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Household Waste Separation Intentions in Mongolia: Persuasive Communication Leads to Perceived Convenience and Behavioral Control

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Abstract: This study contributes by developing a set of household waste separation (HWS) attributes to address waste mishandling and to enhance waste separation intentions in households. In Mongolia, a lack of waste separation at the household level needs to be addressed to improve municipal solid waste management systems. However, prior studies have not established attributes in a hierarchical structure, nor do they understand their cause-effect interrelationships. First, the fuzzy Delphi method (FDM) was used to screen out the unnecessary attributes in qualitative information. The fuzzy decision-making trial and evaluation laboratory (FDEMATEL) was then applied to understand the hierarchical structure of the attributes and their cause-effect interrelationships. The study identifies a valid set of attributes consisting of five aspects and 17 criteria under uncertainties. A hierarchical framework consisting of environmental attitudes, social norms, perceived behavioral control, perceived convenience, and persuasive communication is provided. The findings reveal that persuasive communication and environmental attitudes are causal group aspects. Furthermore, persuasive communication has a strong causal impact and higher importance in improving HWS intentions, and it leads to perceived convenience and behavioral control. For policymakers, credibility of information, knowledge and information, awareness of consequences, willingness to sort, and perceived policy effectiveness are the key causal criteria for enhancing HWS intentions. Theoretical and practical policy implications are discussed.

Keywords: theory of planned behavior; household waste separation intentions; persuasive communication; fuzzy delphi; fuzzy DEMATEL

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1. Introduction

In Mongolia, rapid urbanization and improved living standards result in more than 3.4 million tons of waste generated annually, representing quadruple growth relative to a decade ago; 92% of this waste comes from municipal solid waste [1]. The improper management and mishandling of waste pose a substantial danger to human health, sustainable economic development, and environmental wellbeing [2,3]. Delgermaa and Matsumoto [4] argued that if wastes are presorted and collected, it is possible to cut the total solid waste disposed at landfills by 30–40% in Mongolia. Households are the foremost source of waste, and enhancing household waste separation (HWS) will reduce waste generation, improve municipal solid waste management systems, and mitigate adverse consequences [5–7]. HWS is necessary to lessen the challenges of sustainable waste management practices such as recycling or reusing [8]. However, Knickmeyer [9] found that there are still gaps in knowledge, particularly concerning the social attributes that influence HWS intentions. Thus, to address the improper management and mishandling of waste, it is necessary to

understand the attributes that influence HWS intentions [3,7,10]. This study investigates HWS intention attributes to establish a hierarchical structure and to understand their cause-effect interrelationships.

Prior studies have attempted to identify the attributes that influence households' intentions to sort waste. The theory of planned behavior (TPB) has helped understand the social factors influencing HWS intentions [8,10,11]. The TPB encompasses environmental attitudes, social norms, and perceived behavioral control. However, recent studies have raised concerns about the inclusiveness of the TPB in explaining HWS and sustainable waste management intentions [2,12,13]. Wang et al. [6] asserted that the TPB does not adequately elucidate sustainability intentions; therefore, it is necessary to incorporate more aspects into the TPB to gain better insights and results [13,14]. The TPB accepts extra attributes that are significant for the problem under investigation [3,9,11]. This study argues that integrating perceived convenience and persuasive communication into the TPB enables an understanding of how HWS intentions are formed.

The study aims to trace how persuasive communication and perceived convenience interact with environmental attitudes, norms, and control beliefs that affect HWS intentions. Razali et al. [8] argued that the perceived convenience of facilities and methods significantly affects households' attitudes and stimulates a positive drive to HWS. However, the implementation of HWS does not depend merely on value appeals, and for many households the possibility of sorting more waste is unrealized [15,16]. Hence, communication campaigns, including information on classification and recycling, play a vital role in realizing this potential. Muranko et al. [17] emphasized that persuasive communication positively elevates sustainability attitudes and behavioral intentions to participate. In summary, this study integrates perceived convenience and persuasive communication into the TPB to establish HWS intention attributes in a hierarchical structure and understand their cause-effect interrelationships.

Prior studies have addressed HWS intentions in several ways. Razali et al. [8] highlighted that items should be used cautiously and only after their validity as a measure has been established. Chen & Lee [18] noted that the nature of attributes requires exploring their interrelationships in a hierarchical structure and understanding their cause-effect interactions. Furthermore, the characteristics of HWS intention attributes involve both qualitative and quantitative assessments [3,6,15]. This study utilizes the fuzzy Delphi method (FDM) to eliminate ambiguity in expert decision-making, which helps generate valid and reliable attributes of HWS intentions [19–21]. Moreover, the fuzzy decision-making trial and evaluation laboratory (FDEMATEL) was selected to address the qualitative nature of HWS intention attributes by examining the cause-effect interrelationships among the validated attributes [22,23]. Hence, this study adopts a combination of the FDM and FDEMATEL to investigate HWS intentions and develop insightful implications for future improvements. The study objectives are as follows.

1. To identify valid attributes of HWS intentions based on qualitative information.
2. To evaluate the cause-effect interrelationships among HWS intention attributes under uncertainties.
3. To identify criteria for enhancing HWS intentions in Mongolia.

This study makes the following contributions. (1) It proposes a set of valid attributes to understand HWS intentions. (2) It presents a cause-effect model to map the nature of the interrelationships among the attributes. (3) It proposes practical implications to increase HWS intentions. The rest of this study is organized into five sections. The following section discusses the theoretical background, HWS attributes, the proposed methods, and the proposed attributes. The third section describes the status of HWS in Mongolia and the methodologies and data analysis steps adopted in the study. The fourth section presents the study results, and implications are provided in section five. Finally, the conclusions and limitations of this study and suggestions for future studies are discussed in the last section.

2. Literature Review

2.1. Theoretical Background

HWS targets waste reduction at the source to reduce the amount of waste generated and enhance waste recycling. However, waste management efficiency is affected by waste sorting behaviors [24–26]. Meng et al. [26] pointed out that waste management ineffectiveness is caused by households' feeble engagement in categorizing and sorting waste. Fidelis et al. [25] argued that implementing HWS is challenging due to the continuous generation of solid waste and inadequate municipal solid waste management. Thus, identifying attributes that influence HWS intentions is essential. Prior studies have attempted to understand HWS intention attributes [27,28] and, notably, previous studies have extended the TPB to the waste separation field [6,29,30]. The TPB expresses people's intention due to three determinants: attitude toward behavior, social norms, and perceived behavioral control [7,12,31].

First, HWS is personal and related to environmental attitudes, including ecological concerns, willingness to sort, and perceived moral obligation [30,32]. Second, social norms reflect the perception of social influence to accomplish or not accomplish HWS, including community attachment, social pressure, and social responsibility. Thus, individuals are likely to be engaged in a particular action if the persons surrounding them are involved [15,33,34]. Finally, perceived behavioral control indicates that an intention to take part in HWSs is contingent on control over factors that facilitate or interfere, including satisfaction, ascribed responsibility, laws and regulations, beliefs, and trust [13,35]. In summary, according to the TPB, individuals intend to perform HWS when they experience social pressure, positively evaluate it, and believe that they have the opportunities and means to participate in waste sorting. Nevertheless, the TPB has limitations, and prior studies have emphasized that the TPB concept accepts extra attributes that are significant for the research problem under investigation [3,6,9]. Fan et al. [24] sought to enhance the TPB by integrating contextual factors, including public education and environmental knowledge.

However, whether the intention to engage in HWSs is affected by persuasive communication and perceived convenience is an empirical question [3,11,24]. Moreover, HWS has become complicated because of the increase in population and improving living standards. Hence, contextual elements can considerably facilitate or enhance the intention to participate in HWS. Perceived convenience includes perceived ease of use, the amount of time spent, perceived value, the accessibility of facilities, and perceived policy effectiveness [11,29,36]. Cudjoe et al. [2] highlighted that perceived convenience needs to be further investigated to clarify its role in affecting HWS intentions. Persuasive communication consists of social arguments, awareness of consequences, knowledge and information, content types, the source of information, credibility, and educational campaigns [13,23,37]. Ye et al. [38] underlined that persuasive communication with effective messengers and clear messages is a driving force that needs to be considered when studying public intentions. Hence, this study integrates perceived convenience and persuasive communication into the TPB to deepen our understanding of the determinants of HWS intentions.

