



Exploring Individual, Social and Structural Determinants of Current Waste Segregation Practices at Urban Households in India

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Abstract

With the steep rise in population and migration from various countries, effective municipal solid waste management in India has become a critical issue for environmental sustainability and public health. The most critical step of solid waste management process is waste segregation at source, that significantly impacts recycling rates and pollution status. However, majority of existing studies focus on waste generation and disposal aspect instead of exploring psychological factors and individual attitude that may improve solid waste management. This study examines the standard social and behavioral determinants influencing intention as well as actual waste segregation behavior as mandated by the current guidelines for waste management in India. Considering the Swachh Bharat Mission, the presented analysis also evaluates key enablers and barriers, driving someone to become a segregator or non-segregator. The primary data for this investigation is collected randomly from selective urban households across different cities in India. The enablers and barriers in the context of waste segregation is identified with the help of theory of planned behavior framework. Correlation analysis is conducted to establish the effectiveness and importance of standard waste collection methods for identified indicators. Through a mixed-methods approach, this study recommends strategies for enhancing source separation rates to reduce the intention-action gap and to improve compliance with current waste segregation guidelines. Its integration in the working system may encourage environmental sustainability by strengthening enablers and by managing identified barriers efficient.

Keywords: Municipal Solid Waste, Solid Waste Management, Source Segregation, Subjective Norms, Waste Segregation Behavior.

Introduction

Solid Waste Management (SWM) has become a major global environmental crisis, especially in emerging economies such as India. Over the last few decades, due to various socio-economic factors including urbanization, India has transformed from an agriculture-based economy to one dominated by industries and services. This shift has profound implications for the nation's SWM practices, traditionally anchored in the three R Principles of: Reduce, Reuse, and Recycle (1). Moreover, SWM affects several developmental areas including public health, circular economy and environmental health. It propagates the impact to some critical Sustainable Development Goals (SDGs) adopted by all United Nations (UN) member states (2).

Approximately 31.2% of India's population, equating to over 377 million people, lived in 7,935 towns and cities in 2011 and this share is projected to be 50% by 2050 (3). Typically, waste produced

from households, public, and commercial areas is considered as Municipal Solid Waste (MSW) and is broadly categorized as organic waste (food waste, garden waste, etc.) and inorganic waste (paper, glass, plastic, etc.) (4). The estimated fraction of organic waste in MSW in India is 60-70% (5). However, the landscape of waste management in India is rapidly evolving due to accelerated population growth, urbanization and rising consumerism (6). The country is grappling with increasing volumes of solid waste, often dumped openly in landfills in most cities, which leads to significant health and environmental risks. The effectiveness of waste management depends largely on the segregation of MSW at the source, which is the first step in enhancing the efficiency of waste management (7).

Solid Waste Management (SWM) is a pivotal element of the Swachh Bharat Mission (SBM), launched in 2014 to enhance cleanliness, hygiene,

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and quality of life across rural and urban India (8). Additionally, the implementation of Municipal Solid Waste (Management and Handling) Rules, 2000 (9).

Waste separation at the household level involves sorting different household waste items according to its property or use (10). Collection of sorted waste can reduce Green House Gas (GHG) emissions, particularly with more organic waste (11) and can lead to an improved recycling rate (12). The "Solid Waste Management Rules, 2016," released by the Ministry of Environment, Forest and Climate Change (MoEFCC), Government of India, supersedes the Municipal Solid Wastes (Management and Handling) Rules, 2000. While Urban Local Bodies (ULBs) bear the responsibility of SWM services as per the SWM rules, 2016, the guidelines mandate residents to segregate biodegradable (wet waste) and non-biodegradable (dry waste) waste before collection (13).

However, despite clear guidelines, mixed waste is still being disposed of in many cities in landfills, that highlights the challenge of achieving widespread compliance for waste segregation at source (14). Additionally, it also indicates about lack of adequate data concerning the latest social and behavioral factors affecting source segregation trends (15). So, for successful implementation of the waste management system, the behavioral analysis of the country's population must be observed. This behavior-based study also needs to be extended to individual and social determinants for a comprehensive conclusion and actual execution. With this identified research gap in mind, the present study has selected five cities in India to assess the individual, social and structural determinants of current waste segregation in urban households. The main objective of this present study is to identify the top enablers and barriers of individual behavioral constructs for waste segregation in households. It is quite evident that waste generation, separation, treatment and disposal are most often an individual's conscious choice, but factors such as lack of awareness, callous ("not-in-my-backyard") attitudes, inadequate knowledge, infrastructure, and policies contribute to poor waste management practices (16). So, achieving desired waste segregation requires a deeper understanding of the evolving Solid Waste Management Behavior (SWMB) including separation and recycling (17). According

to the Theory of Planned Behavior (TPB), behavior depends on intention which in turn depends on attitude and subjective norms (perceived social pressures or expectations) (18). Using the key takeaways from the TPB model, the contribution of this research can be listed as follows:

- (a) The presented research aims to evaluate the complex interplay of individual, social, and structural determinants towards actual waste segregation behavior in urban households.
- (b) This study adds a unique perspective in tackling social desirability bias while responding to waste segregation behavior by capturing actual current practice, thus contributing to understanding the causality of the 'intention-action' gap.
- (c) The findings of the research are expected to assist policymakers, local administration, the private sector, and NGOs in focusing on improving waste segregation at the source in urban India, supporting the implementation of the latest SWM rules.

