigns can result in the acquisition of separation knowledge, group experiences, family and friends who perform waste sorting, and improved waste sorting capacity. Campaigns should focus on identifying recyclable materials, such as metals, glass, paper, and different types of plastic. Based on trash bins or storage, materials should be organized with different colors that are coded at a national or regional level. Colors such as green, yellow, and gray have been used to identify and collect organic, recyclable plastic and nonrecyclable material, respectively. The existence of colored bins and visual cues near highly populated zones is necessary to increase knowledge. Separation knowledge must also be applied at the household level, and parents are urged to implement waste separation as part of their children's education. Schools and kindergartens have tried teaching students how to sort waste. An adequate strategy is to promote WSE among teachers, directors, and parents, as children learn and repeat based on observation rather than from theory. The correct application of knowledge achieves WSE; know-how is gained through public campaigns, family behavior, and even policies to reward correct waste separation.

Pro-environmental attitude (C2) concerns the decision-making process for protecting and helping the ecosystem, considering actions such as consumer preferences, for instance, acquiring ecological products and reducing consumption. Some individuals consciously behave to protect the environment; however, other individuals seem to be oblivious of their actions and their effect on the ecosystem. Currently, in the coastal region, 34.4% of people still throw away plastic bags and bottles; these individuals' decision-making has a significant impact on wildlife in oceans, forests, and even the most distant places on Earth. Before an individual takes a particular action, there is a deliberate debate over options, sometimes consciously analyzing the consequences, other times unconsciously making decisions. Additionally, postconsumer behavior and actions such as waste sorting and recycling should be considered. Pro-environmental decisions are enhanced by acquiring knowledge about the benefits and consequences of waste sorting and alternatives to dispose of waste. Cultivating the ability to choose from different disposal options to protect the environment through knowledge acquisition and individual benefits facilitates pro-environmental decisions and thus WSE.

In the coastal region, plastic recycling is part of a cognitive attitude, and the individual's needs directly influence the individual's willingness (C1). In this respect, needs such as safety, love and belonging, esteem, and self-actualization are drivers of sorting willingness. Safety is related to the appropriate use of forests, oceans, and land and thinking about the environment and the relationship to one's health. Love and belonging are related to communities, the creation of friendships and working networks that promote waste sorting activities and pro-environment activities and missions. Achievement and respect from others will earn respect for waste sorting as society acknowledges individuals who engage in waste sorting behavior. Identifying individual motivations, passion, experience, and recognition linked to the emotional level will also improve people's willingness to participate in waste sorting. Finally, self-actualization makes the maximum contribution of individuals to helping to solve waste sorting problems in their families and communities. Planning for private or public campaigns to increase WSE among citizens should consider targeting each of the needs described to increase WSE.

Individual social responsibility (C3) involves philanthropic, ethical, and legal frameworks in the community to protect others and the environment. Ecuadorian communities lack the mechanism to improve individual social responsibility; in 2018, 20% of solid waste was thrown into open dumps, gullies, and rivers. In the national constitution, efforts have been made to protect nature, including laws and the creation of governmental institutions that cultivate social responsibility among citizens, dictating legal and ethical frameworks. Social responsibility is passively achieved by avoiding actions that deteriorate the environment, such as throwing away waste and actively performing activities to directly enforce any given area. Social responsibility also involves the awareness of the effect of the actions of individuals and is obtained by addressing the knowledge gap in regard to waste sorting and environmental pollution. Self-perception practices also enhance the understanding of self-behavior and its effects on others and the environment, thus improving social responsibility. Similarly, empathy and emotional skills influence social responsibility, particularly in the ethical constitution. Therefore, building social responsibility through knowledge, actions, and empathy can improve WSE.

Trash bin arrangements (C10) enhance in situ waste classification, thus decreasing energy consumption, recycling costs, and waste sorting processes. Additionally, waste classification increases when trash bins are conveniently located for residents' access, associating trash bin arrangements with WSE. Currently, trash bin arrangements are lacking; for instance, in coastal regions, 84.3% of households are unaware of the existence of waste separation facilities. Hence, this implication focuses on trash bin arrangements in two contexts: indoors and outdoors. Indoor arrangements include knowledge of waste and recyclable materials; identifying materials makes it possible to determine the number of trash bins and the amount of storage space. Relocating trash bins to convenient locations in the kitchen or garden and easily identifying trash bins aids in waste classification at the source. Governments and municipalities can enhance WSE, for example, by subsidizing and discounting trash bins and by creating a community to share success stories and arrangement details. Outdoor arrangements require a deep understanding of residents' movement through public space and the waste composition in a particular community. Increasing accessibility and convenience while considering public space is challenging. An incorrect location on sidewalks and the wrong size may create discomfort for residents as they walk and work in their businesses, thus reducing the efficiency of classification.

6. Conclusion

Ecuador's continental region lacks waste collection and classification efficiency to promote policies to reduce, reuse, and recycle. Unclassified collection and disposal in landfills cause harmful effects on the environment. Landfills and disposal places are located in impoverished indigenous communities, exacerbating social and health impacts. Waste sorting engagement at the household level can mitigate the amount of waste thrown away and help waste management systems recycle and efficiently dispose of waste. Proper classification aids in the recycling process and reuse of material. In this study, five factors of WSE were analyzed: environmental attitudes, perceived convenience, social norms and interactions, economic drivers, and waste sorting capacity. This study applied a combined methodology using fuzzy set theory, the FDM, and FDEMATEL. Fuzzy set theory was used to translate respondents' linguistic preferences into TFNs to evaluate the factors of and criteria for WSE. The FDM was used to filter and obtain a valid list of criteria. FDEMATEL classified relationships among factors into effect and cause groups and identified the driving criteria for WSE.

This study validated 23 criteria covering five factors and contributed to the WSE literature by providing a valid hierarchical framework and the resulting significant attributes that must be addressed to improve waste separation in low- and middle-income households. The results show that waste sorting capacity results from environmental attitudes, perceived convenience, social norms and interactions, and economic factors. Perceived convenience and environmental attitudes have stronger relationships with waste sorting capacity. Additionally, perceived convenience affects environmental attitudes and waste classification facilities and improves people's position toward waste sorting. Previous studies have shown correlations among these factors; however, a clear cause-effect relationship has not been found. The empirical results indicate that perceived convenience affects environmental attitudes, which also affect waste sorting capacity. Thus, WSE is enhanced by addressing the causal attributes leading to waste sorting capacity.

The practical contributions of this study include the identification of five criteria as the most important due to their driving power and dependence values: separation knowledge, pro-environmental attitude, sorting willingness, social responsibility, and trash bin arrangements. Interactions with others can result in separation knowledge, publicity and education, and understanding the correct waste disposal practices can reduce friction and motivate people to classify waste. Pro-environmental decisions require knowledge of human actions, and the effect on the environment is an essential precursor to environmental pollution reduction. Sorting willingness affects WSE based on the necessity of acknowledgment, belonging, achievement, and self-education because as emotional beings, people focus on each need, which means that these needs may influence changes in and the maintenance of environmentally friendly behavior. Finally, self-awareness and knowledge of the impact of actions are drivers of social responsibility. Therefore, to enhance the driving power of the other criteria, addressing separation knowledge is practical. According to the two-way relationships just defined, addressing at least one side of a relationship will improve waste sorting; however, focusing on the correct criteria in the real-world context will enhance WSE. These attributes can enhance WSE and improve municipal waste management.

This study has some limitations. The proposed factors and criteria were extracted from the literature review, thus limiting the theoretical framework and its comprehensiveness. Future studies may include psychological, technological, and legal attributes to expand investigation of the interactions among the factors and criteria. The number of experts who participated was limited to 17; enlarging the sample size in future studies is recommended to avoid favoritism regarding experts' involvement in waste sorting and recycling activities and activism. Finally, this study applied FDM and FDEMATEL and relied on expert judgment, which might have biased the results because of the experts' experience, context, and knowledge. A longitudinal study and comparison among different countries in the Latin American region could enrich the literature, as the contextual factors are similar, making it possible to identify the key drivers of WSE in developing countries.