2.2. Household Waste Separation Intention Attributes

2.2.1. Environmental Attitudes

Households with strong environmental attitudes are more prone to reuse, reduce and recycle waste at home than those without such attitudes [17,39,40]. Meng et al. (2018) found a significant correlation between positive environmental attitudes and HWS intentions. Attitudes guarantee individuals' long-term sustainability behavior and make it easier for individuals to accomplish waste sorting goals. Aboelmaged [12] asserted that attitudes predict individuals' future involvement in sustainability measures and play a substantial role in proenvironmental behavior such as HWS. Environmental attitudes and awareness level are drivers that determine individuals' intentions and involvement in waste sorting activities. Jain et al. [31] highlighted that individuals' environmental concerns and attitudes reduce environmental burdens and positively affect HWS intentions. Wang et al. [11]

emphasized that personal attitudes are essential for accomplishing better social norms and positive perceived moral obligations, making attitude the most important factor affecting intentions to participate in HWS. However, other studies found that HWS normative considerations dominate attitudinal considerations. Hence, the relative importance of environmental attitudes needs to be further investigated.

2.2.2. Social Norms

Social norms indicate the pressure exerted by peers and society to perform or not to perform HWS. These are considered the acceptance or lack of acceptance of others, such as related feelings of pride or shame [8,26,39]. Social norms stimulate an individual's satisfaction, security and cohesion, a stable result that supports positive household engagement in waste management activities [33,40,41]. Social norms affect environmental attitudes. Studies have found that social norms are associated with environmentally responsible behavior and intentions [31,35]. Strong social norms encourage solidarity and involve trust and social connections. Razali et al. [8] noticed that individuals' primary sources of social influence are their family, friends, neighbors, and community. Moreover, they provide affection and support individuals, resulting in higher trust and social connections. Wang et al. [6] asserted that social norms significantly increase HWS intentions; therefore, community collaboration needs to be encouraged by organizing promotional, educational and public welfare activities. In addition, Aboelmaged [12] claimed that social norms drive community intentions; however, the effect depends on factors such as perceived convenience, information, skills, and abilities, which control how individuals relate to the prompts of social norms.

2.2.3. Perceived Behavioral Control

Perceived behavioral control refers to individuals' consciousness, confidence, and control of their abilities and skills to implement HWS. Various studies have found that perceived behavioral control significantly improves an individual's intentions and behavior [6,12,35]. Control beliefs govern peoples' actions, decisions, and performance in a particular situation, consequently determining their behavioral intentions [13,31]. Aboelmaged [12] claimed that an individual's confidence in their ability to control a specific behavior enforces participation in that behavior and significantly affects intentions. Perceived behavioral control is the key determinant that directly predicts waste sorting intentions and behavior [8]. Wang et al. [11] emphasized that improving household residents' perceived behavioral control significantly affects HWS and enhances the willingness to participate in waste sorting activities. Khan et al. [35] suggested that it is necessary to stimulate perceived behavioral control through incentives, awareness campaigns, and platforms for collaboration among communities to enhance waste sorting intentions. In addition, Zhang et al. [3] linked the perceived behavioral control of individuals with informational support, resource availability, and perceived convenience. Hence, considering intentions, the degree to which individuals perceived behavioral control facilitates or impedes performing HWS needs to be investigated.

2.2.4. Perceived Convenience

The perceived convenience of infrastructure, facilities, and resources promotes responsible waste management behavior and the intention to engage in waste separation activities [35,42]. However, few studies have paid attention to the significance of the perceived convenience of the necessary infrastructure as a determinant that predicts HWS intentions [35]. Zhang et al. [7] emphasized that perceived behavioral control is based on subjective feelings. In contrast, perceived convenience comes from an objective sense or is based on physical circumstances such as the availability of facilities. Even though people are willing to perform waste sorting, perceived inconvenience due to a lack of facilities and infrastructure influences them to not engage in HWS activities [13,16,42]. Nainggolan et al. [40] highlighted that HWS intentions and participation highly depend on the level of

inconvenience involved in allocating space and giving up time to perform waste sorting activities. Razali et al. [8] suggested that promoting HWS initiatives requires designing easy and adaptable processes and providing adequate guidelines and facilities to enhance households' perceived convenience. Hence, determining the extent to which the perceived convenience of infrastructure facilitates or interferes with HWS intentions and interacts with TPB attributes is an empirical question and needs to be investigated.

2.2.5. Persuasive Communication

Persuasive communication involves delivering the right message through the right person or the best communicator to change individuals' attitudes and influence their behavioral intentions [13,17,23]. Tseng et al. [23] asserted that creating awareness and improving individuals' knowledge through effective communication positively impacts sustainability behavior. HWS campaigns led by exemplary communicators, such as community members, shape public opinion and form public attitudes toward waste sorting by giving members shared knowledge and explaining HWS values and negative consequences [6,43]. Pedersan & Manhice [16] highlighted that increasing awareness through effective communication is a vital attribute for unlocking the potential role of households in sustainable waste management activities. Cudjoe et al. [2] emphasized that effective persuasive communication should highlight the advantages and disadvantages, as well as the positives and negatives involved in HWS, while promising higher benefits and decreasing burdens. Rizi et al. [8] claimed that communication investment determines changes in individuals' attitudes and intentions to engage in sustainable activities. Moreover, Knickmeyer [9] underlined that changing public attitudes depends on the messenger or the communicator rather than the message itself; hence, the public's trust in the communicator is essential for effective persuasive communication. Combining long-term and short-term communication strategies is necessary to leverage HWS intentions. Therefore, whether persuasive communication has the power to drive perceived behavioral control and perceived convenience needs further study.

2.3. Proposed Method

Prior studies applied qualitative and quantitative methods to address issues in waste separation at the source and overall sustainable waste management intentions. Qualitative approaches have been used in the literature, including interviews, observations, and case studies. Knickmeyer [9] conducted an exploratory literature review to discover that social factors influence HWS intentions and examine best practices for improving waste separation. Alhassan et al. [27] gathered data from structured interviews to gain insights into the critical determinants affecting HWS among residents. Pedersan & Manhice [16] conducted participatory observations, semistructured interviews, user surveys, and a waste composition analysis to comprehend everyday life in households and to discover the underlying attributes of HWS. Azevedo et al. [44] applied case study analysis and benchmarking to investigate attributes for improving household waste management in developing countries. Zheng et al. [7] conducted interviews and simulations for evolutionary analysis of environmentally friendly conduct and explored the dissemination of dynamic information that improves HWS intentions.

Quantitative methods have also been adopted to investigate HWS intention attributes. Fan et al. [24] used structural equation modeling to evaluate comparative data on the similarities and differences in HWS attributes in cultural and country contexts. [29]. Leeabai et al. [29] performed an analysis of variance and experimental data collected on the effects of the noticeability of, and color preference for, garbage cans on waste separation. Zhang et al. [7] utilized partial least squares structural equation modeling to examine the impacts of facility availability, individual attitudes, and government incentives on HWS intentions. Wang et al. (2020) used partial least squares structural equation modeling to assess the HWS intention formation process and examine the attributes' overall relationships. Aboelmaged [12] used partial least squares structural equation modeling

to discover the significant determinants of waste recycling intentions among young consumers. Ling et al. [5] applied a generalized linear mixed model to investigate attributes that encourage HWS and participation in incentivized waste separation programs. Jain et al. [31] employed structural equation modeling to analyze the key determinants that lead to positive intentions toward waste recycling at the source.

Although prior studies have applied qualitative and quantitative approaches, the validity of HWS intention measures in qualitative information has been neglected [2,8,41]. Thus, the validity of such measures needs to be established. Furthermore, due to the complex nature of attributes, it is necessary to conduct an appropriate investigation into the cause-effect interrelationships among the attributes to better understand them [18,43]. This study adopts the FDM to establish HWS intention measures' validity and screen out unnecessary attributes. FDEMATEL was also employed to address the cause-effect interrelationships among the attributes [19,20,23]. Hence, this study utilizes a hybrid approach consisting of the FDM and FDEMATEL to confirm the validity and to explore the cause-effect interrelationships among the attributes.

2.4. Proposed Attributes

This study proposes a set of HWS intention attributes that includes five aspects and 30 criteria to enhance a household's participation in waste reduction at the source and to improve waste management processes (see Table A1 in the Appendix A.)

Environmental attitudes (A1) consist of the criteria that shape a household's positive or negative perception of environmental actions, consequently affecting HWS intentions [8,17,26]. Willingness to sort (IC1) represents household individuals' inclination to implement and participate in sustainable and responsible separation activities [2,6,30]. Environmental concerns (IC2) embody households' feelings toward accelerating environmental burdens and beliefs in the need for environmental protection [28,38,44]. Sustainability attitudes (IC3) are people's feelings toward balancing environmental, social, and economic aspects, which actively predict people's intention to participate in HWS [16,44]. Moral obligations (IC4) denote the sense of feeling obligated and morally responsible for performing waste separation, and shape personal environmental attitudes [3,11]. Costs and benefits (IC5) are the financial expenses and incentives involved in the HWS process, affecting households' environmental attitudes [2,8,41]. Personal hygiene (IC6) refers to individuals' feeling that waste separation activities express their sanitation and the cleanliness of their environment [14,27]. Enthusiasm (IC7) is the level of household interest and enjoyment in participating in waste separation activities, maintaining good performance, and learning about HWS [11,12,41].

