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# Assessing Household's Solid Waste Segregation Behavior in the City of Nepal: A Structural Equation Modeling Approach

***Umesh Khadka***

Department of Economics and Mathematics,
Janta Multiple Campus,
Itahari, Sunsari, Nepal
Corresponding Author:
umeshkhadka91@gmail.com

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## Abstract

**Background:** In the context of rapid urbanization and rising municipal solid waste generation, solid waste segregation is crucial for effective management; however, poorly researched behavioral issues in the developing world, including Nepal, hinder its implementation.

**Purpose:** This research examines the psychological, social, and ethical drivers of household waste-segregation behavior in Itahari Sub-Metropolitan City, utilizing a combined framework that integrates the Extended Theory of Planned Behavior (ETPB) and the Norm Activation Model (NAM).

**Design/methodology/approach**: A cross-sectional survey was conducted, in which 502 households were chosen by using stratified random sampling from urban and semi-urban wards. The Partial Least Squares Structural Equation Modeling (PLS-SEM) technique, using SmartPLS4, was employed to analyze both measurement and structural models.

**Findings:** Based on its findings, it has been observed that behavioral attitude, subjective norms, perceived control over behavior, moral obligation, and moral obligation judgment play a critical role in determining the willingness to segregate waste, which, in turn, significantly influences the observability of segregation behavior. Knowledge of environmental outcomes has no substantive effect on intention. It does not have a positive impact on behavior, but a weak yet significant negative relationship with practice indicates the existence of an awareness-behavior gap. These findings underscore the importance of developing moral responsibility, social norms, and perceived self-efficacy rather than relying solely on awareness-based interventions.

**Conclusion:** The paper thus concludes that sustainable household waste segregation behavior in Nepal can be promoted through culture-based, psychologically informed, and infrastructure-based initiatives that extend beyond typical educational campaigns.

**Keywords:** Solid waste, Segregation, Intention Behavior, PLS-SEM

# 1. Introduction

Any stuff that the property owner rejects as unwanted solid substances is considered solid waste material (Bhuiyan, 2010). The management of solid waste in the city is a pressing issue, particularly given its rapid growth and the increasing volume of waste being generated. (Goyal et al., 2020; Labra et al., 2024). Solid waste management encompasses the entire process of segregating, collecting, treating, and safely disposing of solid waste (Abdel-Shafy & Mansour, 2018; Hamer, 2003). The city's rapid urbanization, increasing industrial activities, extensive resource use, rural-urban migration, and high population growth have all contributed to a significant increase in solid waste generation in the city area (Olay-Romero et al., 2020; Singh, 2019). The continuous generation of municipal solid waste has become a severe problem in terms of quantity and variety. The United Nations Environment Programme & International Solid Waste Association (2019) predicted that municipal waste generation will increase from 2.1 million tonnes in 2023 to 3.8 million tonnes by 2050. The global cost of waste management was USD 252 billion in 2020, rising to USD 361 billion by 2023 and projected to grow to USD 640.3 billion by 2050.

Improper municipal solid waste management can lead to environmental contamination and pose serious health risks to the local community (Khadka, 2023). Inadequate solid waste management services are associated with high carbon emissions, environmental degradation, and health and safety concerns (Mor & Ravindra, 2023). Water, soil, and the atmosphere can become contaminated by inadequate solid waste management, leading to the spread of infectious diseases and unpleasant odors (Tian et al., 2013). Therefore, environmental concerns have become significant challenges for developed and developing countries. Effective solid waste management is critical to environmental sustainability, protecting public health, conserving natural resources, and reducing greenhouse gas emissions (Caicedo-Concha et al., 2021; Gautam & Agrawal, 2021).

The behavior of solid waste segregation plays a crucial role in effective management; however, segregation remains very low in developing countries like Nepal. Waste segregation involves categorizing waste into distinct groups: biodegradable, non-biodegradable, hazardous, and e-waste (ADB, 2011; Kong et al., 2023). When properly segregated, biodegradable waste can be composted to make organic fertilizers, reducing reliance on the import and use of chemical fertilizers (Chew et al., 2019; Wei et al., 2017). The segregation of solid waste at the source reduces contamination, which allows more efficient collection and transportation for further processing. Pre-collection segregation of solid waste significantly mitigates management costs by minimizing labor and infrastructure requirements for the collection, transport, and disposal of solid waste (Di Maria et al., 2016).

Developed countries have adopted the 3Rs (Reduce, Reuse, and Recycle) policies, recognizing the value of source segregation of solid waste for effective management. In contrast, developing countries struggle with poor waste management (Hye Chowdhury et al., 2014). The crucial obstacles to managing solid waste effectively in Itahari, a sub-metropolitan city, are the lack of source segregation of solid waste. The lack of segregation leads to significant environmental challenges, including increased land and water pollution through overloaded landfills. Sorting mixed waste after collection requires additional manpower and time, which increases the cost and logistical difficulties for solid waste management (Moh & Abd Manaf, 2017). The mix of non-biodegradable waste with general household waste increases the likelihood of disease transmission to the collectors and handlers (Nalwanga et al., 2023). The occupational health hazard posed by lacerations from sharp objects could be mitigated by properly implementing rigorous segregation protocols (Lambrechts & Hector, 2016).

Earlier studies conducted by Chang et al. (2011), Eriksson et al. (2005), Marshall & Farahbakhsh (2013), Nanda & Berruti (2021), and Sliusar et al. (2022) on solid waste management from a predominantly technical and infrastructural perspective often examined waste collection systems, disposal techniques, and recycling technologies. Similarly, Ayantoyinbo and Adepoju (2018), Bing et al. (2016), and Salman and Hasar (2023) have examined the logistical and administrative challenges of waste collection and disposal. Ikhlayel (2018), Nnorom & Osibanjo (2008), and Ziraba et al. (2016) have studied solid waste

management in developing countries, emphasizing policy frameworks, management systems, and the environmental impacts of improper waste disposal. This research investigated the behavioral factors that influence household-level waste segregation practices through observations of individual behavior, as well as social norms and psychological influences on proper waste separation at the source, within Nepal's unique cultural context. By analyzing behavioral motivations, including moral responsibility toward the environment, this research aims to understand the waste segregation practices of Itahari residents using traditional factors. This research examines behavior patterns related to waste source separation within the Nepalese context, enabling the development of culturally specific recommendations for policy and behavior change. The study establishes sustainable waste practice relationships through Structural Equation Modeling (SEM) to produce an empirical analysis with robust findings between linked variables. The study integrates behavioral constructs such as intention, moral norms, and environmental concern to analyze household waste segregation in a least developed country. It also contributes by providing empirical insights from Nepal, a setting that remains under-researched in terms of solid waste segregation behavior. Additionally, the study employs PLS-SEM to analyze the interrelationships among behavioral factors influencing waste segregation, thereby facilitating the formulation of evidence-based policies to promote effective household waste management.