References

1. Araee, E., Manavizadeh, N., Bosjin A.S. 2020. Designing a multi-objective model for a hazardous waste routing problem considering flexibility of routes and social effects. *Journal of Industrial and Production Engineering*, 37(1), 33-45

2. Ajzen, I. 1991. The theory of planned behavior. Organizational Behavior and Human Decision Processes, 50 (2) 179-211
3. Bui, T. D., Tsai, F. M., Tseng, M. L., Ali, M. D. H. 2020. Identifying sustainable solid waste management barriers in practice using the fuzzy Delphi method. *Resources, Conservation and Recycling*, *154*, 104625.
4. Chen, L., Gao, M. 2020. A new learning interaction rule for municipal household waste classification behavior based on multi-agent-based simulation. *Journal of Cleaner Production*, *271*, 122654.
5. Chen, Z., Ming, X., Zhang, X., Yin, D., Sun, Z. 2019. A rough-fuzzy DEMATEL-ANP method for evaluating sustainable value requirement of product service system. *Journal of Cleaner Production*, *228*, 485–508.
6. *Constitución Política de la República del Ecuador (Political constitution of the Republic of Ecuador)*. 2008. Available from: https://www.oas.org/juridico/pdfs/mesicic4_ecu_const.pdf
7. Crociata, A., Agovino, M., Sacco, P. L. 2016. Neighborhood effects and pro-environmental behavior: The case of Italian separate waste collection. *Journal of Cleaner Production*, *135*, 80–89.
8. Dong, L., Fujita, T., Dai, M., Geng, Y., Ren, J., Fujii, M., Wang, Y., Ohnishi, S., 2016. Towards preventative eco-industrial development: an industrial and urban symbiosis case in one typical industrial city in China. *Journal of Cleaner Production*, 114, 387–400.
9. Eriksen, M. K., Christiansen, J. D., Daugaard, A. E., Astrup, T. F. 2019. Closing the loop for PET, PE and PP waste from households: Influence of material properties and product design for plastic recycling. *Waste Management*, *96*, 75–85.
10. Fan, B., Yang, W., Shen, X. 2019. A comparison study of 'motivation–intention–behavior' model on household solid waste sorting in China and Singapore. *Journal of Cleaner Production,* 211, 442-454
11. Feng, C., Ma, R. 2020. Identification of the factors that influence service innovation in manufacturing enterprises by using the fuzzy DEMATEL method. *Journal of Cleaner Production*, *253*, 120002.
12. Gholizadeh, H., Tajdin, A. 2019. Optimizing and evaluating performance quality control of the production process of disposable essentials using approach vague goal programming. *Journal of Industrial and Production Engineering* 36(4), 258-270
13. Grazhdani, D. 2016. Assessing the variables affecting on the rate of solid waste generation and recycling: An empirical analysis in Prespa Park. *Waste Management*, 48, 3–13.
14. Instituto Nacional de Estadística y Censos (INEC-National institute of stadistic and census), 2020 . https://www.ecuadorencifras.gob.ec/documentos/web-inec/Encuestas_Ambientales/Municipios_2018/Residuos_solidos_2018/Boletin_Tecnico_Residuos_2018.pdf
15. Knickmeyer, D. (2020). Social factors influencing household waste separation: A literature review on good practices to improve the recycling performance of urban areas. *Journal of Cleaner Production*, 245, 118605.
16. Lee, M., Choi, H., Koo, Y., 2017. Inconvenience cost of waste disposal behavior in South Korea. *Ecol. Econ.* 140, 58–65
17. Leeabai, N., Suzuki, S., Jiang, Q., Dilixiati, D., Takahashi, F. 2019. The effects of setting conditions of trash bins on waste collection performance and waste separation behaviors;

distance from walking path, separated setting, and arrangements. *Waste Management*, *94*, 58–67.

18. Li, Y., Xu, F., Zhao, X. 2017. Governance mechanisms of dual-channel reverse supply chains with informal collection channel. *Journal of Cleaner Production*, *155*, 125–140.
19. Lin, X., Ling, M., Lu, Y., Shen, M. 2017. Understanding Household Waste Separation Behaviour: Testing the Roles of Moral, Past Experience, and Perceived Policy Effectiveness within the Theory of Planned Behaviour. *Sustainability*, 9, 625
20. Lindbeck, A. 1997. Incentives and social norms in household behavior. American Economic Review 87 (2), 370–377
21. Liu, X., Wang, Z., Li, W., Li, G., Zhang, Y. 2019. Mechanisms of public education influencing waste classification willingness of urban residents. *Resources, Conservation & Recycling,* 149, 381-390
22. Meng X., Tan X., Wang Y., Wen Z., Tao Y. Qian Y. 2019. Investigation on decision-making mechanism of residents' household solid waste classification and recycling behaviors. *Resources, Conservation & Recycling*, 140, 224-234
23. Meng X., Wen, Z., Qian, Y. 2018. Multi-agent based simulation for household solid waste recycling behavior. *Resources, Conservation and Recycling*, 128, 535-545
24. Moreira B.,J.E., García C., F.A., Moran Q., M.L., Jama C., L.R., Lucio V.,L.F. 2021. Educación ambiental en la separación de desechos en la ciudad de Jipijapa (Environmental education in waste sorting in the Jipijapa city). *Revista Cientifica Multidisciplinaria*, 5, 121-134.
25. Negash, Y.T., Calahorrano S., L.S., Tseng, M.L., Jantarakolica, K., Tan, K. 2021. Sustainable product-service system hierarchical framework under uncertainties: The pharmaceutical industry in Ecuador. *Journal of Cleaner Production*, 294, 126188.
26. Ofstad, S.P., Tobolova, M., Nayum, A., Kl€ockner, C.A., 2017. Understanding the mechanisms behind changing people's recycling behavior at work by applying a comprehensive action determination model. *Sustainability,* 9 (2), 1e17.
27. Passafaro, P., Livi, S. 2017. Comparing determinants of perceived and actual recycling skills: The role of motivational, behavioral and dispositional factors. *The Journal of Environmental Education,* 48(5), 347-356.
28. Pedersen, J. T. S., Manhice, H. 2020. The hidden dynamics of household waste separation: An anthropological analysis of user commitment, barriers, and the gaps between a waste system and its users. *Journal of Cleaner Production*, 242.
29. Pei, Z. 2019. Roles of neighborhood ties, community attachment and local identity in residents' household waste recycling intention. *Journal of Cleaner Production*, *241*, 118217.
30. Pincay, M., Garcpia B., S., Cevallos, S., Mite, M., Romo, M. 2018. Actitudes y comportamientos ecológicos de consumidores adultos guayaquileños de clase media (Environmental attitudes and behavior of Guayaquil's middle-class adults). *Revista Tecnológica ESPOL, 31 (1), 53-66.*
31. Ragaert, K., Delva, L., Geem, K., 2017. Mechanical and chemical recycling of solid plastic waste. *Waste Manage*, 69, 24-58.
32. Razali, F., Daud, D., Weng-Wai, C., Anthony Jiram, W. R. 2020. Waste separation at source behaviour among Malaysian households: The Theory of Planned Behaviour with moral norm. *Journal of Cleaner Production*, *271*, 122025.