Social norms (A2) encompass the criteria related to the community's waste separation standards, which affect a household's intention to engage in HWS practices [12,44,45]. Community attachment (IC8) involves the extent to which households interact with their community problems and their willingness to become involved in community-oriented efforts such as waste separation [33,41]. Social pressure (IC9) is a social influence that encourages intentions, such as psychological pressure from the knowledge that neighboring households are undertaking waste separation, or social expectations that one should perform separation [9,41]. In this context, social responsibility (IC10) is ethical guidance that pushes individuals to fulfill their obligations to societal wellbeing by participating in HWS practices [11]. Public figure behavior (IC11) involves the role of public figures in influencing individuals' performance and their public persuasive power to enhance people's intentions to participate in HWS [12,41]. The social atmosphere (IC12) denotes the social environment, such as the relationships among society, waste management institutions, cultural factors, and physical structures, which influence an individual's intentions [14,43]. Institutional support (IC13) emphasizes the necessary support for HWS from the government and organizations, such as resources, incentives, policies, guidelines, processes, and technologies, which affect intentions [2].

Perceived behavioral control (A3) encompasses the criteria related to perceptions of whether households possess the skills, motivation, and abilities needed to undertake HWS. Self-motivation (IC14) is intrinsic motivation or individuals' internal voluntary driving force to perform HWS [7]. Satisfaction (IC15) is perceived as contentment from the fact that waste sorting improves community health, environmental wellbeing, or the economic status of households [12]. Ascribed responsibility (IC16) refers to the sense of responsibility to solve or mitigate the adverse outcomes of not participating in HWS [6]. Laws and regulations (IC17) are the available regulations that guide individuals and provide a framework for HWS activities [2,31,41]. Beliefs and trust (IC18) involve government and community, as well as the confidence of individuals in their abilities and skills to attain the overall goals that benefit households [37].

Perceived convenience and efforts (A4) include individuals' subjective perception of the convenience and ease of performing HWS [35,42]. Perceived ease of use (IC19) concerns individuals' belief that waste separation is convenient and easy to achieve in households' daily routines [6,7,16]. Time convenience (IC20) involves perceptions of the amount of time needed to carry out waste separation tasks, such as whether a minimum time is necessary or whether the individual can perform waste separation even though there is not enough time to do so [14,27]. Perceived value (IC21) is the perception or psychological evaluation of the merits and value of HWS compared to throwing away waste without sorting [2,28]. Facility accessibility (IC22) represents the availability of the facilities necessary for helping with waste separation [16,27]. Perceived policy effectiveness (IC23) represents the adequacy, clarity, and favorability of existing HWS policies and the possibility of achieving sustainability by implementing them [36,41,43].

Persuasive communication (A5) involves awareness building and knowledge expansion to motivate HWS [2,16,21]. Social arguments (IC24) are social messages emphasizing behavior contributing to better waste sorting [9,46]. Awareness of consequences (IC25) represents individuals' awareness of the outcomes, whether positive or negative, of HWS [16,27,28]. Knowledge and information (IC26) are the availability of adequate educational and promotional guidelines that clarify what, how, and why in the performance of HWS [27,41]. The content type (IC27) is the type of information, channels, and ways available for member of the public to increase their participation intentions [3,38]. The source of information (IC28) concerns the validity and trustworthiness of information sources for improving waste sorting. Credibility (IC29) is the communicator's positive characteristics and the credibility of the information available to the public. Educational campaigns (IC30) are initiatives to inform the public about the significance of HWS and strengthen households' environmental concerns [14,38].

3. Method

This section provides an overview of household waste generation in Mongolia, the methodology and data collection, and the analysis steps used.

3.1. Case Background

Mongolia is a lower-middle-income country where 68.54% of people live in urban areas. A 7.6 unit drop in the environmental performance index has indicated a significant deterioration in ecosystem vitality and environmental health (Wendling et al., 2020). In addition, the pursuit of economic prosperity manifested in urbanization suggests the need for more attention to the collection and treatment of household wastes in a manner that controls environmental risks. More goods are being consumed due to population growth and economic development, leading to higher household waste generation rates. In 2018, more than 3.4 million tons of waste were generated, representing quadruple growth relative to the 2008 level [1]. Ninety-two percent of total waste comes from municipal solid waste [1].

The volume of waste generated is anticipated to rise in the coming years with the size and population in urban areas. The infrastructure, technology, and administrative

capability to manage this municipal waste are lacking or very poor, causing a substantial problem. For instance, the largest city, Ulaanbaatar, where half of the country's population lives, generates almost 60% of the total waste of the country; however, a significant part of the city lacks an appropriate waste management system [47,48]. Ninety-seven percent of waste is disposed of using open dumps, 50% of waste is classified as recyclable, and only 0.31% is recycled [49]. When there is HWS, recycling waste or adopting other sustainable practices can be quickly implemented. However, there is a lack of waste separation at the source in Mongolia that needs to be addressed [5,50]. In Mongolia, it is possible to cut the total solid waste disposed of at landfills by 30–40% if recyclable wastes are sorted and collected [4]. The outcomes of this study can help policymakers, local practitioners, and urban managers formulate suitable policies and strategies, and thus enhance households' participation in HWS.

3.2. Fuzzy Delphi Method

The FDM combines the traditional Delphi method with fuzzy set theory, considering the vagueness of expert judgments. FDM is suitable for capturing the uncertainty involved in human decisions and serves as a screening tool for removing nonessential criteria from the initial set of attributes [20,22]. The procedures necessary for the FDM are discussed below:

Linguistic terms are transformed into fuzzy triangular numbers (TFNs) using Table 1, and then the geometric mean is applied to aggregate the scores for each criterion. Subsequently, the fuzzy weight (w_j) of all criteria is calculated using Equation (1).

$$w_j = \left\{ a_j = \min(a_{ij}),\ b_j = \left(\sum_{i=1}^{n} (b_{ij})\right)^{\frac{1}{n}},\ c_j = max\ (c_{ij}) \right\} \quad (1)$$

where j is the score of criterion j, i is expert, n is the total number of experts, and a, b, and c are the lower, middle and upper values of TFNs, respectively.

Table 1. TFNs for FDM and FDEMATEL assessment.

Linguistic Terms	Meanings (Importance)	Corresponding TFNs
VH	Very high	(0.70, 0.90, 1.00)
H	High	(0.50, 0.70, 0.90)
M	Medium	(0.30, 0.50, 0.70)
L	Low	(0.10. 0.30, 0.50)
VL	Very low	(0.00, 0.10, 0.30)

Then, the defuzzification process is performed for each criterion using Equation (2).

$$S_j = \frac{a_j + b_j + c_j}{3}\ j\ =\ 1, 2, 3 \ldots\ldots m \quad (2)$$

where m is the number of proposed criteria.

Finally, a threshold ($\alpha = \sum S_j)/n$) value for removing nonessential criteria is set. If $S_j \geq \alpha$, the jth criterion is valid and accepted; on the other hand, if $S_j \leq \alpha$, the jth criterion is invalid and deleted.

3.3. Fuzzy Decision-Making Trial and Evaluation Laboratory

FDEMATEL combines the traditional DEMATEL with fuzzy set theory to resolve the ambiguity surrounding experts' decision-making quality [22,46]. This study utilizes FDEMATEL to discover the cause-effect interrelationships among HWS intention attributes. Assuming that n is the number of experts involved, $\tilde{z}_{ij}^{f}$ represents the fuzzy weight that the fth expert assigns to the relationship between the ith attribute and the jth attribute. This study follows the procedure below to perform FDEMATEL analysis:

Normalized TFNs are calculated as follows:

$$S = \left(\tilde{sz}^f_{lij},\ \tilde{sz}^f_{mij}, \tilde{sz}^f_{uij}\right) = \left[\frac{\left(z^f_{lij} - minz^f_{lij}\right)}{\left(maxz^f_{uij} - minz^f_{lij}\right)}, \frac{\left(z^f_{mij} - minz^f_{mij}\right)}{\left(maxz^f_{uij} - minz^f_{lij}\right)}, \frac{\left(z^f_{uij} - minz^f_{mij}\right)}{\left(maxz^f_{uij} - minz^f_{lij}\right)}\right] \quad (3)$$

where $\left(\tilde{sz}^f_{lij},\ \tilde{sz}^f_{mij},\ \tilde{sz}^f_{uij}\right)$ represents the normalized form of TFNs.