# 2. Literature Review

The Extended Theory of Planned Behavior (ETPB) represents a significant theoretical expansion of the original Theory of Planned Behavior (TPB) developed by Ajzen. Some limitations of TPB in accounting for very complex pro-environmental behavior change are overcome by adding additional psychological and contextual layers. The ETPB thus encompasses components of moral norms (Schwartz, 1977), environmental concern (Stern, 2000), habitual processes (Verplanken & Orbell, 2003), and institutional factors (Bamberg & Möser, 2007) to provide a comprehensive conceptualization of sustainability behavior, including household waste segregation. This extension posits that environmental decision-making transcends rational cognitive processes by incorporating moral imperatives that create personal ethical obligations, affective environmental concerns that shape behavioral attitudes, automatic habitual responses that may bypass intentional processes, and perceived effectiveness of policy interventions that enhance behavioral control (Bagozzi, 1992). The theoretical propositions of ETPB are far-reaching in their significance and implications for research and practical applications in environmental management. From a policy perspective, the model suggests that sustainable waste management strategies should be implemented to address cognitive (awareness campaigns), normative (moral appeals), infrastructural (consistent service provision), and institutional (policy enforcement) factors, thereby promoting sustainable behavioral change (Heidari et al., 2018). ETPB provides environmental researchers with a robust analytical framework, especially useful in developing-world contexts such as Nepal, where the complex interplay among cultural values, inadequate infrastructure, and weak policy implementation shapes overall waste segregation behavior (Mensah, 2020). ETPB is theoretically and practically meaningful as the model can highlight the multidimensional nature of pro-environmental behavior in complex socio-environmental systems (Le Dinh et al., 2024). In the present study, constructs such as environmental concern, moral norms, and perceived behavioral control are expected to influence the intention to segregate household waste. So ETPB provides the theoretical framework for examining household waste segregation behavior.

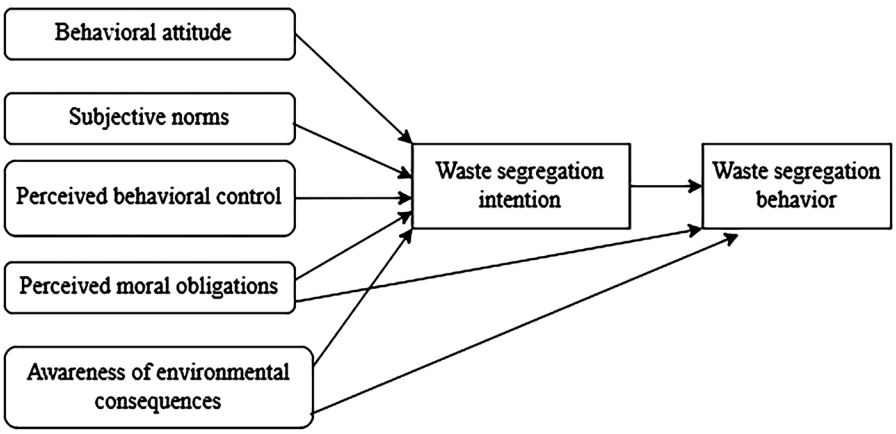
### *Norm activation model (NAM)*

The Norm Activation Model (NAM), developed by Schwartz (1977), provides a framework for elucidating the multifaceted processes of prosocial behavior, particularly in moral decision-making. The model posits that individuals engage in prosocial actions because they adhere to moral norms and become active when others require assistance or identify opportunities to promote public benefits (Gao et al., 2017). The activation process for moral responses relies on a step-by-step mental and emotional evaluation, which begins with understanding the effects of one's activities before assuming accountability and responsibility (Kiatkawsin et al., 2020). Individuals who demonstrate awareness of consequences understand how their

behaviors affect others or the environment, positively or negatively. At the same time, the ascription of responsibility represents the internal drive to act despite situational limitations or the diffusion of accountability (Joanes, 2018). People who confront the damaging effects of their actions and accept the need to prevent those effects become driven to take environmentally responsible actions (Kollmuss & Agyeman, 2002). Environmental psychology uses the NAM extensively to explain individual behaviors related to recycling, energy management, waste sorting, and the adoption of sustainable practices (Xuan et al., 2023). This theory is significant because it demonstrates how people make decisions by considering moral standards, a factor that standard decision models often overlook. The NAM demonstrates how ethics embedded within people help guide sustainable conduct, thus guiding practical efforts when external rules are weak, yet societal rules are influential (Han, 2014). In this context, awareness of consequences and moral norms is proposed to shape an individual's sense of responsibility, thereby increasing the intention to segregate waste.

Both ETPB and NAM suggest that intention acts as an intermediary process through which psychological, moral, and contextual determinants of waste segregation behavior. Figure 1 systematically presents the conceptual framework underpinning this research. The conceptual framework outlines the hypothesized relationship between the key constructs.

Figure 1: Conceptual framework




## Hypothesis formulation

### Waste segregation behavior

Waste segregation is the process of categorizing waste into distinct types, such as organic, recyclable, hazardous, and non-recyclable materials, at the point of origin (Moura et al., 2018). This behavior plays a significant role in optimizing waste management systems, reducing environmental pollution, and recovering resources through increased recycling and composting. From a psychological and behavioral perspective, waste segregation behavior is determined by various internal and external factors. The Extended Theory of Planned Behavior (ETPB) suggests that a person's behavior is primarily determined by their prospective actions, which in turn are influenced by their attitudes toward the behavior, norms about the behavior, and their perceived implications for the behavior (Mirhashemi et al., 2020). When individuals have a positive attitude toward segregating waste, perceive social support for the practice, and feel capable of dividing up the waste effectively, they are more likely to adopt this behavior (Knickmeyer, 2020). More importantly, based on the Norm Activation Model (NAM), moral factors such as perceived moral obligations and awareness of environmental effects influence people's waste segregation behavior(Setiawan et al., 2020). Individuals with a strong sense of moral responsibility and an understanding of the environmental benefits of proper waste segregation tend to be more environmentally conscious and exhibit strong behavior towards waste segregation (Savari et al., 2023).