Methodology

Over the past few years, household source segregation has improved due to intensive awareness initiatives. Theory of Planned Behavior (TPB) provides evidence about the factors that shape the behavioral intention of people towards waste segregation at home. These factors are driven by their perception about the likely outcomes of their behavior (attitude) as well as their belief about the expectation of others that motivate or demotivate them to segregate (subjective norms). It also includes beliefs about the presence of factors that may facilitate ease or difficulty in the segregation behavior (perceived behavioral control) for the intended community. In addition, awareness also plays a vital role in affecting behavioral intention, which is measured by the ability of respondents to classify the type of waste, whether dry or wet and is taken as an additional variable.

During the study of existing state-of-the-art (SOTA), it is found that majority of the works have focused on waste generation and disposal. Very few investigations have explored the internal and external situational factors that affect individual waste management behavior (19). Additionally, some research have assessed social factors related to waste segregation and recycling behavior with

their relevance being deeply contextual (20). However, there is a growing emphasis on research in understanding the psychological models and human behavior to improve waste management systems (21). For better understanding, the co-occurrences of major author keywords are mapped in for household waste segregation behavior in India. Figure 1 represents the bibliometric map generated for 94 Scopus documents using VOS viewer (22). The sizes of circles and texts in the map are determined by the weight of the item in the collection of 237 keywords available in the selected research articles on household waste segregation behavior in India. It is worth noting that keywords such as waste management, solid waste management,

circular economy, composting, efficiency, and domestic waste are the major keywords in the study of household waste management systems. These studies collectively underscore the complex interplay between demographic factors, public awareness, government policies, and individual behaviors in shaping effective Municipal Solid Waste Management (MSWM) practices. On the other hand, attitude and perception, lack of resource recycling and source separation of wastes and willingness to pay strongly affect successful MSWM outcomes. Alternatively, sustainable development is often considered the responsibility of the local government and not that of individual citizens (23).

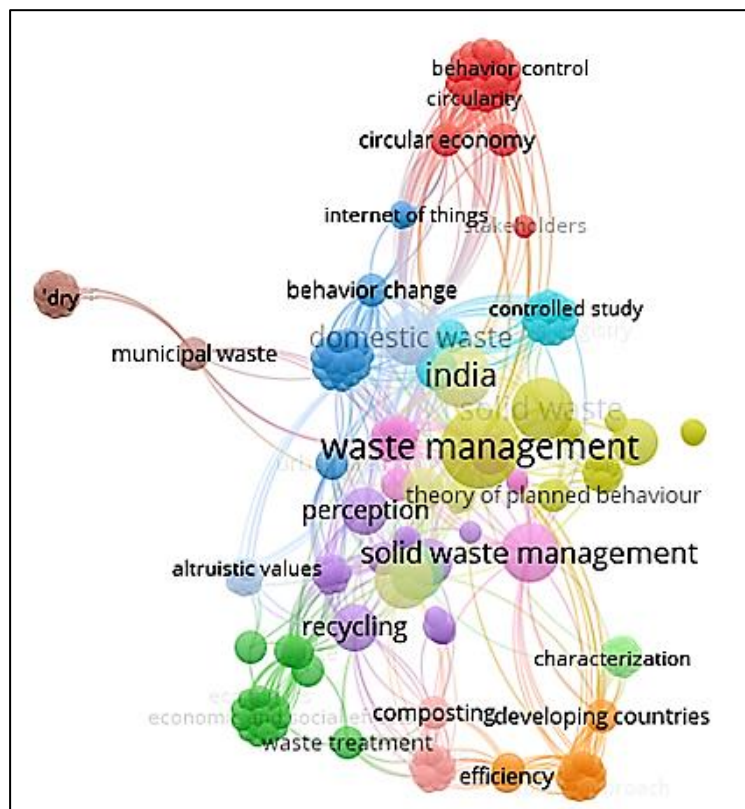


Figure 1: Keyword Mapping from 94 Scopus Documents for Waste Segregation Behavior in India

Hence, adequate opportunities, facilities, and knowledge should be made available by the respective local authorities for significant impact on personal attitudes towards actual waste separation. So, this study captures current household segregation practices and key social and behavioral determinants, leading to intention towards segregation along with current segregation behavior.

The data considered in the presented analysis investigate the participants' intentions towards

segregation quantitatively, measured on a Likert scale. On the other hand, the current segregation behavior is considered to have binary outcomes as segregators and non-segregators. It also includes some independent variables that represent TPB factors like attitude, subjective norms, perceived behavioral control and waste collection methods. This list extends to incorporate one additional unique variable namely, waste classification score, that evaluates participants' cognitive ability to correctly classify different waste items into

organic (wet) and inorganic (dry). This variable was computed from responses to identify common household waste items (such as vegetables/fruit peels, used tea/coffee powder, eggshells, used leaves and flowers, brush, leftover food, paper, glass, plastic, cardboard etc.) as wet or dry. Systematic waste sorting practices and effective waste collection methods are critical structural elements of the entire SWM process, which makes an appropriate infrastructure crucial for its smooth execution (24). Some segregation practices and waste collection methods are shown in Figure 2. So, one variable is also designated to capture the current waste collection method into three categories based on responses, like,

(i) organized (door-to-door collection by municipality, private collectors, or NGO),

(ii) semi-organized (collection by municipality from a nearby dump and not door to door), and

(iii) unorganized (no waste collection facility).