The left (S^f_{ltij}) and right (S^f_{rtij}) normalized values are obtained as follows:

$$\left(S^f_{ltij}, S^f_{rtij}\right) = \left[\frac{\tilde{sz}^f_{mij}}{\left(1 + \tilde{sz}^f_{mij} - \tilde{sz}^f_{lij}\right)}, \frac{\tilde{sz}^f_{uij}}{\left(1 + \tilde{sz}^f_{uij} - \tilde{sz}^f_{mij}\right)}\right] \quad (4)$$

The total normalized crisp values are obtained as follows:

$$S^f_{ij} = \left[\frac{S^f_{ltij}\left(1 - S^f_{ltij}\right) + \left(S^f_{rtij}\right)^2}{\left(1 - S^f_{ltij} + S^f_{rtij}\right)}\right] \quad (5)$$

Crisp values are computed as follows (Equation (6)):

$$\tilde{w}^f_{ij} = min\tilde{z}^f_{lij} + S^f_{ij}\left(maxz^f_{uij} - minz^f_{lij}\right) \quad (6)$$

The initial direct relation matrix (*IDRM*) is obtained by aggregating the expert judgments as follows:

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

where w_{ij} represents the extent to which attribute i influences attribute j.

The normalized direct relation matrix (U) is generated by standardizing the *IDRM*

$$U = w \otimes IDMR \quad (8)$$

where $w = max\left(\sum_{j=1}^{n} w^f_{ij}\right)$ for all i from 1 to n.

The total interrelationship matrix Y is determined as follows:

$$Y = U(I - U)^{-1} \quad (9)$$

where I characterize size n and an identity matrix.

Finally, vectors D and R, which represent the sum of rows and columns, are computed. Each attribute's prominence or importance is calculated by combining D and R. If the (D-R) value is negative, the attribute falls into the effect group; if the (D-R) value is positive, it falls into the causal group. The strength of the cause-effect relationship is determined by obtaining the inner dependence matrix.

$$D = \sum_{j=1}^{n} U_{ij} \text{ for all } j \text{ from 1 to } n \quad (10)$$

$$R = \sum_{i=1}^{n} U_{ij} \text{ for all } i \text{ from 1 to } n \quad (11)$$

3.4. Data Collection and Analysis

Thirty criteria were proposed based on the literature analysis (Appendix A). A Delphi panel consisting of 27 experts was formed for assessment. The respondents were chosen based on purposive and convenient sampling. The respondents' profiles are given in

Table A2 (see Appendix A. Equal numbers of experts from private recycling firms, Mongolian waste management agencies, and the academic sector were chosen. The respondents had a practical and theoretical understanding of waste separation and collection. The data collection and analysis steps are briefly described below and summarized in Figure 1.

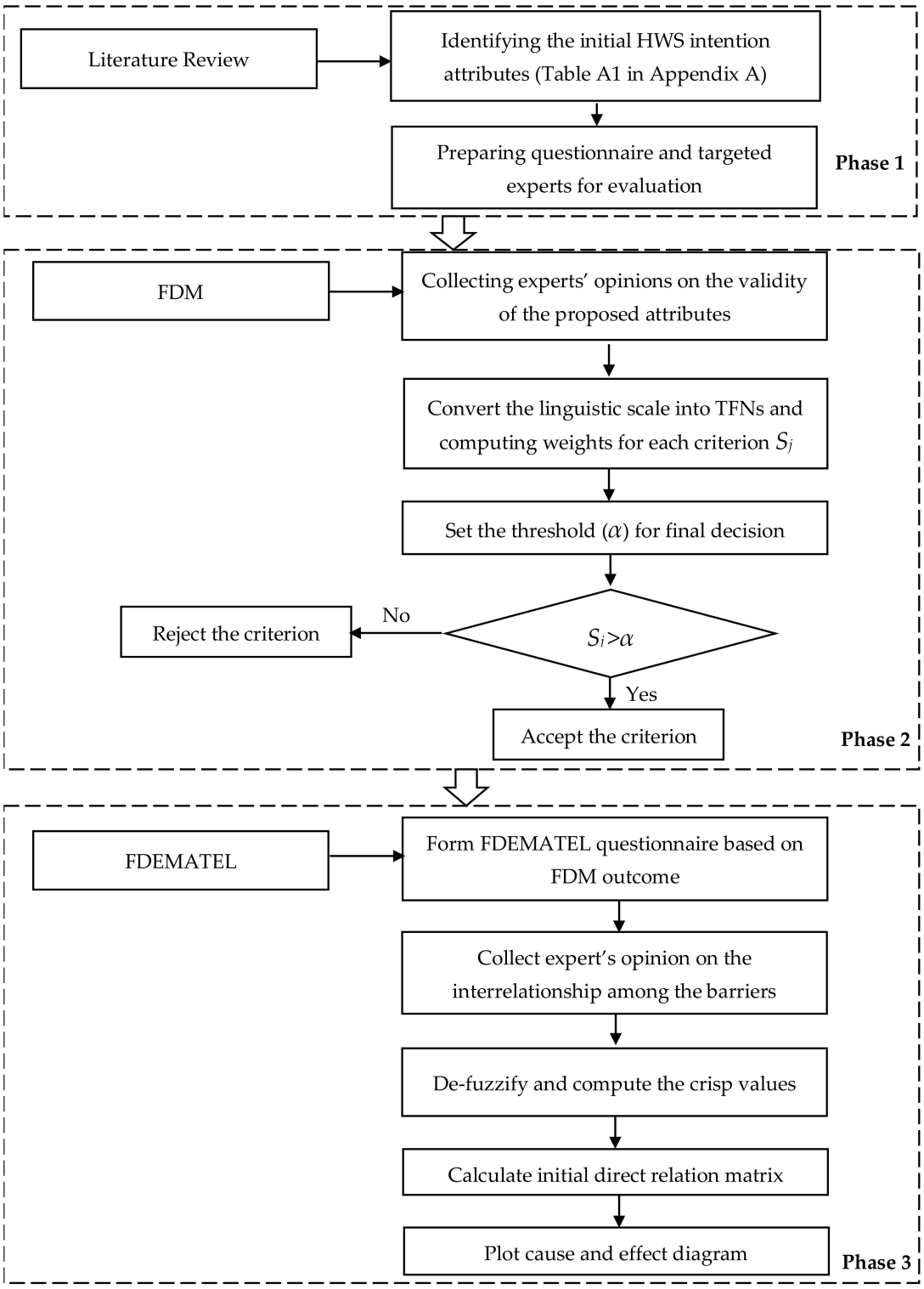

Figure 1. The proposed analytical step.

1. An FDM questionnaire on the significance of the attributes was formed to validate the criteria, and the experts gave responses in linguistic terms. Equations (1) and (2) were applied to remove unimportant criteria.
2. Based on the FDM results, the FDEMATEL questionnaire was formulated and online interviews were carried out. The defuzzification process was performed using Equations (3)–(6).
3. Equation (7) was applied to obtain the IDRM, and Equation (8) determined the normalized direct relation matrix. Then, the total interrelationship matrix was calculated utilizing Equation (9).
4. The (D + R) values and the (D-R) values were determined by employing Equations (10) and (11). Then, the values were used to plot a diagram of the cause-effect interrelationships among the HWS attributes.
5. The graph was divided into four quadrants. Attributes falling into quadrant I are identified as "driving attributes," which have higher importance and strong causal impact; in quadrant II, "voluntary attributes" have lower importance but a strong causal effect. Quadrant III represents "independent attributes," which have a weak causal effect and low importance, and those attributes in quadrant IV are "core attributes," which have higher but important weak causality.

4. Results

This section provides the results from the data collection and analysis process described in the prior section.