**Behavioral attitude**

Behavioral attitudes encompass psychological characteristics, including thoughts, emotions, and actions, that reflect personal inclinations (Bagozzi, 1992). Behavioral science and social psychology utilize attitudes as evaluative tendencies that shape how people perceive and interact with environmental stimuli (Chaiklin, 2011). Throughout the Extended Theory of Planned Behavior (ETPB) framework, behavioral attitude is the fundamental element that shows how people evaluate their intention to perform a specific action, either positively or negatively (Teo et al., 2016). Household waste segregation behavioral attitude includes both mental perceptions and emotional evaluations of waste separation procedures for proper handling (Barr, 2017). The perception that waste segregation yields benefits in both personal and social realms fosters positive attitudes toward waste management practices.

H1: Behavioral attitude positively influences the household waste segregation intention

**Subjective norms**

Subjective norms within the Extended Theory of Planned Behavior framework assess the influence of significant social reference groups, including family members, friends, neighbors, and broader community groups, on the formation of behavioral intentions. (White et al., 2009). Face-to-face communication about household waste segregation demonstrates how strongly people respect or care about being expected to separate their waste correctly. People who sense that essential community members support waste segregation tend to adopt their expectations, thereby strengthening their motivation to engage in waste segregation behavior (Hu et al., 2021). Subjective norms lead to behavioral change through external social pressure, personal values, and identity development (Terry et al., 1999). The formation of intentions occurs through interactions between subjective norms and personal factors, which comprise beliefs about behavioral control and moral obligation (Åstrøsm & Rise, 2001). People who face social pressure and consider themselves capable of sorting waste exhibit stronger intentions to segregate garbage than those who are only affected by social pressure (McNeill & Venter, 2019).

H2: Subjective norms have a positive effect on waste segregation intention

**Perceived behavioral control**

Perceived behavioral control, a core construct of ETPB, reflects the individual's beliefs in their ability to perform a waste segregation behavior based on their skills and available resources (Ayob et al., 2017). A person determines the difficulty associated with solid waste behavior through past experiences, anticipated challenges, and available resources (Agwu, 2012). People who consider waste segregation an easy task and possess sufficient understanding, access to various waste bins, and the time to perform these actions are more likely to develop stronger intentions to participate (McNeill & Venter, 2019).

H3: Perceived behavioral control has a positive effect on waste segregation intention

**Perceived moral obligations**

Perceived moral obligation refers to a person's internal sense of duty or responsibility to act in accordance with their personal moral principles, even in the absence of external pressure (Gorsuch & Ortberg, 1983). In the context of environmental behavior, it demonstrates the internal feelings that drive environmental responsibility, such as segregating waste, based on personal conviction rather than compliance with social norms or convenience (Vijayan et al., 2023). In the norm activation model, individuals promote moral responsibility as a fundamental internal standard after recognizing the environmental effects of their conduct and adopting oversight for these effects (Zhu et al., 2024). People who strongly believe in their moral responsibilities tend to maintain environmental responsibility without requiring strong social support or a high perceived level of behavioral control (Stern et al., 2012). Moral obligation serves in dual roles, as it initiates intentions and motivates people to act independently.

H4: Higher perceived moral obligations to protect the environment positively influence waste segregation intention

H5: Perceived moral obligations directly influence waste segregation behavior

**Awareness of environmental consequences**

Knowledge of environmental damage resulting from inadequate waste-disposal practices strongly motivates individuals to practice waste segregation (Sparks & Shepherd, 2002). People have become more appreciative of responsible waste management after becoming aware of the effects of pollution on air, water, and soil degradation, as well as resource depletion, biodiversity loss, and environmental harm and health issues resulting from improper waste disposal (Borusiak et al., 2021). People who understand the harms of waste disposal will initiate a cognitive sequence by recognizing waste segregation as a crucial protection against environmental damage, thereby activating their values and moral responsibility for environmental conservation (López-Mosquera et al., 2014). The fundamental knowledge about waste segregation remains essential yet insufficient to achieve consistent waste segregation practices, as adequate infrastructure, supportive social norms, enabling policies, and established habits must also be in place.

H6: Awareness of environmental consequences positively influences waste segregation intention
H7: Awareness of environmental consequences positively influences waste segregation behavior

**Solid waste segregation intention**

Intention is a predictor of behavior in the extended theory of planned behavior, and it is crucial for enhancing solid waste segregation behavior (Stern et al., 2012). Without a strong intention to segregate solid waste, people are unlikely to take the necessary steps for proper management. Intention links behavioral attitudes, subjective norms, perceived behavioral control, moral obligations, and environmental awareness to waste segregation behavior (Fikadu et al., 2022). Numerous studies (Stern et al., 1985; Wang et al., 2021; Zhu et al., 2024) have consistently demonstrated significant interrelationships between behavioral outcomes and key psychological variables, including behavioral intention, subjective norms, perceived behavioral control, moral obligation, and awareness.

H8: Waste segregation intention has a significant positive effect on waste segregation behavior
H9: The intention to segregate waste positively mediates the relationship between behavioral attitude and solid waste segregation behavior.
H10: The intention to segregate waste positively mediates the relationship between subjective norms and solid waste segregation behavior.
H11: Waste segregation intention positively mediates the relationship between perceived behavioral control and solid waste segregation behavior.
H12: The intention to segregate waste positively mediates the relationship between perceived moral obligation and the behavior of segregating solid waste.
H13: The intention to segregate waste positively mediates the relationship between awareness of environmental consequences and the behavior of segregating solid waste.