In this dataset, several intentional questions are used to shape the intention variable, reflecting individual decision making and behavioral tendencies. Therefore, data are primarily categorized into six predictors:

- (a) influencing the behavioral intention towards waste segregation,
- (b) individuals' attitudes,
- (c) subjective norms (SN),
- (d) Perceived Behavioral Control (PBC),
- (e) waste classification score, and
- (f) intention and waste collection method influencing an individual's segregation behavior.

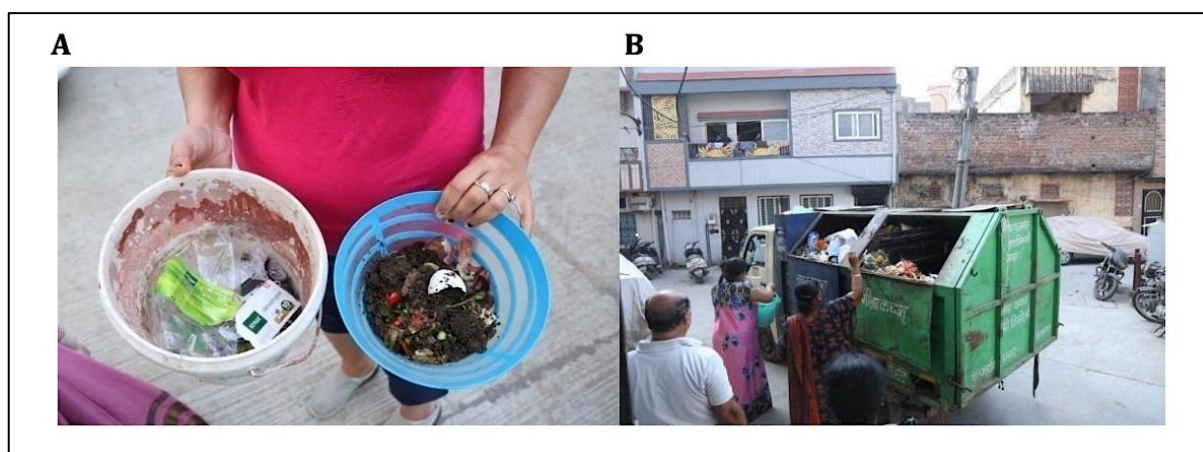


Figure 2: Different Waste Disposal Practices in Urban India. (A) Waste Segregation (B) Waste Collection

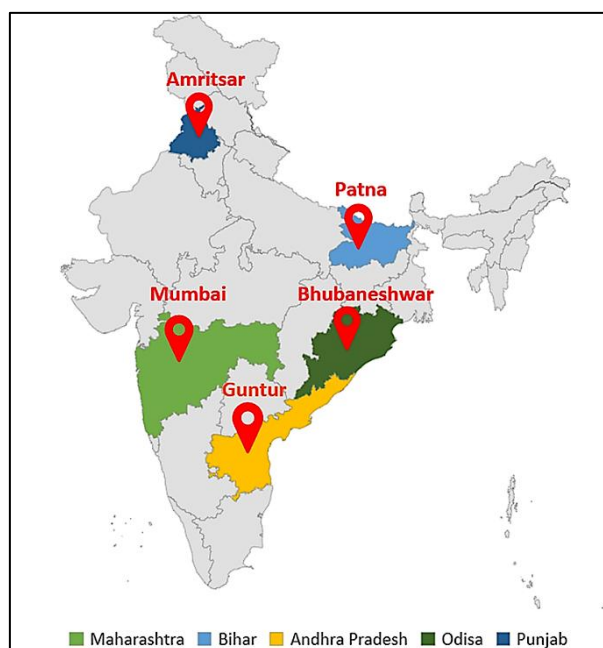


Figure 3: Location of Cities from which Primary Data was Collected

Table 1: TPB Parameters with Enablers and Barriers

Parameter	Enablers and Barriers
Attitude	Enablers: belief in positive outcomes, awareness of benefits, adequate knowledge. Barriers: lack of belief, negative perceptions, limited knowledge.
Perceived Behavioral Control	Enablers: supportive policies, easy access to facilities, convenient collection system. Barriers: unfavorable conditions, perceived difficulty, lack of facilities.
Subjective Norm	Enablers: social approval, peer influence, community participation. Barriers: lack of support, absence of role models, social indifference.

Here, the 'Intention' variable is the internal and 'waste collection method' is external construct in understanding how individuals are motivated to perform specific behavior, such as waste segregation and proper disposal. All observed indicators in the data are directly tied to an individual's intention and the actual behavior towards effective MSWM. These factors are not isolated; rather, they collectively shape how individuals think, feel, and behave in relation to environmental practices, reinforcing or impeding behavior. In the context of waste segregation, the psychological forces that shape individuals' intentions and actions are termed as enablers and barriers. Table 1 lists the enablers and barriers for TPB constructs considered in the presented analysis. Additionally, this investigation ensures a comprehensive understanding of the current level of awareness, attitudes, perceptions, and contextual factors, impacting waste management practices across diverse urban contexts, as marked in Figure 3. The cities are selected from the southern, northern, eastern and western zones of India, thus providing a balanced geographical representation of different parts of India. This shortlisting includes five cities, namely Mumbai (18.89°–19.30° N, 72.77°–72.99° E), Patna (25.52°–25.67° N, 85.00°–85.23° E), Bhubaneswar (20.19°–20.38° N, 85.74°–85.90° E), Guntur

(16.24°–16.38° N, 80.36°–80.49° E) and Amritsar

(31.57°–31.72° N, 74.79°–74.98° E), all having diverse demographics, culture and social practices.