1. The FDM results, including the weights of each criterion and their threshold, which is 0.647, are shown in Table 2. A total of 17 criteria were accepted as the valid set, as shown in Table 2.
2. Based on the validated criteria from the FDM, the experts assessed the interrelationships among the attributes using a linguistic scale. The qualitative information from the experts was transformed into corresponding TFNs, respondents' assessments were normalized, right and left values were calculated, and total normalized crisp values and crisp overall values were calculated. The results from one of the experts and the defuzzification process for aspects are shown in Table A3 (see Appendix A).
3. Averaging the crisp values from each respondent, the IDRM in Table 3 was obtained. From the total interrelationship matrices in Tables A4 and A5 (see Appendix A), their dependence and driving power were generated. Tables 4 and 5 depict aspects and criteria and their dependence and driving power.
4. The diagram of the cause-effect interrelationships among the aspects is given in Figure 2. Using the (D-R) axis, the aspects are categorized into causal group aspects, which are those on the positive side of the (D-R). Thus, persuasive communication (A5), environmental attitudes (A1), social norms (A2), perceived behavioral control (A3), perceived convenience and efforts (A4) belong to the effect group. Persuasive communication (A3) is the most influential aspect that can improve HWS intentions.
5. The cause-effect interrelationships among the criteria are shown in Figure 3. The driving criteria consist of willingness to sort (C1), environmental concerns (C2), awareness of consequences (C9), perceived policy effectiveness (C11), knowledge and information (C12), content types (C14), the source of information (C15), credibility (C16) and educational campaigns (C17).

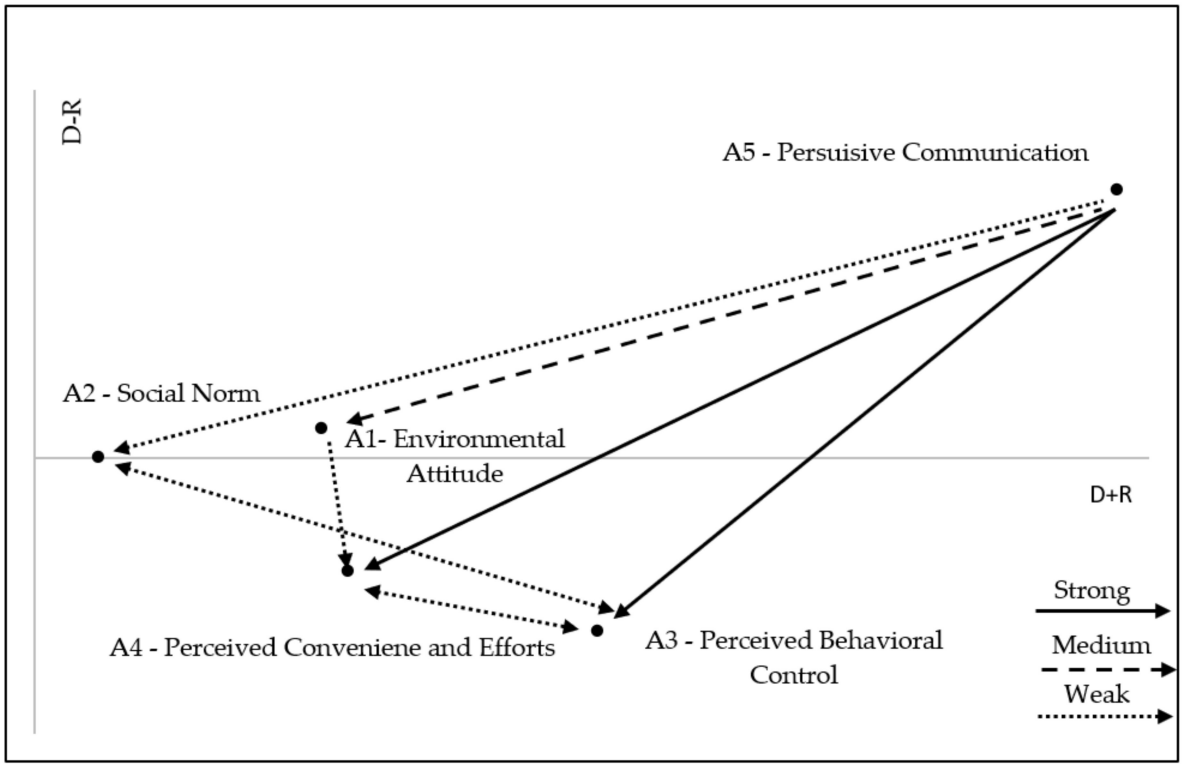

Figure 2. Causal interrelationships diagram among the aspects.

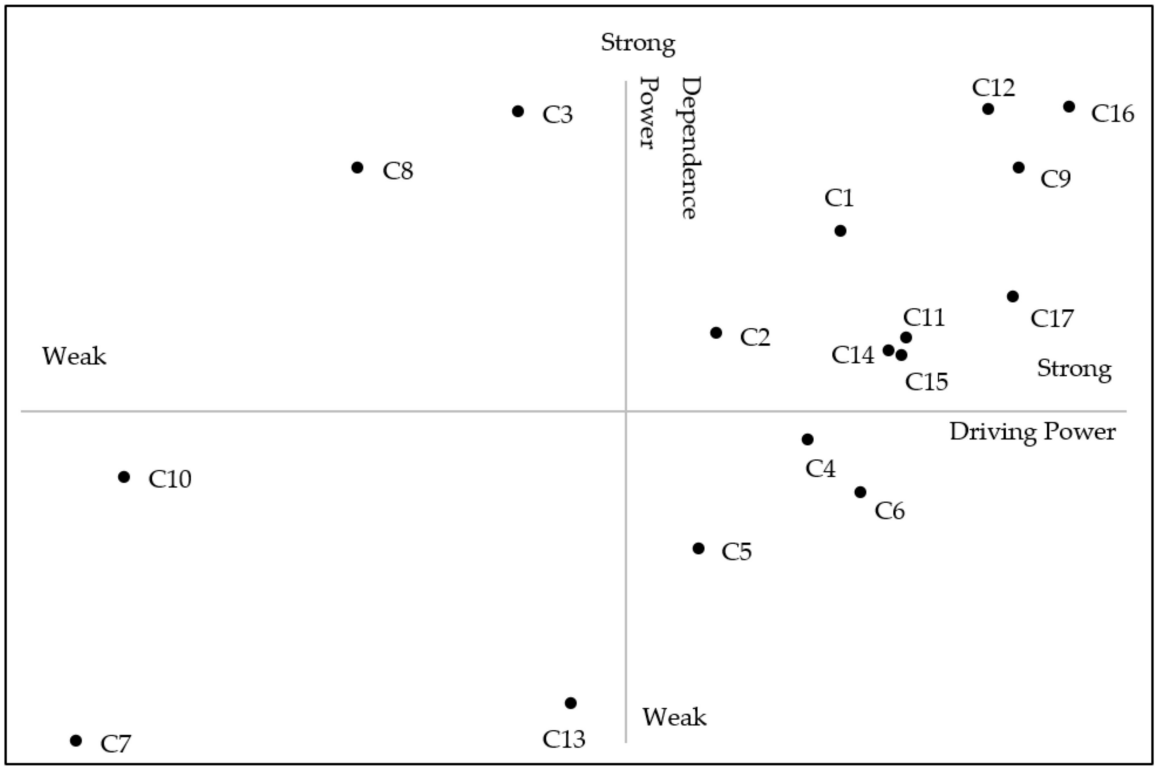

Figure 3. Causal effect diagram among the criteria.

Table 2. FDM Results.

Initial Criteria		Weight	Decision	Validated and Renamed
IC1	Willingness to sort	0.699	Accepted	C1
IC2	Environmental concerns	0.706	Accepted	C2
IC3	Sustainability attitude	0.620	Rejected	
IC4	Perceived moral obligations	0.634	Rejected	
IC5	Perceived cost and benefits	0.589	Rejected	
IC6	Personal hygiene	0.607	Rejected	
IC7	Enthusiasm	0.689	Accepted	C3
IC8	Community attachment	0.612	Rejected	
IC9	Social pressure	0.596	Rejected	
IC10	Social responsibility	0.693	Accepted	C4
IC11	Public figures behavior	0.596	Rejected	
IC12	Social atmosphere	0.674	Accepted	C5
IC13	Institutional support	0.687	Accepted	C6
IC14	Self-motivation	0.670	Accepted	C7
IC15	Satisfaction	0.689	Accepted	C8
IC16	Ascribed responsibility	0.601	Rejected	
IC17	Laws and regulations	0.599	Rejected	
IC18	Beliefs and trust	0.604	Rejected	
IC19	Awareness of consequences	0.687	Accepted	C9
IC20	Perceived ease of use	0.572	Rejected	
IC21	Time convenience	0.686	Accepted	C10
IC22	Perceived value	0.581	Rejected	
IC23	Facilities accessibility	0.615	Rejected	
IC24	Perceived policy effectiveness	0.647	Accepted	C11
IC25	Knowledge and information	0.681	Accepted	C12
IC26	Social argument	0.673	Accepted	C13
IC27	Content-type	0.684	Accepted	C14
IC28	Source of information	0.664	Accepted	C15
IC29	Credibility	0.669	Accepted	C16
IC30	Education campaign	0.692	Accepted	C17
Threshold		0.647		

Table 3. Initial direct relation matrix for aspects.