33. Schanes, K., Dobernig, K., Gözet, B. 2018. Food waste matters - A systematic review of household food waste practices and their policy implications. *Journal of Cleaner Production*, *182*, 978–991.
34. Shan, X., Ang, W. L., Yang, E. H. (2020). Mobile app-aided risks, attitudes, norms, abilities and self-regulation (RANAS) approach for recycling behavioral change in Singapore. *Resources, Conservation and Recycling*, *162*, 105049.
35. Solíz T., M.F., Yépez F., M.A. Ecuador: transitar del enterramiento de residuos a Basura Cero. (Ecuador: transit from waste burial to zero waste). In J.M. Simon (Ed.) Basura Cero. Editoral Kaicron SL, Malaga.
36. The World Bank. 2020. What a waste 2.0: Trends in Solid Waste Management. Available from: https://datatopics.worldbank.org/what-a-waste/trends_in_solid_waste_management.html#:~:text=The%20world%20generates%202.01%20billion,from%200.11%20to%204.54%20kilograms.
37. Tsai, F.M., Bui, T.D., Tseng, M.L., Wu, K.J., Chiu, A.SF. 2020. A performance assessment approach for integrated solid waste management using a sustainable balanced scorecard approach. *Journal of Cleaner Production,* 251, 119740
38. Tseng, M. L., Lin, S., Chen, C. C., Calahorrano S., L. S., Tan, C. L. 2019. A causal sustainable product-service system using hierarchical structure with linguistic preferences in the Ecuadorian construction industry. *Journal of Cleaner Production*, *230*, 477–487.
39. Tseng, M. L., Wu, K. J., Chiu, A. S., Lim, M. K., Tan, K. 2018. Service innovation in sustainable product service systems: Improving performance under linguistic preferences. International Journal of Production Economics, 203, 414–425.
40. Tseng, M.L., Tran, T.P.T., Ha, M.H., Bui, T.D. & Lim, M.K. 2021. Sustainable industrial and operation engineering trends and challenges Toward Industry 4.0: a data driven analysis, *Journal of Industrial and Production Engineering*, DOI: 10.1080/21681015.2021.1950227
41. Vaccari, M., Tudor, T., Vinti, G. 2019. Characteristics of leachate from landfills and dumpsites in Asia, Africa and Latin America: an overview. *Waste Management*, *95*, 416–431
42. Varotto, A., Spagnolli, A. 2017. Psychological strategies to promote household recycling. A systematic review with meta-analysis of validated field interventions. *Journal of Environmental Psychology*, *51*, 168–188
43. Wang, Z., Dong, X., Yin, J. 2018. Antecedents of urban residents' separate collection intentions for household solid waste and their willingness to pay: Evidence from China. *Journal of Cleaner Production*, *173*, 256–264.
44. Wang, Z., Wang, Q., Chen, B., Wang, Y. 2020. Evolutionary game analysis on behavioral strategies of multiple stakeholders in E-waste recycling industry. *Resources, Conservation and Recycling*, *155*, 104618.
45. Wang, Q., Long, X., Li, L., Kong, L., Zhu, X., Liang, H. 2020a. Engagement factors for waste sorting in China: The mediating effect of satisfaction. *Journal of Cleaner Production*, *267*, 122046.
46. Xu, L., Ling, M., & Wu, Y. 2018. Economic incentive and social influence to overcome household waste separation dilemma: A field intervention study. *Waste management*, *77*, 522-531.

47. Xu, L., Ling, M., Lu, Y., Shen, M. 2017. Understanding household waste separation behaviour: Testing the roles of moral, past experience, and perceived policy effectiveness within the theory of planned behaviour. *Sustainability*, *9, 625.*
48. Yuan, Y., Nomura, H., Takahashi, Y., Yabe, M. 2016. Model of Chinese household kitchen waste separation behavior: A case study in Beijing city. *Sustainability*, 8(10), 1083.
49. Zhang, B., Lai, K., Wang, B., Wang, Z. 2019. From intention to action: How do personal attitudes, facilities accessibility, and government stimulus matter for household waste sorting?. *Journal of Environmental Management,* 233, 447-458
50. Zhang, B., Lai, K.H., Wang, B., Wang, Z., 2018. Financial *benefits* from corporate announced practice of industrial waste recycling: empirical evidence from chemical industry in China. *Resource Conservation and Recycling,* 139, 40-47
51. Zhang, S., Zhang, M., Yu, X., Ren, H., 2016. What keeps Chinese from recycling: accessibility of recycling facilities and the behavior. *Resources Conservation & Recycling*, 109, 176–186

Table 1. Linguistic scales

Importance	FTN
Extreme	(0.75, 1.00, 1.00)
Demonstrated	(0.50, 0.75, 1.00)
Strong	(0.25, 0.50, 0.75)
Moderate	(0.00, 0.25, 0.50)
Equal	(0.00, 0.00, 0.25)

Table 2. Expert's profile

Expert Description	Experience in waste sorting (years)	Number of experts
Community Leader	6 – 30	4
Environmental Engineer	5 – 6	3
Environmental Science Professor	5 – 20	3
Environmental Activist	7 – 18	4
Recycler	6 – 19	3
Total		17

Table 3. FDM results

Factor	Valid criteria	l_b	u_b	D_b	Decision
A1: Environmental attitudes	C1: Sorting willingness	(0.0590)	0.9340	0.4523	Accepted
	C2: Pro-environment decisions	(0.0433)	0.9183	0.4483	Accepted
	C3: Social responsibility	(0.0036)	0.8786	0.4384	Accepted
A2: Perceived convenience	C4: Time spent	(0.0159)	0.8909	0.4415	Accepted
	C5: House storage space	(0.0118)	0.8868	0.4404	Accepted
	C6: Abundant rubbish bins	0.0157	0.8593	0.4336	Accepted
	C7: Waste sorting complexity perception	0.0157	0.8593	0.4336	Accepted
	C8: Recycling facilities accessibility	(0.0118)	0.8868	0.4404	Accepted
	C9: Facilities appearance	(0.0590)	0.9340	0.4523	Accepted
	C10: Trash bin arrangement	0.0212	0.8538	0.4322	Accepted
A3: Social norms and interactions	C11: Family waste separation	(0.0076)	0.8826	0.4394	Accepted
	C12: Friends and colleges waste separation	0.0157	0.8593	0.4336	Accepted
	C13: Social media influence	0.0549	0.8201	0.4238	Accepted
	C14: Neighborhood ties	0.0212	0.8538	0.4322	Accepted
	C15: Community attachment	0.0287	0.8463	0.4303	Accepted
	C16: Waste cosorting	(0.0325)	0.9075	0.4456	Accepted
A4: Economic drivers	C17: Cost-saving	(0.0036)	0.8786	0.4384	Accepted
	C18: Waste disposal fee	(0.0076)	0.8826	0.4394	Accepted
A5: Waste sorting capacity	C19: Materials and pollutants knowledge	(0.0220)	0.8970	0.4430	Accepted
	C20: Environmental pollution reduction	(0.0590)	0.9340	0.4523	Accepted
	C21: Environmental literacy	(0.0705)	0.9455	0.4551	Accepted
	C22: Waste and separation knowledge	(0.0178)	0.8928	0.4419	Accepted
	C23: Recycled consumption	(0.0220)	0.8970	0.4430	Accepted
Threshold (γ)				0.4189	

Table 4: Total interrelationship matrix of aspects

	A1	A2	A3	A4	A5	D
A1	3.612	3.457	3.090	3.099	3.617	16.875
A2	3.271	3.374	2.863	2.939	3.390	15.837
A3	3.130	3.094	2.742	2.795	3.188	14.949
A4	3.072	3.045	2.686	2.891	3.159	14.854
A5	3.844	3.767	3.345	3.352	3.961	18.270
R	16.931	16.736	14.726	15.075	17.315	