Data Collection and Analysis

Primary data were collected through self-administered questionnaires distributed to respondents through an online form from May 2022 to August 2022. Participation in this survey was voluntary, and data was collected anonymously to safeguard all personal information. The online data collection form was in both English and Hindi and was supported by an NGO, FINISH Society. The sample consisted of 550 respondents selected through convenience random sampling from online databases and personal networks in five cities.

The questionnaire was structured to cover

- (a) demographic attributes,
- (b) knowledge and awareness (related to different waste types, and current regulations),
- (c) individual segregation behavior (current waste disposal practice),
- (d) enablers and barriers, and
- (e) external factors affecting waste segregation.

Enablers and barriers were further assessed to identify behavioral determinants, including perception, intrinsic motivation and attitudes, subjective norms, and perceived control. The survey questionnaire was pre-tested with research scholars, academic experts and sector experts.

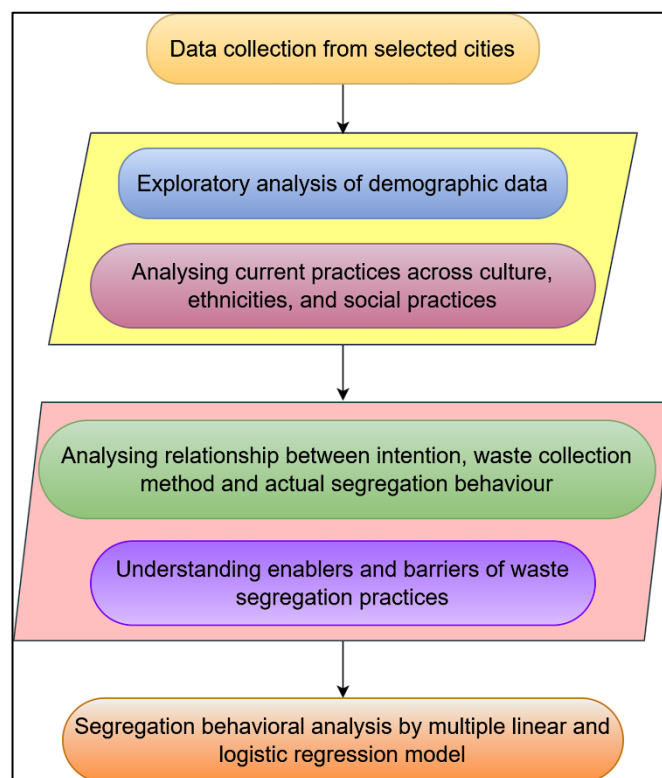


Figure 4: Steps of Data Analysis

The data analysis was structured in successive parts as shown in Figure 4. After collecting data from the selected cities, the first step consisted of an exploratory data analysis of the general demographic picture of the data. It also explored how behavioral constructs, such as attitudes, subjective beliefs, perceived behavioral control, and classification knowledge based on various properties of waste, influence individuals' intentions to engage in segregation behavior. In the subsequent part, we analyzed the relationship between the intention (internal factor) and type of waste collection system implemented in the area (external factor), and the extent to which residents engage in waste segregation practices. This process helped in understanding enablers and barriers in current context. Statistical Package for Social Sciences for Windows (SPSS, v25.0) was used for correlation analysis, which primarily included multiple linear and logistic regression methods and the level of significance was set at 5%.

Descriptive Statistics of Data Sample

This section discusses the statistical attributes of the samples utilized by this investigation to achieve the proposed objectives. Table 2 displays the distribution of respondents across different age groups. Most respondents fell within the 31-42

years and 18-30 years age groups, accounting for 74.2% of the sample. The 43-55 years age group comprised the remaining 25.8%. This distribution enables investigating potential variations in waste segregation behaviour due to different educational exposure, employment status, household responsibilities, and environmental awareness. Figure 5, on the other hand, highlights the gender distribution of respondents in this study. Females constituted the majority, accounting for 66.5% of the sample, while males accounted for 33.5%. This gender distribution provides a stronger representation of female perspectives, offering valuable insights into attitudes and behaviors towards waste segregation.

Waste Segregator and non-Segregator

One of the most important attributes fetched from the data collection is the category of participants as waste segregator or non-segregator. It is observed that for the 550 respondents, 489 (88%) are aware of the concept of wet and dry waste. However, there are high possibility that individuals might incorrectly report their waste segregation practices due to societal pressures or the desire to present a socially desirable image. To avoid such influence of social desirability bias on data sample, the households are also classified as segregator and non-segregator based on their current waste

disposal practices instead of asking them to self-identify as segregators or non-segregators. Using this approach, 61% (n=334) of the total sample is found to currently disposing of segregated waste, whereas 39% (n=216) disposed of mixed waste. This shows a large variance with their current awareness level, where 88% said they were aware of the expected disposal categories. Addressing such misrepresentation improves the reliability and generalization of the presented analysis.

Waste classification score

Understanding different types of waste is critical for effective source segregation, which is driven by

a classification score in the presented analysis. Hence, in addition to the core constructs of the Theory of Planned Behavior (TPB), this study incorporates an additional variable identified in state-of-the-art research, namely Waste Classification Score (WCS). Psychological and social constructs do not always capture the entire variation in the outcome. So, Waste classification ability is itself a significant behavioral factor that directly influences both intention and actual waste-segregation behavior. To calculate this score, respondents are asked to categorize the 19 items, listed in Table 3, as wet or dry.