Table 1: Constructs and variables included in the research

| Constructs | Item notation | Items description | References |
|---|---|---|---|
| Waste segregation behavior | SB3 | I maintain separate bins or containers | Metcalfe et al. (2012); Moeini et al. (2023) |
| | SB4 | I follow waste segregation guidelines. | |
| | SB5 | I practice a new waste segregation habit. | |
| | SB6 | I have a daily routine to segregate waste. | |
| | SB8 | I learn about new waste segregation techniques. | |
| Waste segregation intention | SI1 | I intend to separate my household waste soon | Akmal et al. (2023); Cheng et al. (2020) |
| | SI3 | I will encourage others to segregate waste. | |
| | SI4 | We plan to separate solid waste for recycling. | |
| | SI5 | I intend to segregate waste to protect the environment. | |
| | SI7 | I intend to separate waste into appropriate categories. | |

| | | | |
|---|---|---|---|
| Behavioral attitude | BA1 | Waste separation conserves resources and the environment | Xu et al. (2017) |
| | BA3 | Separating waste at the source is a moral responsibility. | |
| | BA4 | Separating waste before disposal is necessary. | |
| Subjective norms | SN1 | Most people who are important to me think I should do waste separation | Razali et al. (2020) |
| | SN2 | Most people who are important to me would approve of my waste separation behavior. | |
| | SN6 | I believe that society values individuals who engage in waste segregation. | |
| Perceived behavioral control | PBC1 | I will separate solid waste at its source if I have the necessary resources to segregate my waste effectively. | Trushna et al. (2024) |
| | PBC2 | I will separate solid waste at its source if I experience regular solid waste collection services. | |
| | PBC3 | If I understand the different components within our waste stream, I will separate solid waste at its source. | |
| | PBC4 | I will separate solid waste at its source for recycling purposes if we receive an incentive. | |
| | PBC7 | I feel confident in my ability to follow waste segregation guidelines. | |
| Perceived moral obligations | PMO1 | I separate waste as a matter of responsibility to protect the environment. | Lou et al. (2020) |
| | PMO2 | Waste separation behavior is a virtue. | |
| | PMO3 | I would feel guilty if I did not separate waste properly. | |
| | PMO5 | I believe that segregating waste is essential for the well-being of future generations. | |
| | PMO6 | I believe that failing to segregate waste has negative environmental consequences. | |
| Awareness of environmental consequences | AEC1 | I am aware that improper waste segregation can lead to significant environmental harm. | Cheng et al. (2020); Lou et al. (2020) |
| | AEC2 | I realize that poor waste management contributes to climate change. | |
| | AEC3 | I understand that improper waste disposal can lead to long-term environmental damage. | |
| | AEC4 | I am conscious that mixed waste in landfills contaminates soil and groundwater. | |
| | AEC5 | I am aware that mixed waste creates unpleasant odors in my community. | |

## Methodology

### Research Design

The study adopts a cross-sectional quantitative analysis using survey data to investigate how various factors influence households' engagement in proper waste disposal practices in urban areas of Nepal. This research design allows the researcher to collect data systematically and simultaneously. The research applies deductive reasoning to examine the hypotheses proposed based on the Extended Theory of Planned Behavior and the Norm Activation Model. SEM is applied to evaluate both the measurement

and structural relationships between latent variables. Partial Least Squares Structural Equation Modeling (PLS-SEM) was selected because the study focuses on prediction, theory extension, and the assessment of complex relationships among multiple latent constructs, which are more appropriately handled by PLS-SEM than by covariance-based SEM (CB-SEM).

**Study Area and Population**

The study examined household waste segregation in Itahari Sub-Metropolitan City, a rapidly growing urban center in eastern Nepal. Itahari is a rapidly growing urban center strategically located at the intersection of the East-West Highway and the Koshi Highway. It is a vital commercial and transit hub, connecting the Terai, Hill, and Himalayan regions. The study includes the households from wards 1, 6, 10, 14, and 20 of the Itahari sub-metropolitan city. These wards are purposefully selected to capture the municipality's socio-economic, demographic, and spatial diversity. Wards 6 and 20 are the core urban areas, characterized by high population density, busy commercial zones, and high levels of waste generation. Where the waste management system is more formalized and accessible. On the contrary, Wards 1, 10, and 14 were typical rural and peri-urban areas, representing cases of dispersed settlements with limited functioning waste management services. By introducing households from both urban and rural areas, the study can analyze household waste segregation practices across different environmental and infrastructural contexts. The city serves as an ideal case study to examine the factors influencing the waste segregation behavior of urban households, thereby informing the development of effective policies and interventions to promote sustainable urban waste management.

**Sampling**

Rapid population growth and urbanization have driven up household consumption, leading to increased waste generation and higher demands for city infrastructure in waste management. However, residents' poor solid waste segregation behavior has impeded the city's waste management operations. The city was selected for this research as it reflects a range of population characteristics, rapid urbanization, and urgent demand for innovative approaches to managing waste. The multistage sampling method was employed to select the sample households for studying segregation behavior. Initially, Itahari, a sub-metropolitan city, was selected because it faces growing challenges in waste management due to its expanding business and increasing population trends. To represent the core city and rural areas, wards 1, 6, 10, 14, and 20 are chosen. The national population census 2021 reported 2,484, 1,846, 1,772, 1,440, and 3,320 households, respectively, with a total population of 10,641, 7,252, 6,779, 6,266, and 13,098. At first, 502 households were determined as the sample size by using the formula developed by Joskow & Yamane (1965), . The sampling interval is determined as $k = N/n = 10862/502 = 21.62 \sim 22$. Then, taking each ward as a stratum, sample units are chosen using systematic random sampling at intervals of 22$^{nd}$ households based on the record of the municipality office. The list of households was obtained directly from the official municipal household registration records provided by the Itahari Sub-Metropolitan City Office. These ward-level household lists included updated address codes and household IDs, enabling the researcher to draw samples systematically and avoid duplication.

**Data Collection Tools and Techniques**

To analyze the behavior of solid waste segregation, this study collected primary data through a meticulously structured survey questionnaire that employed the Extended Theory of Planned Behavior (ETPB) and the Norm Activation Model (NAM). The instrument is designed to measure the effects of various factors on solid waste segregation behavior in urban areas of Nepal. The questionnaire comprised both closed-ended categorical questions for socio-demographic profiling and Likert-scale statements (5-point scale ranging from 1 = *Strongly Disagree* to 5 = *Strongly Agree*) to capture latent constructs. The five latent constructs that appeared on the questionnaire were Behavioral Attitude (BA), Subjective Norms (SN), Perceived Behavioral Control (PBC), Perceived Moral Obligation (PMO), and Awareness of Environmental Consequences (AEC). Before being used in the study, all constructs were formed and validated through a literature review, expert guidance, and a pilot survey conducted with 30 households from a nearby community. Data were collected using face-to-face household surveys conducted by trained enumerators.