Table 5. Aspect’s relation and prominence axis

Aspect	D	R	D + R	D – R
A1	16.875	16.931	33.806	0.056
A2	15.837	16.736	32.573	0.900
A3	14.949	14.726	29.675	(0.222)
A4	14.854	15.075	29.929	0.221
A5	18.270	17.315	35.584	(0.955)
Max			35.584	0.900
Min			29.675	(0.955)
Average			32.314	0.000

Table 6: Total Interrelationship Matrix of Criteria

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20	C21	C22	C23	D
C1	0.32	0.31	0.28	0.28	0.27	0.27	0.28	0.27	0.26	0.30	0.28	0.26	0.28	0.26	0.27	0.28	0.27	0.25	0.32	0.34	0.32	0.32	0.28	6.56
C2	0.31	0.32	0.28	0.28	0.27	0.28	0.28	0.27	0.26	0.30	0.28	0.26	0.28	0.25	0.27	0.29	0.26	0.25	0.31	0.34	0.32	0.33	0.28	6.58
C3	0.30	0.30	0.30	0.28	0.27	0.27	0.28	0.27	0.27	0.29	0.27	0.26	0.28	0.25	0.28	0.29	0.26	0.25	0.32	0.34	0.32	0.32	0.29	6.58
C4	0.28	0.28	0.26	0.29	0.25	0.25	0.26	0.25	0.24	0.26	0.25	0.23	0.26	0.23	0.24	0.26	0.24	0.22	0.29	0.30	0.29	0.29	0.26	5.98
C5	0.28	0.27	0.25	0.25	0.28	0.25	0.25	0.25	0.24	0.27	0.24	0.23	0.25	0.23	0.24	0.26	0.24	0.22	0.29	0.30	0.28	0.29	0.25	5.93
C6	0.27	0.28	0.25	0.26	0.26	0.29	0.26	0.25	0.25	0.28	0.24	0.23	0.25	0.23	0.25	0.26	0.25	0.23	0.29	0.31	0.29	0.29	0.25	6.02
C7	0.27	0.26	0.24	0.25	0.24	0.25	0.28	0.24	0.24	0.26	0.23	0.22	0.25	0.22	0.23	0.25	0.24	0.22	0.28	0.29	0.27	0.28	0.24	5.77
C8	0.27	0.27	0.25	0.26	0.26	0.26	0.26	0.28	0.25	0.28	0.24	0.23	0.26	0.23	0.24	0.27	0.24	0.22	0.29	0.30	0.28	0.29	0.25	5.97
C9	0.27	0.26	0.25	0.26	0.25	0.26	0.26	0.26	0.27	0.27	0.24	0.24	0.26	0.24	0.25	0.26	0.24	0.22	0.29	0.30	0.28	0.29	0.25	5.97
C10	0.29	0.29	0.27	0.28	0.28	0.28	0.28	0.27	0.26	0.31	0.26	0.25	0.28	0.25	0.26	0.29	0.26	0.24	0.31	0.33	0.30	0.31	0.27	6.43
C11	0.28	0.28	0.26	0.26	0.26	0.26	0.26	0.25	0.25	0.27	0.28	0.24	0.26	0.24	0.25	0.26	0.25	0.23	0.28	0.31	0.29	0.29	0.26	6.06
C12	0.25	0.25	0.24	0.24	0.24	0.24	0.24	0.23	0.23	0.25	0.23	0.25	0.25	0.22	0.23	0.24	0.23	0.21	0.26	0.29	0.27	0.27	0.24	5.60
C13	0.27	0.27	0.25	0.24	0.25	0.25	0.25	0.25	0.24	0.27	0.24	0.23	0.28	0.23	0.24	0.26	0.23	0.22	0.28	0.30	0.28	0.29	0.26	5.89
C14	0.26	0.26	0.24	0.24	0.24	0.25	0.24	0.23	0.23	0.26	0.23	0.23	0.25	0.25	0.24	0.25	0.23	0.21	0.27	0.29	0.27	0.28	0.24	5.70
C15	0.26	0.26	0.24	0.24	0.24	0.25	0.24	0.24	0.23	0.26	0.23	0.23	0.24	0.22	0.26	0.25	0.23	0.21	0.27	0.29	0.28	0.28	0.24	5.69
C16	0.26	0.25	0.24	0.24	0.23	0.24	0.24	0.24	0.23	0.26	0.23	0.22	0.24	0.22	0.23	0.28	0.22	0.21	0.27	0.29	0.27	0.27	0.24	5.63
C17	0.28	0.28	0.26	0.27	0.26	0.27	0.26	0.26	0.25	0.28	0.25	0.25	0.27	0.24	0.25	0.27	0.28	0.24	0.30	0.32	0.30	0.30	0.27	6.21
C18	0.25	0.24	0.23	0.24	0.23	0.24	0.23	0.22	0.23	0.25	0.22	0.21	0.24	0.21	0.22	0.24	0.22	0.24	0.26	0.28	0.26	0.27	0.23	5.47
C19	0.30	0.30	0.28	0.28	0.28	0.28	0.29	0.28	0.27	0.30	0.26	0.26	0.28	0.25	0.26	0.29	0.27	0.25	0.33	0.33	0.32	0.32	0.28	6.54
C20	0.33	0.33	0.31	0.31	0.30	0.31	0.31	0.30	0.29	0.33	0.29	0.29	0.31	0.28	0.30	0.32	0.29	0.27	0.34	0.38	0.34	0.35	0.31	7.19
C21	0.31	0.31	0.29	0.29	0.28	0.28	0.29	0.28	0.27	0.30	0.28	0.27	0.29	0.26	0.27	0.29	0.28	0.25	0.32	0.34	0.34	0.33	0.29	6.71
C22	0.33	0.33	0.31	0.30	0.30	0.30	0.31	0.29	0.28	0.32	0.29	0.29	0.31	0.28	0.29	0.31	0.29	0.27	0.34	0.36	0.34	0.36	0.31	7.10
C23	0.28	0.28	0.26	0.26	0.25	0.25	0.25	0.24	0.24	0.26	0.25	0.24	0.26	0.23	0.24	0.26	0.24	0.22	0.28	0.30	0.28	0.29	0.28	5.92
R	6.50	6.48	6.05	6.10	5.98	6.07	6.11	5.92	5.77	6.44	5.83	5.61	6.14	5.54	5.83	6.22	5.76	5.36	6.81	7.23	6.79	6.90	6.07	

Table 7. Criteria's relation and prominence axis

Criteria	D	R	D + R	D – R
C1	6.5604	6.5048	13.0652	0.0556
C2	6.5833	6.4785	13.0617	0.1048
C3	6.5785	6.0511	12.6297	0.5274
C4	5.9827	6.1002	12.0829	(0.1175)
C5	5.9289	5.9799	11.9088	(0.0510)
C6	6.0231	6.0657	12.0888	(0.0426)
C7	5.7731	6.1054	11.8786	(0.3323)
C8	5.9671	5.9162	11.8833	0.0509
C9	5.9694	5.7749	11.7443	0.1945
C10	6.4294	6.4357	12.8650	(0.0063)
C11	6.0644	5.8267	11.8911	0.2377
C12	5.6024	5.6123	11.2147	(0.0099)
C13	5.8937	6.1368	12.0305	(0.2430)
C14	5.6961	5.5423	11.2384	0.1537
C15	5.6894	5.8296	11.5189	(0.1402)
C16	5.6338	6.2239	11.8577	(0.5901)
C17	6.2131	5.7636	11.9767	0.4496
C18	5.4683	5.3628	10.8311	0.1055
C19	6.5373	6.8099	13.3472	(0.2726)
C20	7.1897	7.2302	14.4199	(0.0405)
C21	6.7064	6.7864	13.4929	(0.0800)
C22	7.1016	6.8993	14.0009	0.2023
C23	5.9172	6.0732	11.9904	(0.1560)
Max			14.4199	0.5274
Min			10.8311	(0.5901)
Average			12.3052	0.0000