Table 2: Age-wise Distribution of Respondents

Age group	Frequency	Percent	Cumulative %
18-30 years	204	37.1	37.1
31-42 years	204	37.1	74.2
43-55 years	142	25.8	100.0

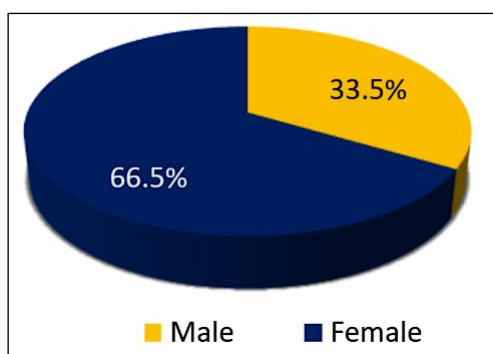


Figure 5: Visualization of Gender Composition in Data Samples

Table 3: Items Considered for Waste Identification Score

Item	Sample images	Item	Sample images
Vegetable/Fruit peels		Used tea/coffee powder	
Food packaging material		Cardboard	
Brush		Soap covers	
Metal		Rubber	

Paper		Tissue paper	
Glass		Egg shells	
Plastic		Chocolate wrappers	
Used leaves and flowers from Pooja		Leftover food	
Piece of furniture		Small broken toys	
Used bottles, tubes, cans			

The images used in the table represent the categories considered in the analysis and are fetched from publicly accessible online resources. A score of 1 is assigned for every correct response and 0 for an incorrect one. Based on their responses, a score is calculated as the proportion of summation of correctly identified items from the

available collection. Equation [1] represents the mathematical expression using which classification score is allotted to each individual. This approach provides a standardized measure of classification ability, which serves as an important explanatory variable in understanding waste-segregation behavior.

$$\text{Classification score} = \frac{\text{Correctly identified items}}{19} \quad [1]$$

Reliability Analysis

A reliability analysis is also conducted for identified enablers and barriers of TPB constructs considered in this research. It includes Attitude, Subjective norm, Perceived behavior control, and Intention. Each of these constructs represents a psychological factor, reflecting an individual's overall inclination toward waste segregation. They are measured using specifically designed set of

related questions as given in Table 4. These groups of related items are commonly referred to as measurement scales and they are sufficiently capable of capturing a specific construct. For ensuring the statistical reliability of considered theoretical group, Cronbach's Alpha (α) is used, which helps in determining how consistently a group of questions measures the characteristics of a certain aspect.

Equation [2] represents mathematical formula for Cronbach's Alpha.

$$\alpha = \frac{N \cdot \bar{c}}{\bar{c} + (N-1) \cdot \bar{c}} \quad [2]$$

Here, N is the number of items in the scale (e.g., number of questions used to measure Attitude), $\bar{c}$ is mean covariance between item pairs, and $\bar{v}$ is mean variance of individual items. A score above 0.7 is acceptable enough to group related items (25).

As explained in the preceding text, Reliability analysis calculates the internal validity of a set of items used to construct within a scale. Thus, it

ensures that the recognized factors of behavioral tendency are not only well grounded in the presented literature but also supported by robust statistical evidence.

Table 4: Cronbach Alpha for Each Construct and Indicators

Construct	Indicators	Cronbach alpha
Attitude	I care about nature and I do it as my part in protecting our environment (AT1)	0.742
	Learned about the importance in college (AT2)	
	Learned about the importance at workplace (AT3)	
	Separating waste is a hygienic choice (AT4)	
	Separating waste prevents contamination and reduces the chances of spreading diseases (AT5)	
	I don't find the need to do so since wet and dry waste are eventually mixed and dumped in the garbage pick-up truck (AT6)	
	I don't find it necessary to separate waste (AT7)	
	It is not my responsibility; Govt. should do it (AT8)	
Subjective Norm	I was made aware about the importance of waste segregation through an awareness campaign/drive (SN1)	0.695
	The importance of waste segregation was taught to my kid in school and I learnt it from him/her (SN2)	
	The municipality has made it mandatory to separate waste (SN3)	
	Building/complex has made it mandatory to separate waste (SN4)	
	My friends/family/neighbors practice waste segregation and I learnt the importance of the same through them (SN5)	
Perceived Control Behavior	I find it to be a tedious task in maintaining two different bins for wet and dry waste (PCB1)	0.759
	Too much time and effort required (PCB2)	
	Too dirty for me to do (PCB3)	
	I cannot differentiate between wet and dry waste, therefore I dispose it together (PCB4)	
	I need external help to separate waste (PCB5)	
Intention	I will try to find a garbage bin and dispose the waste (IN1)	0.771
	I will always try to find two bins and I will segregate waste as wet and dry and then dispose (IN2)	
	In absence of a garbage bin, I will dispose it once I get back home (IN3)	
	In absence of a garbage bin, I will dispose on heap of waste near me (IN4)	
	Irrespective of availability of garbage bin, I will dispose the waste on the roads/street/gutter (IN5)	
	I will try to find a garbage bin, if I don't find one, I will dispose the waste on the road/street/gutter (IN6)	

Results

From the preceding discussion, it is evident that the TPB model considers attitude, subjective norms, and perceived control behavior as internal factors that further influence intention. In addition to these three, an additional parameter, Waste Classification Score (WCS) is also included as an internal factor in the presented exploratory analysis. It considers WCS to be a significant

contributor to the intention that enhances explanatory power of the proposed framework.