## Data Analysis

Due to the high correlation between the indicators of the same latent variable, the model comprises seven composite variables. The PLS-SEM is the most suitable method for estimating composite variables. The proposed model of this study is estimated by using the software SmartPLS4. A bootstrapping procedure with 10000 subsamples was performed to test the hypothesis.

## Result and discussion

### Socio-demographic and economic characteristics

In this study, 502 household representatives participated, yielding a 100% response rate. The age category, whether the respondent is a household head or not, and the respondent's education level are presented in Table 2.

Table 2: Socio-demographic classification of respondents

| Category | Subgroup | Female | | Male | | Total | |
|---|---|---|---|---|---|---|---|
| | | Freq. | % | Freq. | % | Freq. | % |
| Age Group | Less than 18 | 22 | 4.38 | 13 | 2.59 | 35 | 6.97 |
| | 19–30 | 80 | 15.94 | 57 | 11.35 | 137 | 27.29 |
| | 31–45 | 44 | 8.76 | 79 | 15.74 | 123 | 24.50 |
| | 46–60 | 54 | 10.76 | 98 | 19.52 | 152 | 30.28 |
| | Above 60 | 33 | 6.57 | 22 | 4.38 | 55 | 10.96 |
| Household Head | Not Head | 112 | 22.31 | 68 | 13.55 | 180 | 35.86 |
| | Head | 121 | 24.10 | 201 | 40.04 | 322 | 64.14 |
| Education Level | Illiterate | 12 | 2.39 | 23 | 4.58 | 35 | 6.97 |
| | Basic (Grades 1–8) | 72 | 14.34 | 37 | 7.37 | 109 | 21.71 |
| | Secondary (Grades 9–12) | 91 | 18.13 | 97 | 19.32 | 188 | 37.45 |
| | Bachelor | 41 | 8.17 | 43 | 8.57 | 84 | 16.73 |
| | Master and Above | 17 | 3.39 | 69 | 13.75 | 86 | 17.13 |
| | **Total** | 233 | 46.41 | 269 | 53.59 | 502 | 100.00 |

Source: Author's calculation

The socio-demographic characteristics of the respondents (n = 502) reveal a moderately male-dominant population, with 53.59% and 46.41% of the participants being male and female, respectively, in this study. Most are within the economically active age brackets, with the highest percentage of 30.28 in the 46-60 age group, 27.29 in the 19-30 age group, and 24.50 in the 31-45 age group. The underrepresentation of the youngest (<18 years) and oldest (>60 years) cohorts is 6.97% and 10.96%, respectively. Male dominance in household headship is also evident, as 64.14% of the respondents are household heads, 40.04% are male, and 24.10% are female, indicating the dominant role of this gender in household leadership. The level of education is relatively high: 37.45% of participants completed secondary education, 16.73% have a bachelor's degree, and 17.13% have a master's or higher degree, indicating a significant proportion of highly educated individuals. It is also worth noting that 6.97 percent of the respondents are illiterate, which is slightly higher in males at 4.58 percent compared to 2.39 % in females. Such demographic patterns indicate a well-developed and educated sample, with a balanced gender mix, and can be used to examine behavioral, socio-economic, and policy-relevant phenomena, as well as present indicators of structural imbalance in education and household heads, which can influence the attitudes and views of people and their social relationships.

Table 3: Profession of the respondent and household income

| Variable | Category | Frequency | Percent (%) |
|---|---|---|---|
| Profession | Agriculture | 128 | 25.50 |
| | Business | 96 | 19.12 |
| | Government Service | 45 | 8.96 |
| | Private Employee | 91 | 18.13 |
| | Housewife | 47 | 9.36 |
| | Retired | 68 | 13.55 |
| | Student | 27 | 5.38 |
| Monthly Household Income | Less than USD 100 | 24 | 4.78 |
| | USD 101–200 | 130 | 25.90 |
| | USD 201–500 | 171 | 34.06 |
| | USD 501–1000 | 134 | 26.69 |
| | More than USD 1000 | 43 | 8.57 |

Source: Author's calculation

Note: USD 1 is equivalent to Rs 138.

The occupational breakdown of the respondents indicates that 25.50 percent are in the agricultural sector, showing that there is still reliance on agriculture for livelihoods in the study region. This is due to the representation of respondents from rural areas. The business activities (19.12%) and employment in the private sector (18.13%) are also significant, indicating moderate diversification towards entrepreneur-type urban employment and wage-based persons. Formal sector integration is constrained and stable, as the government service is at 8.96%. Female homemakers (9.36%) and retired people (13.55%) are the factors that support the range of non-working people and those above working age. By contrast, a relatively small portion (5.38 percent) belongs to students, which could be attributed to the adult-geared nature of the sample. In the case of monthly household income, the large group of respondents (34.061%) reports monthly salaries of USD 201-500, followed closely by 26.691% in the USD 501-1000 category, which means that more than 6 out of 10 households have a lower-middle-income status. There is a relatively low percentage of high-income households, with a quarter of the sample reporting incomes between USD 101 and USD 200, and 8.57 percent stating that their incomes are above USD 1000 per month. However, on the other hand, fewer than 5% of those earning below USD 100 may imply that this group is underrepresented in the expressed demographics of extreme income deprivation. Household income and occupational analysis indicate mixed livelihoods and emerging diversification beyond subsistence farming. The findings offer valuable insights into socio-economic heterogeneity, which is crucial for understanding the impact of behavioral, policy, or development-related interventions.

**Inferential statistics**

This study used structural equation modeling (SEM), a statistical method, to examine the interactive relationship between variables. Partial least squares structural equation modeling is a valuable method for researchers who aim to explore the complex relationships among variables. PLS-SEM algorithm calculates the structural and measurement model relationship separately through ordinary least squares regression.