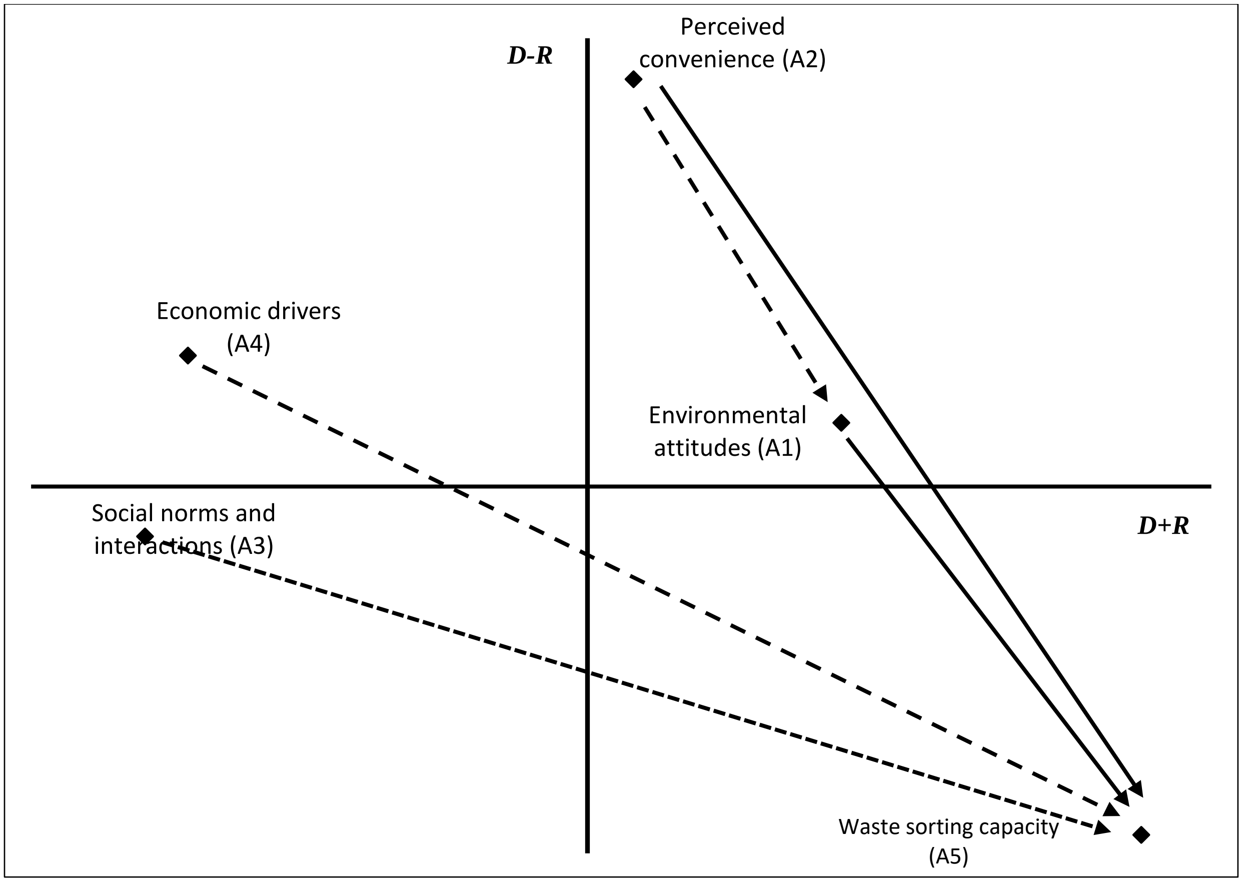

Figure 1. Causal effect interrelationship of aspects

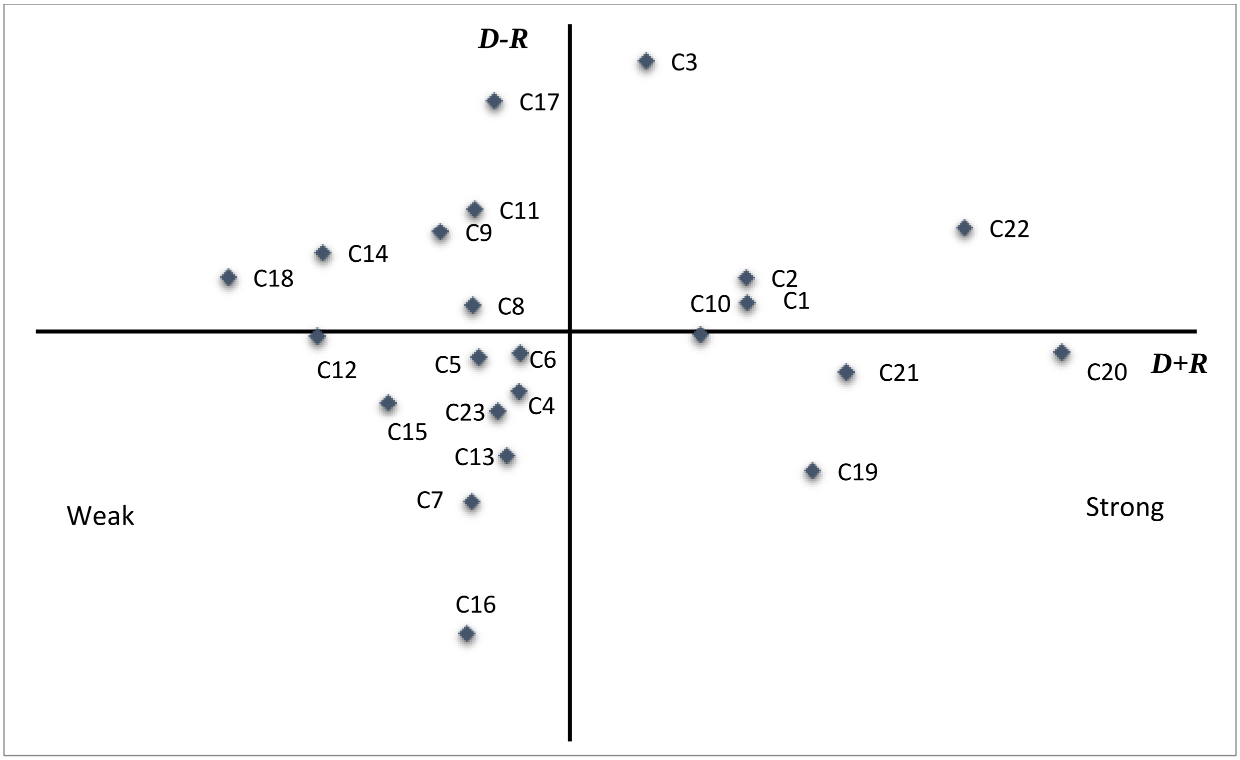

Figure 2. Waste sorting engagement criteria

Appendix 1. List of proposed criteria

Criteria		References
IC1	Sorting willingness	Meng et al., 2019; Wang et al., 2020a; Liu et al., 2019
IC2	Pro-environment	Meng et al., 2019; Wang et al., 2020b; Chen and Gao, 2020; Shan et al, 2020
IC3	Example to others	Lin et al., 2017
IC4	Social responsibility	Liu et al., 2019; Meng et al., 2019
IC5	Time spent	Liu et al., 2018; Meng et al., 2019; Chen and Gao, 2020; Meng et al., 2018
IC6	House storage space	Liu et al., 2018; Meng et al., 2019
IC7	Abundant rubbish bins	Liu et al., 2019
IC8	Waste sorting complexity	Passafaro and Livi, 2017
IC9	Recycling facilities accessibility	Meng et al., 2019; Zhang et al., 2019; Fan et al., 2019
IC10	Facilities appearance	Miller et al., 2016; Leebai et al., 2019; Knickmeyer, 2020
IC11	Trash bin arrangement	Leebai et al., 2019
IC12	Waste collection distance	Erfani et al., 2017; Leebai et al., 2019; Chen and Gao, 2020
IC13	Product packaging	Schanes et al., 2018
IC14	Family waste separation	Lin et al., 2017; Liu et al., 2019; Sujata et al., 2019
IC15	Friends and colleges waste separation	Lin et al., 2017; Liu et al., 2019; Chen and Gao, 2020
IC16	Community support	Lin et al., 2017; Meng et al., 2018; Liu et al., 2019; Chen and Gao, 2020
IC17	Recycling website	Sujata et al., 2019
IC18	Video recycling events	Sujata et al., 2019
IC19	Recycling activities statement	Sujata et al., 2019
IC20	Mobile apps	Knickmeyer, 2020
IC21	Social media influence	Sujata et al., 2019
IC22	Neighborhood ties	Crociata et al., 2016; Pei, 2019
IC23	Community attachment	Crociata et al., 2016; Pei, 2019
IC24	Waste cosorting	Wang et al., 2020a
IC25	Cost-saving	Meng et al., 2019; Meng et al., 2018
IC26	Waste sorting remuneration	Lin et al., 2017
IC27	Garbage disposal fee	Meng et al., 2018
IC28	Formal collector	Li et al., 2017; Wang et al., 2020b
IC29	Informal collector	Li et al., 2017; Wang et al., 2020b
IC30	Recyclers separation	Fan et al., 2019
IC31	Recyclers mess up	Fan et al., 2019
IC32	Recyclers interest	Fan et al., 2019
IC33	Environmental publicity	Meng et al., 2019; Meng et al., 2018; Zhang et al., 2019
IC34	Organization encouragement	Lin et al., 2017; Liu et al., 2019
IC35	Environmental organization encouragement	Lin et al., 2017; Sujata et al., 2019
IC36	Separation campaigns	Lin et al., 2017
IC37	Government waste laws and regulations	Lin et al., 2017; Meng et al., 2018; Chen and Gao, 2020
IC38	Government reward policies	Meng et al., 2018; Liu et al., 2019; Zhang et al., 2019; Chen and Gao, 2020
IC39	Government punishment policies	Liu et al., 2019
IC40	Pollution control cost	Lin et al., 2017
IC41	Environmental education	Grazhdani, 2016; Meng et al., 2019; Meng et al., 2018
IC42	Waste separation information	Liu et al., 2019
IC43	Facilities trust	Crociata et al., 2016
IC44	Disposal information	Passafaro and Livi, 2017; Fan et al., 2019
IC45	Facilities management	Fan et al., 2019
IC46	Waste disposal facility	Wang et al., 2020a
IC47	Environmental cost	Chen and Gao, 2020
IC48	Environmental pollution reduction	Wang et al., 2020a
IC49	Environmental literacy	Meng et al., 2019; Wang et al., 2020a