Correlation analysis

To assess the underlying relationship of the proposed predictors with the dependent variables, a stepwise correlation analysis (r) is performed among all variables of interest. A moderate positive correlation ($r=0.361$) is observed between

individuals' Attitudes towards waste segregation and their intention to engage in the segregation behavior. This indicates that individuals who hold favorable beliefs about the importance and benefit of waste segregation are more likely to possess stronger intentions to segregate waste. However, another internal factor, Subjective norm, seems to be a weak predictor ($r=0.160$) of intention, yet establishing positive relationship. This suggests that social pressure or expectations from family, friends, or the community have influence on individuals' intentions to segregate waste in limited capacity. Remaining two variables, Perceived control behavior and waste classification score ($r=0.384$ and $r=0.379$) exhibit a moderate positive correlation with intention. Hence, while social norms should play a crucial role, their impact is less pronounced than that of

other factors, indicating that individuals are primarily driven by their personal beliefs rather than external social influences. This implies that greater ease or control over the process of waste segregation along with knowledge and awareness about waste type play a significant role in shaping behavioral intention. Additionally, it also highlights the importance of education and sensitization campaigns as well as practical support and infrastructure to enhance populations' confidence in their ability to perform segregation. Further, there is a moderate positive relationship ($r=0.359$) between the intention to segregate waste and actual segregation behavior, as shown in Figure 6. This underscores the importance of intention as a key predictor of behavior, consistent with TPB.

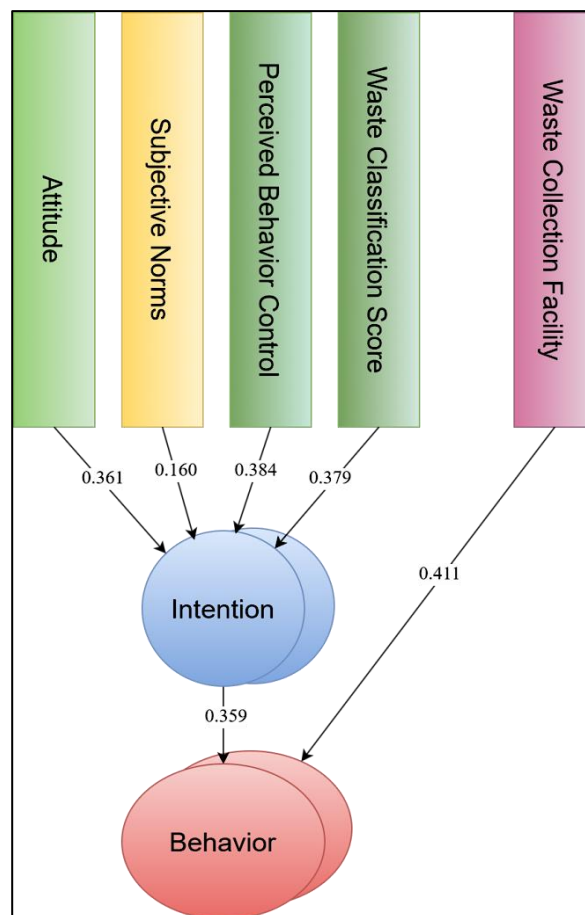


Figure 6: Correlation Pathways for Observed Indicators and Latent Constructs

Table 5: Correlation between Waste Collection Facility and Segregation Behavior

Type of waste collection facility	Correlation Coefficient (r)
Organized	0.411
Semi-organized	-0.235
Unorganized	-0.185

The finding of correlation analysis suggests that fostering strong intentions through interventions that enhance attitudes, perceived behavioral control, and waste classification knowledge can lead to improved waste segregation practices. However, the moderate strength of the correlation also highlights that intention alone is not sufficient to guarantee behavioral change. Table 5 lists the correlation coefficients for various categories of waste collection facility, which depends on the external factor, like infrastructural support. It is quite evident that availability of organized waste collection systems ($r=0.411$) plays a significant role in translating intention into action.

Regression Analysis

This section discusses the results achieved through regression analysis that measure the magnitude of change in dependent variable due to independent variable i.e., internal factors. The regression coefficient (β) indicates the strength and direction of effect of inter-variable relationships. Intuitively, a positive β signifies that target variable rises with the independent variable, whereas a negative beta indicates an inverse relationship. It is accompanied by a p-value to establish statistical significance of the effect. A detailed overview of regression coefficient for different key factors that influence intention of waste segregation, is presented in subsequent text.

Table 6: Result of Regression Analysis

Predictors	β	SE	p-value
Attitude	0.757	0.195	0.000
Perceived behavioral control	0.597	0.148	0.000
Subjective norm	-0.437	0.150	0.10
Waste classification score	0.579	0.093	0.000

Note: β = Regression Coefficient, SE = Standard Error.

For effective MSWM, the most important aspect is intention, which depends primarily on psychological inclination of population. As per the analysis of proposed framework, TPB constructs, namely Attitude, PBC, and Subjective Norms, contribute significantly to induce psychological beliefs towards practical waste management practices. Further, this behavior is impacted positively by successful categorization of waste (Waste Classification Score).