**Assessment of the measurement model**

The first step in testing the theoretical model in the PLS-SEM is to assess the measurement or outer model. To evaluate the measurement model, we have to test its reliability and validity (Hair et al., 2012). Table 5 presents the results of the reliability and validity of the seven key constructs related to waste segregation behavior. Item consistency is measured through the outer loadings, and the threshold for item loadings is greater than 0.7 (Hair et al., 2017). The result of the item loadings demonstrates a strong association between the questionnaire and its intended constructs, as all the outer loadings values exceed the threshold values. Internal consistency reliability was confirmed through Cronbach's Alpha and Composite Reliability (CR). The Cronbach's Alpha values ranged from 0.731 to 0.836, and the CR values ranged from 0.803 to 0.884, all exceeding the recommended threshold of 0.70 suggested by Hair et al. (2017) and Shmueli et al. (019). This result demonstrates a high level of consistency among the indicators for each construct. The convergent validity was assessed through the average variance extracted (AVE). AVE reflected the average commonality of each construct, and AVE should be greater than 0.5 for all latent variables. Table 5 demonstrates that the AVE of each construct exceeds the 0.050 benchmark suggested by Sarstedt et al. (2014), confirming strong convergent validity. This indicates that each construct successfully explains a significant proportion of the variance and its indicators.

Table 4: Items loading, composite reliability, and average variance explained

| Constructs | Item notation | Loadings (>0.70) | Cronbach's Alpha | Composite Reliability | AVE (>0.50) |
|---|---|---|---|---|---|
| Waste segregation behavior | SB3 | 0.715 | 0.789 | 0.852 | 0.535 |
| | SB4 | 0.752 | | | |
| | SB5 | 0.726 | | | |
| | SB6 | 0.711 | | | |
| | SB8 | 0.750 | | | |
| Waste segregation intention | SI1 | 0.728 | 0.814 | 0.870 | 0.574 |
| | SI3 | 0.730 | | | |
| | SI4 | 0.725 | | | |
| | SI5 | 0.787 | | | |
| | SI7 | 0.813 | | | |
| Behavioral attitude | BA1 | 0.832 | 0.794 | 0.879 | 0.708 |
| | BA3 | 0.842 | | | |
| | BA4 | 0.851 | | | |
| Subjective norms | SN1 | 0.787 | 0.731 | 0.803 | 0.576 |
| | SN2 | 0.750 | | | |
| | SN6 | 0.738 | | | |
| Perceived behavioral control | PBC1 | 0.760 | 0.800 | 0.861 | 0.553 |
| | PBC2 | 0.748 | | | |
| | PBC3 | 0.790 | | | |
| | PBC4 | 0.712 | | | |
| | PBC7 | 0.704 | | | |
| Perceived moral obligations | PMO1 | 0.799 | 0.803 | 0.862 | 0.556 |
| | PMO2 | 0.752 | | | |
| | PMO3 | 0.741 | | | |
| | PMO5 | 0.717 | | | |
| | PMO6 | 0.719 | | | |
| Awareness of environmental consequences | AEC1 | 0.794 | 0.836 | 0.884 | 0.605 |
| | AEC2 | 0.743 | | | |
| | AEC3 | 0.822 | | | |
| | AEC4 | 0.781 | | | |
| | AEC5 | 0.745 | | | |

Source: Author's calculation

In sum, these findings are comprehensive enough to convince an audience that all the research constructs are measured with adequate reliability and validity, which forms a strong baseline for analyzing their correlations.

**Discriminant validity**

Discriminant validity represents the degree to which the constructs in a measurement model are empirically different. It confirms that the items of each construct measure different concepts and are not overlapping or redundant. The HTMT criterion is appreciated for its ability to predict discriminant validity issues, particularly in complex models and when there is a high correlation among constructs (Wong, 2019). This conservative threshold is widely recommended for conceptually distinct constructs, especially when they are theoretically very similar. Discriminant validity is established if the HTMT value between any two constructs is below 0.85 (Guenther et al., 2023).

Table 5: Heterotrait-Monotrait ratio (HTMT) & Fornell-Larcker criterion

| Constructs | BA | SN | PBC | PMO | AEC | SI | SB |
|---|---|---|---|---|---|---|---|
| BA | **0.842** | 0.366 | 0.681 | 0.757 | 0.745 | 0.607 | 0.333 |
| SN | 0.259 | **0.759** | 0.697 | 0.654 | 0.518 | 0.747 | 0.651 |
| PBC | 0.542 | 0.499 | **0.744** | 0.834 | 0.718 | 0.692 | 0.502 |
| PMO | 0.590 | 0.486 | 0.702 | **0.746** | 0.819 | 0.707 | 0.518 |
| AEC | 0.605 | 0.376 | 0.599 | 0.703 | **0.778** | 0.610 | 0.322 |
| SI | 0.485 | 0.540 | 0.582 | 0.585 | 0.507 | **0.758** | 0.774 |
| SB | 0.257 | 0.461 | 0.406 | 0.423 | 0.264 | 0.622 | **0.731** |