IC50	Waste and separation knowledge	Meng et al., 2019; Lin et al., 2017; Liu et al., 2019; Chen and Gao, 2020
IC51	Recycled consumption	Sujata et al., 2019

Appendix 2. Round - 1 FDM results

	l	u	D_b	Decision
IC1	(0.4075)	0.9075	0.3519	Accepted
IC2	(0.0433)	0.9183	0.4483	Accepted
IC3	0.0000	0.5000	0.2500	Unaccepted
IC4	(0.3555)	0.8555	0.3389	Accepted
IC5	(0.3671)	0.8671	0.3418	Accepted
IC6	(0.3410)	0.8410	0.3352	Accepted
IC7	0.0157	0.8593	0.4336	Accepted
IC8	(0.3373)	0.8373	0.3343	Accepted
IC9	(0.3631)	0.8631	0.3408	Accepted
IC10	(0.4075)	0.9075	0.3519	Accepted
IC11	0.0212	0.8538	0.4322	Accepted
IC12	0.0000	0.5000	0.2500	Unaccepted
IC13	0.0000	0.5000	0.2500	Unaccepted
IC14	(0.3593)	0.8593	0.3398	Accepted
IC15	(0.2373)	0.7373	0.3093	Unaccepted
IC16	(0.2373)	0.7373	0.3093	Unaccepted
IC17	(0.2373)	0.7373	0.3093	Unaccepted
IC18	0.0000	0.5000	0.2500	Unaccepted
IC19	(0.2527)	0.7527	0.3132	Unaccepted
IC20	0.0000	0.5000	0.2500	Unaccepted
IC21	(0.3167)	0.8167	0.3292	Accepted
IC22	(0.2822)	0.7822	0.3206	Accepted
IC23	(0.3119)	0.8119	0.3280	Accepted
IC24	(0.3053)	0.8053	0.3263	Accepted
IC25	(0.3826)	0.8826	0.3457	Accepted
IC26	0.0000	0.5000	0.2500	Unaccepted
IC27	(0.3337)	0.8337	0.3334	Accepted
IC28	(0.3500)	0.8500	0.3375	Accepted
IC29	0.0000	0.5000	0.2500	Unaccepted
IC30	(0.2622)	0.7622	0.3155	Accepted
IC31	0.0000	0.5000	0.2500	Unaccepted
IC32	(0.3337)	0.8337	0.3334	Accepted
IC33	(0.3373)	0.8373	0.3343	Accepted
IC34	0.0000	0.5000	0.2500	Unaccepted
IC35	0.0000	0.5000	0.2500	Unaccepted
IC36	0.0000	0.5000	0.2500	Unaccepted
IC37	(0.4032)	0.9032	0.3508	Accepted
IC38	(0.3688)	0.8688	0.3422	Accepted
IC39	0.0000	0.5000	0.2500	Unaccepted
IC40	(0.3500)	0.8500	0.3375	Accepted
IC41	0.0000	0.5000	0.2500	Unaccepted
IC42	0.0000	0.5000	0.2500	Unaccepted
IC43	0.0000	0.5000	0.2500	Unaccepted
IC44	0.0000	0.5000	0.2500	Unaccepted
IC45	0.0000	0.5000	0.2500	Unaccepted
IC46	0.0000	0.5000	0.2500	Unaccepted
IC47	(0.3728)	0.8728	0.3432	Accepted
IC48	(0.4075)	0.9075	0.3519	Accepted
IC49	(0.0705)	0.9455	0.4551	Accepted
IC50	(0.3688)	0.8688	0.3422	Accepted
IC51	(0.0220)	0.8970	0.4430	Accepted
Threshold (γ)			0.3149	

Appendix 3. Round - 2 FDM results

	l	u	D_b	Decision
IC1	(0.0590)	0.9340	0.4523	Accepted
IC2	(0.0433)	0.9183	0.4483	Accepted
IC4	(0.0036)	0.8786	0.4384	Accepted
IC5	(0.0159)	0.8909	0.4415	Accepted
IC6	(0.0118)	0.8868	0.4404	Accepted
IC7	0.0157	0.8593	0.4336	Accepted
IC8	0.0157	0.8593	0.4336	Accepted
IC9	(0.0118)	0.8868	0.4404	Accepted
IC10	(0.0590)	0.9340	0.4523	Accepted
IC11	0.0212	0.8538	0.4322	Accepted
IC14	(0.0076)	0.8826	0.4394	Accepted
IC21	0.0157	0.8593	0.4336	Accepted
IC22	0.0549	0.8201	0.4238	Accepted
IC23	0.0212	0.8538	0.4322	Accepted
IC24	0.0287	0.8463	0.4303	Accepted
IC25	(0.0325)	0.9075	0.4456	Accepted
IC27	(0.0036)	0.8786	0.4384	Accepted
IC28	(0.3500)	0.8500	0.3375	Unaccepted
IC30	(0.2622)	0.7622	0.3155	Unaccepted
IC32	(0.3337)	0.8337	0.3334	Unaccepted
IC33	(0.0076)	0.8826	0.4394	Accepted
IC37	(0.4032)	0.9032	0.3508	Unaccepted
IC38	(0.3688)	0.8688	0.3422	Unaccepted
IC40	(0.3500)	0.8500	0.3375	Unaccepted
IC47	(0.0220)	0.8970	0.4430	Accepted
IC48	(0.0590)	0.9340	0.4523	Accepted
IC49	(0.0705)	0.9455	0.4551	Accepted
IC50	(0.0178)	0.8928	0.4419	Accepted
IC51	(0.0220)	0.8970	0.4430	Accepted
Threshold (γ)			0.4189	