Table 6 lists values of different parameters of identified predictors determined by the regression analysis. Here, attitude ($\beta = 0.757$, $p < 0.05$) and behavioral control ($\beta = 0.597$, $p < 0.05$) are found to be the most significant predictors of intention to segregate waste. It suggests that individuals with favorable attitudes and perceived ease towards waste segregation are more likely to form strong intentions to segregate. The waste classification score ($\beta = 0.579$, $p < 0.05$) also positively and significantly influences intention, although their impact is relatively weaker compared to attitude but approximately equal to knowledge. This indicates that better knowledge of waste types is also more likely to lead to strong intentions to segregate. Subjective Norms ($\beta = -0.437$, $p > 0.05$) also negatively influenced intention but the effect is not significant. This indicates that when social norms are analyzed in the presence of other

predictors (Attitude, Perceived Behavior Control, Identification Score), their unique contribution to predicting intention is not significant. While Subjective Norms may contribute to intention in isolation, its role is less critical when compared to Attitude, Perceived Behavioral Control (PBC) and classification knowledge in predicting intention.

To enable more accurate interpretation of user behavior patterns based on their intent to segregate waste, logistic regression is used. This analysis results in estimating regression coefficient (β), its standard error (SE), and the odd ratio ($\text{Exp}(B)$). They collectively indicate an increase or decrease in the segregation behavior with the specific predictor i.e., intention in the current analysis. The result shown in Table 7 strongly suggests that intention has a significant and positive impact on actual behavior. The odds ratio of 2.7 indicates a substantial effect; that is, for every one unit increase in intention score, the odds of engaging in waste segregation is 2.7 times higher.

The discussion about results in previous section excludes interpretations of improper waste collection which is assumed as a predictor named as 'Waste Collection Method (WCM)', in the presented work. It is supposed to be one of the major factors that might bypass intention and directly influence behavior. Table 8 shows that

organized waste collection ($\beta = 2.034$, $p = 0.000$) is statistically the most significant ($p < 0.05$) variable and is associated with a much higher log-odds of segregating behavior. The results indicate that households with organized waste collection are 7.65 times more likely to segregate than those without. Although the presence of semi-organized collection facilities positively influences behavior

($\text{Exp}(B) = 2.39$), the effect is not as strong as that of fully organized systems. The lack of significance ($p=0.088$) might indicate that such facilities do not provide the same level of convenience or clarity required to promote consistent segregation behavior. This finding highlights the importance of infrastructure and system-level interventions in encouraging waste management practices.

Table 7: Logistic Regression Estimates on Intention and Segregation Behavior

Predictor	β	SE	p-value	Exp (B)
Intention	0.993	0.144	0.000	2.700

Note: β =Regression coefficient, SE=Standard Error, p-value=Statistical significance, Exp (B)=Odd Ratio.

Table 8: Parameters with Standard Error and Sigma

Predictors (WCM)	β	SE	p-value	Exp (B)
Organized	1.877	0.492	0.00	6.532
Semi-organized	0.873	0.511	0.088	2.39

Note: β =Regression coefficient, SE=Standard Error, p-value=Statistical significance, Exp (B)=Odd Ratio.

These findings suggest that while individual psychological factors such as intention are critical, external structural factors, such as waste collection infrastructure, play an equally significant role in shaping behaviors. The following section provides a critical analysis of the achieved outcomes and their relevance in Indian socio-culture scenario.

Discussion

Human behavior is a dynamic interplay between encouragement, social influences, and the perceived ability to act. Further, it is significantly impacted by the enablers and barriers of the system. The intention to separate the waste is formed by motivation and capability to segregate while social norms can also encourage others to adopt source segregation (26). In the context of solid waste management, enablers act as facilitators that nurture a positive psychological approach for adopting behaviors such as waste segregation. They have instilled an understanding of its broader impact on health, hygiene, and environmental preservation. External reinforcements such as mandatory rules set by municipalities or housing complexes and practices adopted by friends and family provide a sense of collective commitment. When individuals see waste segregation as a socially supported norm, they are more likely to align their behavior to conform to these expectations. The presence of such enablers strengthens social validation and enhances the perception that behavior is not only important but also achievable.

On the other hand, barriers create friction that hinders motivation and weakens the likelihood of consistent action. Barriers such as the belief that waste segregation is tedious, time-consuming, or dirty, undermine an individual's self-efficacy and cause harm to their belief of performing the task successfully. When individuals view segregation as a burdensome activity, it triggers avoidance behavior. Some barriers reflect a psychological tendency to shift responsibility to external entities, such as the government. This external attribution diminishes one's sense of personal agency, leading to passivity. A lack of understanding of differentiating waste or the need for external assistance highlights gaps in knowledge and skills at society level.

This research intends to address this gap for Indian cities using TPB framework. Section 2 mentions all the major indicators of TPB constructs in Table 4. Top three enablers and barriers are identified for the population considered in the presented analysis, as shown in Figure 7. These findings highlight not only the psychological factors affecting intention but also the practical influences that directly impact behavior. The statistical inference of the analysis provides deeper insights into the factors influencing intentions and behaviors related to waste segregation based on the Theory of Planned Behavior (TPB). Further it also examines how attitude, subjective norm, perceived behavioral control (PBC), and waste classification knowledge contributed to the formation of the intention to segregate waste. The

explanation regarding the outcome of each factor is given in the subsequent text.