Source: Author's calculation

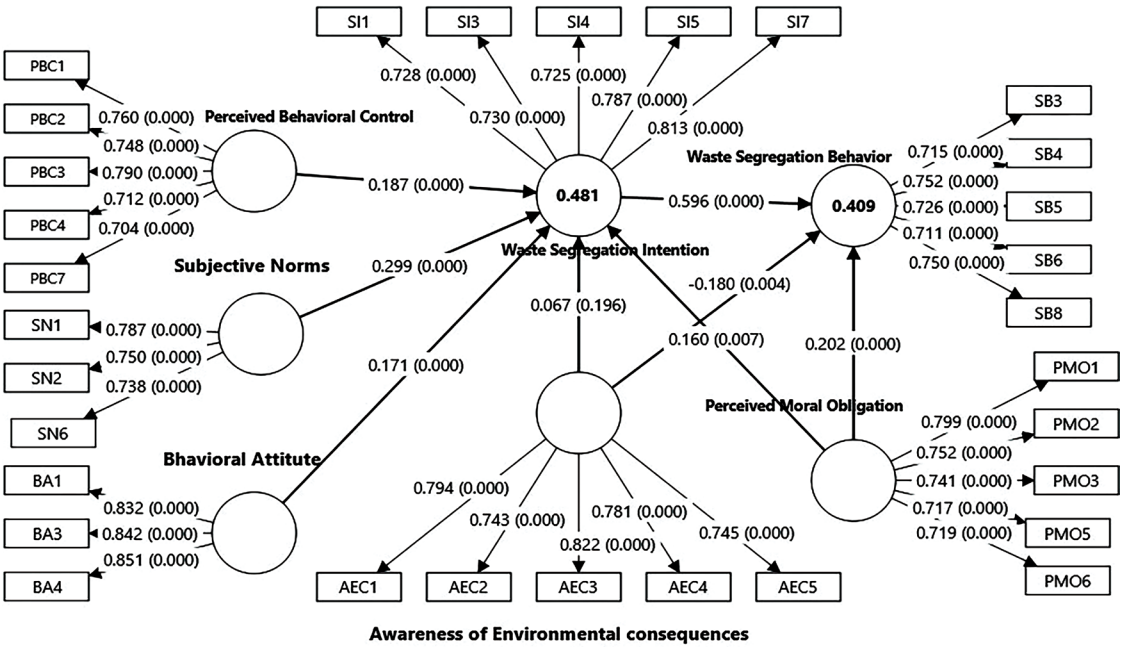
The above diagonal matrix in Table 6 shows the HTMT ratios between seven constructs: BA (Behavioral Attitude), SN (Subjective Norms), PBC (Perceived Behavioral Control), PMO (Perceived Moral Obligation), AEC (Affective Environmental Concern), SI (Waste Segregation Intention), and SB (Waste Segregation Behavior). The above-diagonal values are HTMT ratios for discriminant validity. All HTMT values are consistently low, with none exceeding the threshold of 0.85, providing clear empirical support for the discriminant validity of all constructs in this model. The results indicate the conceptual independence of the constructs, providing a high level of assurance regarding the accurate assessment of the theoretical model. This strong discriminant validity is a prerequisite for using the structural relationships among these constructs in the later analyses of these models, as the theoretical uniqueness between the constructs is now empirically established (Hair et al., 2021).

The discriminant validity of the constructs used in the research was also further assessed using the Fornell-Larcker criterion (Fornell & Larcker, 1981). This criterion compares the square root of the Average Variance Extracted (AVE) for each construct with its correlations to all other constructs in the model. Discriminant validity is established when the diagonal values are greater than the corresponding off-diagonal values in their respective rows and columns. The diagonal bold values in Table 6 represent the square roots of the AVE, and below the diagonal values are the latent variable correlations. This study found √AVE: BA (0.842), SN (0.759), PBC (0.744), PMO (0.746), AEC (0.778), SI (0.758), and SB (0.731). The higher values compared to the inter-construct correlations, which are in the same column and row, demonstrate the validity of all the constructs regarding discriminant validity. This study's Fornell-Larcker result fulfills the criteria of discriminant validity. The consistent fulfillment of the Fornell-Larcker criterion provides compelling evidence that each construct is empirically distinct and measures a unique underlying concept. This thereby mitigates concerns of redundancy or excessive overlap between the latent variables, lending strong support to the integrity of the measurement model.

## Structural Model and Hypothesis Testing

The structural model analysis thoroughly evaluates the proposed hypotheses on the relationships between the constructs, providing considerable insights into the direct and indirect pathways that influence waste segregation behavior (Liu et al., 2020). The bootstrapping (10000 resamples) procedure was applied to calculate t-values and percentile confidence intervals. The $R^2$ is used to analyze the predictive power of a model, where the $R^2$ for solid waste segregation is 0.481, indicating that the five latent predictor constructs explain 48.1% of the variance in waste segregation intention. This $R^2$ value suggests that nearly half of an individual's intention to segregate waste is influenced by psychological and moral factors. Similarly, the variance explained is 40.9% for solid waste segregation behavior. Both $R^2$ values exceed the minimum value of 25% prescribed by Hair et al. (2011).

Figure 1: Results




Source: Author's calculation

Indeed, following investigation on direct effect, behavioral attitude (BA to SI: = 0.171, p=0.000), subjective norms (SN to SI: = 0.299, p=0.000), perceived behavioral control (PBC to SI: = 0.187, p=0.000), and perceived moral obligations (PMO to SI: = 0.160, p=0.010), had positive and significant effects. This finding is consistent with studies by Abdulghaffar & Bakr (2024), Bakr & Abdulghaffar (2023), and Shin & Hancer (2016). This supports the fact that a positive attitude, perception of social pressure, sense of control, and moral obligation are all significant antecedents of an individual's intention to segregate waste (Comber & Thieme, 2013). It is noteworthy to mention that the intention to segregate waste proved to be a strong predictor of actual behavior (SI > SB: 0.596, $p < 0.001$). Interestingly, there was also a significant direct effect of perceived moral obligations on waste segregation behavior, which is also supported by the literature (Wang et al., 2021). In its turn, awareness of environmental consequences (AEC) demonstrated a multifaceted and counter-intuitive linear relationship by not having a significant influence on the intention to segregate wastes (AEC to SI: = 0.067, p =0.196) and a significant adverse linear effect on the behavior of waste segregation (AEC to SB: = 0.180, p = 0.01). The unexpected negative coefficient suggests that an elevated awareness, where a desirable level of awareness corresponds to higher actual segregation of waste, may paradoxically also be associated with reduced levels of actual waste segregation (Mohamad et al., 2022). This observation warrants further theoretical exploration regarding the awareness-behavior gap or the potential for psychological detachment.

Table 6: Results of the Structural Model

| Hypothesis | Relationship | Coefficient | t-Statistic | p-values | 95% CI (Lower) | 95% CI (Upper) | Decision |
|---|---|---|---|---|---|---|---|
| **Direct effect** | | | | | | | |
| H1 | BA → SI | 0.171 | 3.408 | 0.000 | 0.069 | 0.260 | Significant |
| H2 | SN → SI | 0.299 | 7.454 | 0.000 | 0.216 | 0.380 | Significant |
| H3 | PBC → SI | 0.187 | 3.824 | 0.000 | 0.093 | 0.286 | Significant |
| H4 | PMO → SI | 0.160 | 2.725 | 0.007 | 0.036 | 0.269 | Significant |
| H5 | PMO → SB | 0.202 | 3.492 | 0.000 | 0.087 | 0.305 | Significant |
| H6 | AEC → SI | 0.067 | 1.284 | 0.196 | -0.024 | 0.182 | Not Significant |
| H7 | AEC → SB | -0.180 | -2.822 | 0.004 | -0.304 | -0.047 | Significant |
| H8 | SI → SB | 0.596 | 14.121 | 0.000 | 0.511 | 0.679 | Significant |
| **Indirect effect** | | | | | | | |
| H9 | BA-> SI -> SB | 0.102 | 3.452 | 0.001 | 0.049 | 0.166 | Significant |
| H10 | SN -> SI -> SB | 0.178 | 6.378 | 0.000 | 0.127 | 0.233 | Significant |
| H11 | PBC -> SI -> SB | 0.112 | 3.602 | 0.000 | 0.053 | 0.182 | Significant |
| H12 | PMO -> SI -> SB | 0.095 | 2.682 | 0.007 | 0.022 | 0.160 | Significant |
| H13 | AEC -> SI -> SB | 0.040 | 1.257 | 0.209 | -0.022 | 0.113 | Not Significant |