Appendix 4. Aspect's directional matrix and defuzzied from Respondent 1

	$[sz^1_{A1l}$	sz^1_{A1m}	$sz^1_{A1u}]$	$[sz^1_{A2l}$	sz^1_{A2m}	$sz^1_{A2u}]$	$[sz^1_{A3l}$	sz^1_{A3m}	$sz^1_{A3u}]$	$[sz^1_{A4l}$	sz^1_{A4m}	$sz^1_{A4u}]$	$[sz^1_{A5l}$	sz^1_{A5m}	$sz^1_{A5u}]$
A1	[1.000	0.714	0.429]	[0.000	0.000	0.000]	[0.286	0.000	0.286]	[0.000	0.000	0.000]	[0.400	0.400	0.200]
A2	[0.286	0.286	0.286]	[1.000	0.714	0.429]	[0.286	0.000	0.286]	[0.286	0.286	0.286]	[0.400	0.400	0.200]
A3	[0.000	0.000	0.000]	[0.000	0.000	0.000]	[1.000	0.000	0.429]	[0.286	0.286	0.286]	[0.400	0.400	0.200]
A4	[0.000	0.000	0.000]	[0.286	0.286	0.286]	[0.000	0.000	0.000]	[1.000	0.714	0.429]	[0.000	0.000	0.000]
A5	[0.286	0.286	0.286]	[0.571	0.571	0.429]	[0.286	0.000	0.286]	[0.286	0.286	0.286]	[1.000	0.600	0.200]
	S^1_{ltA1}	S^1_{rtA1}		S^1_{ltA2}	S^1_{rtA2}		S^1_{ltA3}	S^1_{rtA3}		S^1_{ltA4}	S^1_{rtA4}		S^1_{ltA5}	S^1_{rtA5}	
A1	1.000	0.600		0.000	0.000		0.000	0.222		0.000	0.000		0.400	0.250	
A2	0.286	0.286		1.000	0.600		0.000	0.222		0.286	0.286		0.400	0.250	
A3	0.000	0.000		0.000	0.000		0.000	0.300		0.286	0.286		0.400	0.250	
A4	0.000	0.000		0.286	0.286		0.000	0.000		1.000	0.600		0.000	0.000	
A5	0.286	0.286		0.571	0.500		0.000	0.222		0.286	0.286		1.000	0.333	
	S^1_{A1}			S^1_{A2}			S^1_{A3}			S^1_{A4}			S^1_{A5}		
A1	0.600			0.000			0.040			0.000			0.356		
A2	0.286			0.600			0.040			0.286			0.356		
A3	0.000			0.000			0.069			0.286			0.356		
A4	0.000			0.286			0.000			0.600			0.000		
A5	0.286			0.533			0.040			0.286			0.333		

Appendix 5. TFNs matrix of Respondent 1

	C1			C2			C3			C4			C5			C6			C7			C8			…	C23		
	(x	y	z)	(x	y	z)	(x	y	z)	(x	y	z)	(x	y	z)	(x	y	z)	(x	y	z)	(x	y	z)	…	(x	y	z)
C1	1.0	1.0	1.0	0.7	0.9	1.0	0.5	0.7	0.9	0.7	0.9	1.0	0.7	0.9	1.0	0.5	0.7	0.9	0.7	0.9	1.0	0.7	0.9	1.0	…	0.0	0.1	0.3
C2	0.7	0.9	1.0	1.0	1.0	1.0	0.5	0.7	0.9	0.5	0.7	0.9	0.5	0.7	0.9	0.5	0.7	0.9	0.5	0.7	0.9	0.5	0.7	0.9	…	0.0	0.1	0.3
C3	0.7	0.9	1.0	0.5	0.7	0.9	1.0	1.0	1.0	0.5	0.7	0.9	0.5	0.7	0.9	0.3	0.5	0.7	0.5	0.7	0.9	0.7	0.9	1.0	…	0.1	0.3	0.5
C4	0.7	0.9	1.0	0.5	0.7	0.9	0.3	0.5	0.7	1.0	1.0	1.0	0.5	0.7	0.9	0.3	0.5	0.7	0.7	0.9	1.0	0.5	0.7	0.9	…	0.1	0.3	0.5
C5	0.5	0.7	0.9	0.5	0.7	0.9	0.5	0.7	0.9	0.5	0.7	0.9	1.0	1.0	1.0	0.3	0.5	0.7	0.5	0.7	0.9	0.3	0.5	0.7	…	0.0	0.1	0.3
C6	0.7	0.9	1.0	0.5	0.7	0.9	0.3	0.5	0.7	0.3	0.5	0.7	0.5	0.7	0.9	1.0	1.0	1.0	0.3	0.5	0.7	0.3	0.5	0.7	…	0.0	0.1	0.3
C7	0.7	0.9	1.0	0.7	0.9	1.0	0.5	0.7	0.9	0.7	0.9	1.0	0.5	0.7	0.9	0.5	0.7	0.9	1.0	1.0	1.0	0.5	0.7	0.9	…	0.3	0.5	0.7
C8	0.7	0.9	1.0	0.7	0.9	1.0	0.7	0.9	1.0	0.7	0.9	1.0	0.7	0.9	1.0	0.5	0.7	0.9	0.7	0.9	1.0	1.0	1.0	1.0	…	0.3	0.5	0.7
C9	0.5	0.7	0.9	0.5	0.7	0.9	0.5	0.7	0.9	0.5	0.7	0.9	0.3	0.5	0.7	0.3	0.5	0.7	0.3	0.5	0.7	0.3	0.5	0.7	…	0.1	0.3	0.5
C10	0.7	0.9	1.0	0.7	0.9	1.0	0.7	0.9	1.0	0.5	0.7	0.9	0.5	0.7	0.9	0.5	0.7	0.9	0.5	0.7	0.9	0.5	0.7	0.9	…	0.3	0.5	0.7
C11	0.7	0.9	1.0	0.7	0.9	1.0	0.5	0.7	0.9	0.5	0.7	0.9	0.5	0.7	0.9	0.3	0.5	0.7	0.7	0.9	1.0	0.7	0.9	1.0	…	0.1	0.3	0.5
C12	0.5	0.7	0.9	0.5	0.7	0.9	0.3	0.5	0.7	0.3	0.5	0.7	0.3	0.5	0.7	0.1	0.3	0.5	0.5	0.7	0.9	0.3	0.5	0.7	…	0.1	0.3	0.5
C13	0.7	0.9	1.0	0.5	0.7	0.9	0.5	0.7	0.9	0.5	0.7	0.9	0.3	0.5	0.7	0.3	0.5	0.7	0.7	0.9	1.0	0.5	0.7	0.9	…	0.5	0.7	0.9
C14	0.5	0.7	0.9	0.3	0.5	0.7	0.3	0.5	0.7	0.1	0.3	0.5	0.1	0.3	0.5	0.5	0.7	0.9	0.3	0.5	0.7	0.3	0.5	0.7	…	0.0	0.1	0.3
C15	0.5	0.7	0.9	0.3	0.5	0.7	0.1	0.3	0.5	0.1	0.3	0.5	0.1	0.3	0.5	0.3	0.5	0.7	0.3	0.5	0.7	0.3	0.5	0.7	…	0.1	0.3	0.5
C16	0.3	0.5	0.7	0.3	0.5	0.7	0.3	0.5	0.7	0.3	0.5	0.7	0.3	0.5	0.7	0.3	0.5	0.7	0.7	0.9	1.0	0.7	0.9	1.0	…	0.0	0.1	0.3
C17	0.5	0.7	0.9	0.5	0.7	0.9	0.3	0.5	0.7	0.3	0.5	0.7	0.3	0.5	0.7	0.5	0.7	0.9	0.3	0.5	0.7	0.3	0.5	0.7	…	0.0	0.1	0.3
C18	0.1	0.3	0.5	0.1	0.3	0.5	0.1	0.3	0.5	0.1	0.3	0.5	0.1	0.3	0.5	0.1	0.3	0.5	0.0	0.1	0.3	0.0	0.1	0.3	…	0.0	0.1	0.3
C19	0.3	0.5	0.7	0.5	0.7	0.9	0.5	0.7	0.9	0.3	0.5	0.7	0.5	0.7	0.9	0.5	0.7	0.9	0.3	0.5	0.7	0.3	0.5	0.7	…	0.1	0.3	0.5
C20	0.7	0.9	1.0	0.5	0.7	0.9	0.7	0.9	1.0	0.7	0.9	1.0	0.5	0.7	0.9	0.5	0.7	0.9	0.7	0.9	1.0	0.7	0.9	1.0	…	0.3	0.5	0.7
C21	0.7	0.9	1.0	0.5	0.7	0.9	0.5	0.7	0.9	0.7	0.9	1.0	0.5	0.7	0.9	0.5	0.7	0.9	0.5	0.7	0.9	0.5	0.7	0.9	…	0.0	0.1	0.3
C22	0.7	0.9	1.0	0.5	0.7	0.9	0.7	0.9	1.0	0.7	0.9	1.0	0.7	0.9	1.0	0.7	0.9	1.0	0.7	0.9	1.0	0.5	0.7	0.9	…	0.1	0.3	0.5
C23	0.1	0.3	0.5	0.1	0.3	0.5	0.1	0.3	0.5	0.1	0.3	0.5	0.1	0.3	0.5	0.1	0.3	0.5	0.1	0.3	0.5	0.0	0.1	0.3	…	1.0	1.0	1.0