	A1	A2	A3	A4	A5	SUM
A1	0.712	0.381	0.607	0.435	0.564	2.698
A2	0.381	0.720	0.419	0.472	0.611	2.603
A3	0.606	0.418	0.707	0.498	0.612	2.841
A4	0.435	0.493	0.483	0.701	0.611	2.724
A5	0.567	0.591	0.601	0.600	0.707	3.066
					MAX	3.066

Table 4. Driving and Dependence Power of Aspects.

	D	R	D+R	D-R
A1	10.025	10.011	20.036	0.015
A2	9.617	9.617	19.234	(0.001)
A3	10.468	10.563	21.031	(0.095)
A4	10.032	10.096	20.128	(0.064)
A5	11.519	11.374	22.894	0.145
Max			22.894	0.145
Min			19.234	(0.095)
Average			20.665	0.000

Table 5. Driving and Dependence Power of criteria.

	D	R	D+R	D-R
C1	18.05	17.51	35.56	0.54
C2	17.36	17.13	34.50	0.23
C3	16.85	15.95	32.80	0.90
C4	17.60	17.69	35.28	−0.09
C5	16.96	17.38	34.34	−0.42
C6	17.75	18.00	35.75	−0.25
C7	11.79	15.80	27.59	−4.01
C8	16.08	15.35	31.43	0.73
C9	18.92	18.18	37.10	0.73
C10	14.61	14.81	29.41	−0.20
C11	18.17	17.95	36.12	0.22
C12	18.87	17.96	36.83	0.90
C13	16.18	17.07	33.25	−0.89
C14	18.08	17.90	35.98	0.18
C15	18.13	17.96	36.09	0.17
C16	19.22	18.31	37.53	0.92
C17	18.69	18.36	37.05	0.34

5. Implications

The theoretical and managerial implications are discussed in this section to deepen our understanding of the determinants of HWS intentions.

5.1. Theoretical Implications

The results indicated that persuasive communication possesses the highest dependence and driving power, and provides the basis for HWS attitudes, social norms, and perceived behavioral control, leading to intentions. The cause-effect interrelationships show that persuasive communication and environmental attitudes are causal attributes. The effect group consists of social norms, perceived behavioral control, and perceived convenience and efforts. Thus, for HWS intentions, environmental attitudes tend to carry more weight than social norms or perceived behavioral control.

Persuasive communication (A5) has the strongest causal power and highest importance; it directly influences both perceived behavioral control and perceived convenience

and efforts. Moreover, it moderately influences social norms and environmental attitudes. These results indicate that persuasive communication is crucial for convincing households of the need for waste separation and enhancing their intention to participate in HWS. Persuasive communication involves building good credibility, for example, by demonstrating positive experiences of HWS that motivate people and give them a reason to carry out such tasks. HWS intentions are formed not based on direct observation but by accepting information provided by an outside source. HWS campaigns led by referents such as community leaders shape households' opinions and form their environmental attitudes by giving them knowledge and explaining HWS values and negative consequences [11,43]. Persuasive communication changes people's way of life and intentions because it usually comes from socially reliable and trustworthy sources such as academics, successful celebrities, religious leaders, and public figures capable of influencing people's daily lives and intentions [2,15,17]. The impact of persuasive communication can be amplified by educational programs for households and teaching them about the social, economic and environmental benefits of HWS, the techniques for undertaking HWS, and the negative consequences arising from neglecting HWS. This aspect significantly affects individuals' positive or negative perceptions of environmental actions, inner feelings and abilities, public culture, and perceived easiness. The intention to perform HWS is guided primarily by persuasive communication.

Environmental attitudes (A1) involve households' affective feelings toward waste separation activities and their expectations of the behavioral outcomes of such activities. HWS intentions are affected mainly by environmental attitudes and less so by social norms and perceived behavioral control. Environmental attitudes are a prerequisite for achieving better social norms and positive perceived moral obligation [6,11]. It is the second most influential aspect in the proposed group and drives perceived convenience and efforts. Environmental attitudes play a major role in predicting people's willingness to participate in HWS activities and their overall tendency regarding sustainability [6,26,39]. Due to the significance of environmental attitudes, it is compulsory to consider encouragement measures and policies that can shape the positive attitudes of households. Creating opportunities, providing suitable facilities, and imparting proper knowledge enhance positive environmental attitudes. Another effective way to encourage a positive environmental attitude is to stimulate emotional sympathy toward the environment through movies and site visits, and to emphasize the degradation of nature in a particular area.

5.2. Practical Policy Implications

In practice, the driving criteria for enhancing HWS intentions include the credibility of information (C16), knowledge and information (C12), awareness of consequences (C9), educational campaigns (C17), willingness to sort (C1), and perceived policy effectiveness (C11).

The credibility of information (C16) sources is a significant criterion in the decision-making process and in creating households' attitudes and intentions. Intentions are formed not based on direct observation but by accepting information provided by an outside source. The expertise, trustworthiness, and likability of the information source lead to credibility. Hence, segmentation is necessary to determine which source of information is preferable or accessible to each household and to ensure that practical information delivery is achieved. Social media platforms are major tools for shaping people's attitudes; hence, it is important to prioritize reaching households via social media. Social interactions are one of the most influential information sources, and people learn from each other's behavior and are willing to follow information from their community. Therefore, strengthening social networks enhances household intentions. Moreover, academics and school campaigns are less effective than social media as a source of information. Nevertheless, research papers, surveys, and educational infographics can persuade households to perform waste separation.

Knowledge and information (C12) are critical criteria for forming households' attitudes, increasing understanding, and stimulating HWS intentions. The level of knowledge and information on sustainability issues impacts individuals' positive intentions by creat-

ing a proenvironmental attitude. Emphasizing the potential benefits, expected outcomes, and severe problems that HWS solves motivates households to consider participating in HWS. Knowledge and information are the basis for attitudes, subjective norms, and perceived behavioral control, leading to HWS intentions. Providing guidelines on the sorting process, the necessary tools and facilities, gives households a clear overall view of HWS and increases their willingness and intentions. Promoting educational events and programs through social media, mass media, and academic institutions creates a well-informed society that will participate in HWS efforts. Moreover, setting up counseling centers for people to exchange ideas, raising awareness of the latest issues, and learning the latest techniques will keep households up-to-date and committed.

Awareness of consequences (C9) represents households' understanding of the adverse consequences of not participating in HWS activities, such as environmental problems and health issues. The government and environmental agencies need to organize awareness campaigns and educate people about the consequences of mishandling waste, environmental degradation, and the importance of waste sorting. People with awareness of consequences develop higher ascribed responsibility, pushing households to become involved in sustainable processes and responsibly managing household waste. Awareness of consequences influences people's moral obligations and social norm factors. Therefore, raising awareness helps reduce a mixture of materials that require much effort in recycling facilities, reducing waste that goes directly to landfills and leading to a higher rate of HWS. Providing public information about the negative impacts of unsorted waste motivates households, increases awareness, and improves HWS intentions. People focus on or care about their region or country; therefore, awareness campaigns must highlight the adverse developments in people's particular regions resulting from unsorted waste or improper waste disposal.

In Mongolia, the accumulation of waste dumped in different mountains is among the main factors leading to soil and air pollution. Many households still throw away garbage and harmful waste without separating it. Educational campaigns (C17) are an influential criterion for overcoming the existing challenges hindering the sustainable intentions of households, such as lack of knowledge, poor awareness, negative attitudes and perceptions. Moreover, certain households willing to sort and perform waste separation cannot differentiate waste material categories due to a lack of technical knowledge. Educational campaigns must encompass all the knowledge and information necessary, such as declarative information to teach the concept of waste separation and procedural information to explain how to perform waste separation. Environmental education fosters environmental attitudes, which increase people's willingness to become involved in sustainable practices and realize households' potential. Integrating subjects on environmental protection and sustainability in the national curriculum is an effective means of educating people from a young age and building their attitude from the beginning. These campaigns effectively enhance people's environmental concerns and develop a positive attitude toward pro-environmental activities such as waste sorting.

Willingness to sort (C1) involves households' desires and natural tendencies to implement and participate in HWS. A strong desire to perform HWS is a valuable trait that can help communities improve their environment without feeling pressure and difficulties. Willingness to sort reusable materials derives from external factors such as perceived benefits, ease, and facility availability. The lack of understanding of the numerous difficulties involved while treating unsorted waste discourages willingness to sort, causing reusable waste accumulation in landfills. Hence, waste separation willingness must be supported by infrastructure and financial, educational, and regulatory incentives. Highlighting that waste sorting reduces waste collection and treatment and reduces the amount of money that the community pays for waste management, promotes waste sorting activities and improves HWS willingness. External efforts and educational campaigns increase HWS intentions and lead to innovative ideas to perform HWS.