*Source: Author's calculation*

**Mediation analysis**

This study employed mediation analysis to investigate whether the intention to segregate solid waste mediates the relationship between latent constructs—namely, behavioral attitude, subjective norms, perceived behavioral control, perceived moral obligation, and awareness of environmental consequences—with waste segregation behavior. More precisely, mediation analysis via waste segregation intention (SI) explains how different antecedents shape solid waste segregation behavior. Specifically, significant indirect effects were obtained under behavioral attitude (BA-> SI -> SB: $b = 0.102$, $p < 0.01$), subjective norms (SN -> SI -> SB: $b = 0.178$, $p < 0.001$), perceived behavioral control (PBC -> SI -> SB: $b = 0.112$, $p < 0.001$) and perceived moral obligations (PMO -> SI -> SB: $b = 0.095$, $p < 0.007$. Such results confirm that waste segregation intention is an important mediator of these constructs, and they do absorb a considerable share of the influence of the constructs on actual behavior. This result aligns with the findings of previous studies (Bang et al., 2014; Mohamad et al., 2022). These findings suggest that positive attitudes, the solidity of concepts of social norms, enhanced perception of behavioral control, and moral obligations are all effective ways of promoting waste segregation behavior, primarily by increasing an individual's likelihood of engaging in the behavior (Raghu & Rodrigues, 2020; Zhang et al., 2015). Nevertheless, as expected, awareness of environmental consequences (AEC) did not show a statistically significant indirect effect on waste segregation behavior through intention (AEC -> SI -> SB: 0.040, $p = 0.209$). This negative indirect influence also contributes to the belief that, in this context, generalized environmental awareness has little to no influence on behavioral intentions in a pro-environmental direction (Liobikiene & Poškus, 2019). This supports the growing consensus in environmental psychology that information-based interventions must be paired with affective and normative appeals to yield behavioral shifts.

# Conclusion

This study empirically examines the psychological, normative, and contextual drivers underpinning household solid waste segregation behavior in an emerging urban setting in Nepal. Based on the Extended Theory of Planned Behavior (ETPB) and the Norm Activation Model (NAM), the relationship between solid waste segregation behavior and latent constructs is analyzed by using partial least squares structural equation modeling (PLS-SEM). The research unravels the complex pathways through which waste segregation intention mediates the influence of behavioral attitude, subjective norms, perceived behavior, environmental factors, and moral antecedents on actual waste segregation behavior. The analysis shows that behavioral attitude, subjective norms, perceived behavioral control, and perceived moral obligation have a statistically significant and positive influence on the intention to segregate solid waste. It is worth noting that subjective norms are the best predictor of pro-environmental behavior, indicating that expectations and social identity associated with the community play a predominant role in this situation. The intention to participate in waste segregation is positively correlated with both constructs, perceived behavioral control and moral obligation, which, in turn, have a direct impact on behavior. This means that internalized responsibility and self-efficacy have a multiplier effect, acting as both the willingness and the potential to act sustainably. Moral obligation has a direct and indirect impact on behavior, whereas awareness of environmental effects exhibits a more complex yet paradoxical relationship with behavior. Although environmental awareness is important for shaping behavior, this study found a counterintuitive adverse direct impact on waste segregation behavior. The results of this study provide support for the existence of a substantial knowledge-action gap, whereby a formal understanding of pro-environmental behavior does not faithfully translate into actual behavior. There is empirical support for the effectiveness of interventions at the level of intentions, which are composed of the following four variables: raising intrinsic motivational antecedents, social reinforcement, and perceived self-efficacy. As a whole, these variables explain 48.1% of the variance in intention and 40.9% of the variance in endorsed behavior, demonstrating strong predictive capacity. These findings encourage the adoption of multifactor behavioral campaigns that aim to harness moral identity authorization, utilize social norms, and strengthen the sense of behavioral control. The study extends existing theory by showing that intention functions as a key self-regulatory mechanism, transmitting the influence of cognitive, social, and moral determinants to actual behavior, thereby providing empirical support for the theoretical propositions of both ETPB and NAM. Compared to previous studies, the strong predictive power of subjective norms highlights the collective and socially embedded nature of pro-environmental behavior in collectivistic societies, such as Nepal. The direct and indirect effects of moral obligation confirm prior empirical evidence, emphasizing the importance of personal moral norms in recycling and waste management practices.

Theoretically, the study builds on existing research on pro-environmental behavior by integrating the theory of extended planned behavior (EPB) and the norm-activation model (NAM) within a common analytical framework. Empirical synthesis proves that the rational formation of intentions cannot exist outside the affective and moral cognition forms. In practice, the results show the insufficiency of the traditional approaches of raising awareness, recommending the municipal governing bodies and policymakers focus on the initiatives aimed at shaping the communal set of norms, institutionalizing environmental care in the civic identity, and reducing the perceptive obstacles to action using intentional investment in the infrastructure and the stability of services.

The current research study presents an analytically complex and dimensionally rich image of solid-waste segregation practices in one of the fastest-growing metropolitan cities in Nepal, emphasizing the paramount importance of sustainable waste-segregation behaviors that are not bound by technical interventions. This study not only adds value to the modeling of environmental behavior in high-income urban environments but also serves as an informative guide to the process of formulating culturally sensitive, psychologically informed interventions in low- and middle-income urban settings. More research should aim to understand the underlying processes that create the state of awareness-behavior disconnect and employ longitudinal

designs during that period to induce behavior change in response to varying social and ecological systems.

**Declaration**

**Availability of data and materials**

Data will be made available on request.

**Competing interests**

We declare that we have no conflict of interest in publishing this manuscript.

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