Appendix 6. Crisp Value (θ) of Respondent 1

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20	C21	C22	C23
C1	0.71	0.64	0.44	0.64	0.64	0.44	0.76	0.76	0.38	0.58	0.76	0.58	0.44	0.00	0.64	0.19	0.58	0.00	0.58	0.76	0.76	0.76	0.00
C2	0.64	0.71	0.44	0.44	0.44	0.44	0.58	0.58	0.38	0.58	0.76	0.58	0.22	0.19	0.22	0.38	0.38	0.00	0.58	0.76	0.76	0.76	0.00
C3	0.64	0.44	0.71	0.44	0.44	0.22	0.58	0.76	0.38	0.38	0.58	0.58	0.22	0.38	0.44	0.38	0.38	0.00	0.58	0.58	0.58	0.58	0.19
C4	0.64	0.44	0.22	0.71	0.44	0.22	0.76	0.58	0.38	0.58	0.76	0.58	0.22	0.19	0.22	0.38	0.38	0.00	0.58	0.58	0.38	0.58	0.19
C5	0.44	0.44	0.44	0.44	0.71	0.22	0.58	0.38	0.19	0.38	0.38	0.38	0.22	0.38	0.22	0.58	0.38	0.00	0.38	0.38	0.38	0.38	0.00
C6	0.64	0.44	0.22	0.22	0.44	0.71	0.38	0.38	0.19	0.38	0.19	0.19	0.00	0.38	0.44	0.38	0.19	0.00	0.19	0.38	0.38	0.19	0.00
C7	0.64	0.64	0.44	0.64	0.44	0.44	0.88	0.58	0.38	0.58	0.58	0.58	0.44	0.38	0.00	0.58	0.38	0.00	0.38	0.38	0.58	0.58	0.38
C8	0.64	0.64	0.64	0.64	0.64	0.44	0.76	0.88	0.38	0.76	0.58	0.76	0.44	0.38	0.44	0.58	0.38	0.19	0.38	0.38	0.58	0.58	0.38
C9	0.44	0.44	0.44	0.44	0.22	0.22	0.38	0.38	0.88	0.38	0.38	0.38	0.22	0.19	0.22	0.19	0.19	0.00	0.19	0.19	0.38	0.38	0.19
C10	0.64	0.64	0.64	0.44	0.44	0.44	0.58	0.58	0.38	0.88	0.58	0.38	0.44	0.38	0.00	0.38	0.38	0.38	0.38	0.38	0.58	0.58	0.38
C11	0.64	0.64	0.44	0.44	0.44	0.22	0.76	0.76	0.38	0.58	0.88	0.58	0.22	0.00	0.22	0.38	0.38	0.00	0.38	0.58	0.76	0.76	0.19
C12	0.44	0.44	0.22	0.22	0.22	0.00	0.58	0.38	0.38	0.38	0.38	0.88	0.22	0.00	0.22	0.19	0.19	0.00	0.19	0.38	0.58	0.58	0.19
C13	0.64	0.44	0.44	0.44	0.22	0.22	0.76	0.58	0.38	0.38	0.58	0.58	0.71	0.58	0.44	0.38	0.38	0.00	0.38	0.58	0.76	0.76	0.58
C14	0.44	0.22	0.22	0.00	0.00	0.44	0.38	0.38	0.19	0.38	0.19	0.38	0.22	0.88	0.22	0.38	0.19	0.00	0.19	0.19	0.38	0.38	0.00
C15	0.44	0.22	0.00	0.00	0.00	0.22	0.38	0.38	0.38	0.38	0.38	0.38	0.22	0.38	0.22	0.58	0.19	0.00	0.19	0.38	0.38	0.58	0.19
C16	0.22	0.22	0.22	0.22	0.22	0.22	0.76	0.76	0.38	0.38	0.58	0.38	0.44	0.38	0.22	0.88	0.38	0.00	0.19	0.38	0.38	0.38	0.00
C17	0.44	0.44	0.22	0.22	0.22	0.44	0.38	0.38	0.19	0.58	0.58	0.38	0.22	0.38	0.22	0.38	0.88	0.00	0.19	0.38	0.38	0.19	0.00
C18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.44	0.00	0.00	0.88	0.00	0.00	0.00	0.00	0.00
C19	0.22	0.44	0.44	0.22	0.44	0.44	0.38	0.38	0.19	0.58	0.38	0.38	0.44	0.38	0.00	0.38	0.38	0.00	0.88	0.38	0.58	0.38	0.19
C20	0.64	0.44	0.64	0.64	0.44	0.44	0.76	0.76	0.38	0.58	0.38	0.58	0.44	0.19	0.44	0.58	0.38	0.19	0.38	0.88	0.58	0.58	0.38
C21	0.64	0.44	0.44	0.64	0.44	0.44	0.58	0.58	0.19	0.58	0.38	0.38	0.44	0.38	0.22	0.58	0.38	0.19	0.38	0.58	0.88	0.38	0.00
C22	0.64	0.44	0.64	0.64	0.64	0.64	0.76	0.58	0.38	0.76	0.58	0.58	0.64	0.58	0.22	0.58	0.38	0.00	0.58	0.76	0.76	0.88	0.19
C23	0.00	0.00	0.00	0.00	0.00	0.00	0.19	0.00	0.00	0.00	0.00	0.19	0.22	0.00	0.22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.88