Perceived policy effectiveness (C11) is a catalyst that increases intentions, and is a bridging factor that transforms awareness into action. It involves households' perceptions and favorability of the available regulations and instructions to promote HWS activities. Policymakers need to ensure the possibility and probability of policy effectiveness by proposing transparent, reliable, precise, and adequate policies. In Mongolia, informal waste collectors mainly perform household waste recycling, and most of the waste collected is sent to landfills for disposal. Ninety-seven percent of waste is disposed of using open dumps, indicating a lack of effectiveness. Thus, to enhance effectiveness, this study recommends inviting the public to participate in the policy formulation process and considering its ideas. Households are inclined to participate in HWS activities when they know the goals, expected milestones, and incentives included in the proposed policy. Policy effectiveness is achieved by continuously evaluating policy achievements, monitoring progress, and updating policies based on the outcomes of previously recorded experiences. Information campaigns that include benefits, targets, and past successful experiences can influence public perceptions and elevate HWS intentions. Furthermore, contemplating the appropriate timing for policy formulation, and opting for incentive-based policies rather than punishments, are decisive features for perceived policy effectiveness.

6. Conclusions

HWS is essential to remedy the adverse consequences of high waste generation and improper waste disposal. HWSs help achieve sustainability in municipal waste management systems and implement sustainable practices such as recycling and reuse. Exploring and understanding HWS intentions are fundamental concerns for boosting household participation in HWSs. However, few studies have examined the relative influence of attitudes, social norms, and perceived behavioral control on HWS intentions. Furthermore, there are gaps in knowledge, particularly in regard to the social attributes that influence HWS intentions. By including persuasive communication and perceived convenience in the TPB, this study traces the extent to which they influence environmental attitudes, social norms, and perceived behavioral control with regard to HWS intentions. This study utilizes a hybrid approach, consisting of the FDM and FDEMATEL, to confirm the validity and to explore the cause-effect interrelationships among attributes. The FDM was applied to remove invalid attributes and to generate expert consensus. FDEMATEL was adopted to examine the cause-effect interrelationships among the validated attributes and to address the complex nature of such attributes.

The results indicated that for HWSs, persuasive communication provides the basis for attitudes, social norms, and perceived behavioral control, which, in turn, lead to intentions. Furthermore, among the five proposed aspects, persuasive communication and environmental attitudes were found to be the causal group. These aspects directly influence social norms, perceived behavioral control, and perceived convenience. The results also revealed that willingness to sort, awareness of consequences, perceived policy effectiveness, knowledge and information, the source of information, credibility and educational campaigns are the causal criteria for enhancing HWS intentions. For policymakers, these attributes were the most influential attributes necessary to improve HWS intentions and to increase households' rate of participation in the process of waste sorting at the source.

This study contributes by investigating the attributes that influence HWS intentions. First, to enhance HWS intentions in Mongolian households, the relative contributions of environmental attitudes, social norms, and perceived behavioral control were determined. Second, and equally important, the effects of persuasive communication and perceived convenience were investigated to gain insights into the possible origins of the intentions that serve as the cognitive foundation for behavioral intentions. Finally, the study provides implications to help academics, policymakers, and practitioners implement sustainable waste management. Effective persuasive communication strategies lead to better social norms, proenvironmental attitudes, positive perceived convenience and perceived behavioral control. Practical implications based on willingness to sort, awareness of consequences,

perceived policy effectiveness, knowledge and information, the source of information, credibility and educational campaigns are discussed.

Some limitations need to be addressed in future studies. The initially proposed attributes were based on the literature review and may not fully encompass all the attributes affecting HWS intentions. Therefore, future studies may include additional criteria. Moreover, increasing the number of respondents is recommended, as in this study only 27 experts were involved. The FDM and FDEMATEL were used in this study to examine the attributes. Future studies may apply other suitable methodologies to compare the results with the findings of this study.

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Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Table A1. HWS intention attributes.

Aspect	Criteria	Description	References
Environmental Attitude	IC1: Willingness to sort	Individual's willingness to participate in household waste separation	[2,6,8,11,17,26]
	IC2: Environmental concerns	Personal attitudes and beliefs toward environmental protection	
	IC3: Sustainability attitude	Individual's feelings toward balancing environmental, social, and economic aspects	
	IC4: Perceived moral obligations	Sense of feeling obligated and moral responsibility to do the waste separation	
	IC5: Perceived cost and benefits	Financial expenses and incentives involved in doing waste sorting	
	IC6: Personal hygiene	Waste sorting activities relate and express personal hygiene	
	IC7: Enthusiasm	Happiness and increasing enthusiasm for waste sorting activities	

Table A1. *Cont.*

Aspect	Criteria	Description	References
Social Norm	IC8: Community attachment	Cognitive or affective ties of community to commit waste management measures such as sorting.	[9,12,41,44,45]
	IC9: Social pressure	Social influence on individuals waste sorting behavior intention	
	IC10: Social responsibility	Social obligations forcing the individual to cooperate with the public in reaching social welfare	
	IC11: Public figures' behavior	Public figures separate waste and support waste separation	
	IC12: Social atmosphere	Social and physical settings where people live or stay	
	IC13: Institutional support	Government and environmental organizations support waste separation	
Perceived behavioral control	IC14: Self-motivation	Individuals internal driving force to perform household waste sorting	[2,7,12,31,37,41]
	IC15: Satisfaction	Perceived contentment that waste sorting helps to improve the environment	
	IC16: Ascribed responsibility	A feeling of being responsible for adverse outcomes resulted from not sorting the waste	
	IC17: Laws and regulations	Available laws and regulations guiding waste sorting	
	IC18: Beliefs and trust	The extent of trust and belief in waste sorting goals and benefits	
	IC19: Awareness of consequences	Individual awareness of the negative results of not sorting the waste	
Perceived convenience and efforts	IC20: Perceived ease of use	Individuals believe that waste sorting is easy to do in households	[2,16,27,28,35,42,43]
	IC21: Time convenience	The perception of the amount of time needed to perform waste separation is minimal	
	IC22: Perceived value	Realization of waste sorting merits and values	
	IC23: Facilities accessibility	Availability of necessary facilities in helping waste separation	
	IC24: Perceived policy effectiveness	Adequacy, clarity, and favorability of existing household waste sorting policy effects reaching sustainability	
	IC25: Knowledge and information	The availability of educational guidelines for waste sorting	
Persuasive Communication	IC26: Social argument	Social messages emphasizing the behavior contributing to better waste sorting	[2,16,21,27,28]
	IC27: Content-type	The types of information available for the public to participate in household waste sorting	
	IC28: Source of information	The validity and trustworthiness of source information for improving waste sorting	
	IC29: Credibility	Communicator's positive characteristics and the credibility of information available to the public	
	IC30: Education campaign	Initiatives to educate the public on the importance of household waste sorting	

Table A2. Demographic information of the experts.

Expert	Position	Gender	Age	Education	Experience in Waste Management
1	Director/Plastic recycling company/	Male	41	Master's	3
2	Founder of recycling association	Male	51	Ph.D.	20
3	Researcher/University/	Female	50	Ph.D.	4
4	Researcher/NGO */	Male	29	Master's	3
5	Director/Paper recycling company/	Female	38	Bachelor's	3
6	Researcher/University/	Female	59	Ph.D.	10
7	Researcher/NGO/	Female	34	Master's	10
8	Researcher/NGO/	Female	35	Master's	3
9	Director/Biotechnology company/	Male	40	Bachelor's	10
10	Researcher/University/	Female	48	Master's	10
11	Project manager/Waste recycling plant/	Male	44	Master's	20
12	Director/Ministry/	Male	38	Master's	15
13	Project manager/Plastic recycling company/	Female	26	Master's	10
14	Project manager/Paper recycling company/	Female	36	Master's	3
15	Director/NGO/	Female	45	Bachelor's	3
16	Founder/NGO/	Female	28	Bachelor's	3
17	Director/NGO/	Female	65	Ph.D.	6
18	Director/Waste recycling company/	Female	32	Master's	3
19	Project leader	Male	38	Bachelor's	3
20	Project manager	Male	34	Bachelor's	6
21	Director/Glass and synthetic waste recycling company/	Male	36	Bachelor's	6
22	Project manager/Glass and synthetic waste recycling company/	Female	39	Master's	6
23	Project leader/recycling of association/	Female	43	Master's	3
24	Director/waste collection company/	Female	49	Master's	6
25	Researcher/University/	Female	62	Ph.D.	10
26	Member of recycling association	Female	30	Master's	6
27	Member recycling of association	Male	40	Master's	15

* NGO = Nongovernmental organization.

Table A3. Defuzzification Procedure from expert 1.

	A1	A2	A3	A4	A5
A1	[1.00 1.00 1.00]	[0.30 0.50 0.70]	[0.70 0.90 1.00]	[0.70 0.90 1.00]	[0.70 0.90 1.00]
A2	[0.30 0.50 0.70]	[1.00 1.00 1.00]	[0.50 0.70 0.90]	[0.30 0.50 0.70]	[0.70 0.90 1.00]
A3	[0.70 0.90 1.00]	[0.50 0.70 0.90]	[1.00 1.00 1.00]	[0.70 0.90 1.00]	[0.70 0.90 1.00]
A4	[0.70 0.90 1.00]	[0.30 0.50 0.70]	[0.50 0.70 0.90]	[1.00 1.00 1.00]	[0.70 0.90 1.00]
A5	[0.70 0.90 1.00]	[0.70 0.90 1.00]	[0.70 0.90 1.00]	[0.70 0.90 1.00]	[1.00 1.00 1.00]
	$s\tilde{z}^f_{lij}$ $s\tilde{z}^f_{mij}$ $s\tilde{z}^f_{uij}$	$s\tilde{z}^f_{lij}$ $s\tilde{z}^f_{mij}$ $s\tilde{z}^f_{uij}$	$s\tilde{z}^f_{lij}$ $s\tilde{z}^f_{mij}$ $s\tilde{z}^f_{uij}$	$s\tilde{z}^f_{lij}$ $s\tilde{z}^f_{mij}$ $s\tilde{z}^f_{uij}$	$s\tilde{z}^f_{lij}$ $s\tilde{z}^f_{mij}$ $s\tilde{z}^f_{uij}$
A1	[1.00 0.71 0.43]	[0.00 0.00 0.00]	[0.40 0.40 0.20]	[0.57 0.57 0.43]	[0.00 0.00 0.00]
A2	[0.00 0.00 0.00]	[1.00 0.71 0.43]	[0.00 0.00 0.00]	[0.00 0.00 0.00]	[0.00 0.00 0.00]
A3	[0.57 0.57 0.43]	[0.29 0.29 0.29]	[1.00 0.60 0.20]	[0.57 0.57 0.43]	[0.00 0.00 0.00]
A4	[0.57 0.57 0.43]	[0.00 0.00 0.00]	[0.00 0.00 0.00]	[1.00 0.71 0.43]	[0.00 0.00 0.00]
A5	[0.57 0.57 0.43]	[0.57 0.57 0.43]	[0.40 0.40 0.20]	[0.57 0.57 0.43]	[1.00 0.33 0.00]
	S^f_{ltij} S^f_{rtij}	S^f_{ltij} S^f_{rtij}	S^f_{ltij} S^f_{rtij}	S^f_{ltij} S^f_{rtij}	S^f_{ltij} S^f_{rtij}
A1	1.00 0.60	0.00 0.00	0.40 0.25	0.57 0.50	0.00 0.00
A2	0.00 0.00	1.00 0.60	0.00 0.00	0.00 0.00	0.00 0.00
A3	0.57 0.50	0.29 0.29	1.00 0.33	0.57 0.50	0.00 0.00
A4	0.57 0.50	0.00 0.00	0.00 0.00	1.00 0.60	0.00 0.00
A5	0.57 0.50	0.57 0.50	0.40 0.25	0.57 0.50	1.00 0.00

Table A3. *Cont.*

	A1	A2	A3	A4	A5
	$\tilde{w}_{ij}^{f}$	$\tilde{w}_{ij}^{f}$	$\tilde{w}_{ij}^{f}$	$\tilde{w}_{ij}^{f}$	$\tilde{w}_{ij}^{f}$
A1	0.60	0.00	0.36	0.53	0.00
A2	0.00	0.60	0.00	0.00	0.00
A3	0.53	0.29	0.33	0.53	0.00
A4	0.53	0.00	0.00	0.60	0.00
A5	0.53	0.53	0.36	0.53	1.00
	w_{ij}^{f}	w_{ij}^{f}	w_{ij}^{f}	w_{ij}^{f}	w_{ij}^{f}
A1	0.72	0.30	0.68	0.67	0.70
A2	0.30	0.72	0.50	0.30	0.70
A3	0.67	0.50	0.67	0.67	0.70
A4	0.67	0.30	0.50	0.72	0.70
A5	0.67	0.67	0.68	0.67	1.00

Table A4. Total Interrelationship Matrix of Aspects.

	A1	A2	A3	A4	A5	D
A1	2.012	1.816	2.053	1.911	2.218	10.011
A2	1.819	1.877	1.908	1.857	2.156	9.617
A3	2.073	1.924	2.188	2.031	2.347	10.563
A4	1.924	1.876	2.021	2.022	2.253	10.096
AS5	2.197	2.124	2.298	2.211	2.544	11.374
R	10.025	9.617	10.468	10.032	11.519	

Table A5. Total Interrelationship Matrix of Criteria.

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	D
C1	1.09	1.04	1.02	1.05	1.00	1.06	0.70	0.96	1.13	0.87	1.09	1.13	0.95	1.07	1.08	1.15	1.12	17.51
C2	1.06	1.03	0.99	1.03	0.99	1.03	0.68	0.95	1.11	0.85	1.06	1.10	0.94	1.05	1.05	1.13	1.09	17.13
C3	0.99	0.95	0.94	0.95	0.91	0.96	0.63	0.89	1.03	0.80	0.99	1.03	0.88	0.97	0.98	1.05	1.01	15.95
C4	1.08	1.05	1.00	1.07	1.02	1.07	0.72	0.96	1.14	0.88	1.10	1.14	0.97	1.09	1.10	1.16	1.13	17.69
C5	1.06	1.02	0.98	1.04	1.02	1.06	0.71	0.95	1.12	0.87	1.08	1.12	0.97	1.07	1.07	1.14	1.11	17.38
C6	1.11	1.06	1.03	1.07	1.05	1.10	0.73	0.98	1.16	0.89	1.12	1.16	0.99	1.11	1.12	1.17	1.15	18.00
C7	0.98	0.94	0.92	0.94	0.91	0.95	0.63	0.88	1.02	0.79	0.97	1.01	0.86	0.97	0.97	1.04	1.01	15.80
C8	0.95	0.92	0.90	0.91	0.88	0.93	0.61	0.87	0.99	0.77	0.95	0.98	0.83	0.94	0.94	1.01	0.98	15.35
C9	1.12	1.08	1.05	1.09	1.05	1.11	0.72	1.00	1.18	0.90	1.13	1.17	1.00	1.12	1.13	1.19	1.16	18.18
C10	0.91	0.87	0.85	0.88	0.86	0.89	0.60	0.82	0.96	0.77	0.91	0.95	0.81	0.91	0.91	0.97	0.94	14.81
C11	1.11	1.06	1.03	1.08	1.04	1.09	0.74	0.97	1.15	0.88	1.12	1.15	0.99	1.11	1.11	1.18	1.15	17.95
C12	1.11	1.06	1.03	1.08	1.04	1.09	0.72	0.97	1.16	0.90	1.10	1.16	1.00	1.11	1.11	1.18	1.14	17.96
C13	1.04	1.00	0.98	1.03	1.00	1.03	0.71	0.92	1.09	0.84	1.05	1.09	0.99	1.05	1.05	1.12	1.08	17.07
C14	1.09	1.06	1.02	1.07	1.04	1.08	0.72	0.98	1.16	0.89	1.11	1.16	0.99	1.11	1.11	1.17	1.14	17.90
C15	1.10	1.06	1.02	1.08	1.04	1.09	0.72	0.98	1.16	0.90	1.12	1.16	0.99	1.11	1.12	1.18	1.15	17.96
C16	1.13	1.08	1.05	1.10	1.05	1.10	0.73	1.00	1.18	0.91	1.13	1.18	1.01	1.13	1.13	1.20	1.17	18.31
C17	1.13	1.09	1.05	1.11	1.06	1.11	0.73	1.00	1.18	0.92	1.14	1.18	1.01	1.13	1.14	1.20	1.17	18.36
R	18.05	17.36	16.85	17.60	16.96	17.75	11.79	16.08	18.92	14.61	18.17	18.87	16.18	18.08	18.13	19.22	18.69	

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