- a) Attitude (Significant Positive Influence):** A highly positive coefficient for attitude indicates that individuals who hold favorable beliefs about the benefits or importance of waste segregation are far more likely to form a strong intention to segregate waste. This reflects how intrinsic motivation, and the personal valuation of an activity, play a critical role.
- b) Perceived Behavioral Control (Significant Positive Influence):** PBC represents individuals' perception of their ability to perform a task. A strong positive effect shows that individuals who face ease in facilitating waste segregation (e.g., access to resources, knowledge, or time) are more likely to develop the intention to act. It tells us about an important context that provides any sort of comfort or convenience in the process of waste segregation, whether from a policy point of view or implementation, will always promote the instinct of people to segregate waste.
- c) Subjective Norm (Non-Significant):** The negative and statistically non-significant effect of subjective norms suggests that perceived social pressure or the influence of others (e.g., neighbors, family, or community expectations) does not significantly impact intention in this

context. This could mean that individuals are primarily driven by their own beliefs and abilities rather than external expectations.

- d) Waste Classification Knowledge (Significant Positive Influence):** The strong relationship between waste classification knowledge and intention highlights the role of awareness. Individuals who understand how to classify waste (wet, dry, and recyclable) are more likely to form intentions, reinforcing the importance of education and information dissemination in waste management programs. The second stage focuses on how intention translates into actual waste segregation behavior.
- e) Intention (Significant Positive Influence):** A strong and significant positive relationship between intention and behavior confirms the core principle of the TPB: individuals who are motivated and determined to segregate waste are highly likely to act on that intention. The result represented in Table 7 indicates that for every unit increase in intention, the likelihood of engaging in waste segregation behavior increases more than twofold. This result underscores the importance of fostering strong intentions through strategies to build positive attitudes, enhance perceived control, and provide knowledge.

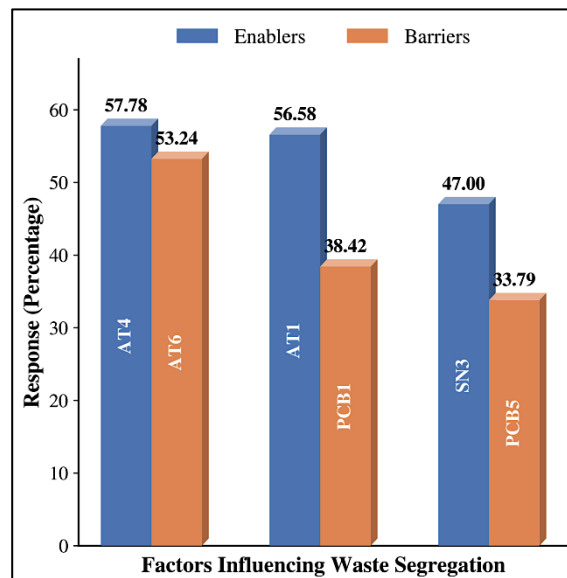


Figure 7: Top Three Enablers and Barriers Identified by the Proposed Framework

These findings are consistent with the existing state-of-the-art (SOTA) studies on waste segregation and recycling behavior, conducted for Thailand and United Arab Emirates (UAE),

respectively (27, 28). They also recognize attitude, subjective norms, and behavioral factors as important determinants of sustainable practice towards waste management as well as emphasize

the role of awareness and behavioral factors in promoting recycling behavior. The present study supports these observations, highlighting the importance of attitude, social influence, and perceived behavioral control in encouraging waste segregation. However, unlike them, the current research specifically focuses on household-level source segregation and incorporates context-specific factors including awareness campaigns, municipal regulations, and practical segregation challenges, providing insights relevant to urban waste management in India. Table 9 presents the comparative analysis of major attributes acknowledged in the presented framework and SOTA.

Additionally, this research reveals that if the available collection method does not ensure the separate collection of dry and wet waste, residents are discouraged from separating their waste. Hence, these insights highlight that future SWM activities should focus on providing improved waste collection systems, continued public education particularly regarding technical know-how, and robust infrastructure to achieve consistent and widespread source segregation of MSW. The results also show that creating awareness or self-motivated behavior may not necessarily translate to improved source segre-

gation unless there is adequate infrastructural support along with continuous monitoring. Therefore, regardless of incorporating important psychological and social factors, the specific geographical and socio-cultural context restricts the generalized interpretation of the presented study. However, the analysis heavily depends on the self-reported responses, which may be subject to social desirability bias. Future research may acquire accurate assessment of actual waste management practices, by combining a detailed survey based on observational and experimental methods.

Despite these limitations, the study contributes to the growing body of knowledge on waste segregation behavior by providing context-specific insights into the role of attitudes, social influences, awareness, and perceived behavioral control in promoting sustainable waste management practices. While the research covers only selected households across randomly selected cities, the findings are useful for the wider urban population in India. This study provides insights into key enablers and barriers to support policymakers, and social and community-based organizations for improving compliance with mandatory source segregation behavior.

Table 9: Comparative Analysis with the State-of-the-Art (SOTA)

Attribute	SOTA 1 (27)	SOTA 2 (28)	Present Study
Attitude	10 items	14 items	8 items
Perceived behavioral control	5 items	Not explicit	5 items
Subjective norm	2 items	Included under Motivation	5 items
Motivation	Not included separately	10 items	Not included separately
Regulatory Factors	1 item	Partly included in Attitude	Included in Subjective Norm
Challenges/Barriers	Limited	9 items	Reflected through PBC items
Intention	1 item	Not separate	6 items

Conclusion

This study provides a comprehensive understanding of the factors influencing waste segregation behavior among urban households in India, integrating both psychological and structural determinants. By applying the Theory of Planned Behavior (TPB) framework, the research highlights the complex interplay between individual attitudes, social norms, perceived behavioral control, waste classification knowledge, and the role of organized waste collection systems

in shaping waste segregation practices. To strengthen intentions, policymakers should focus on implementing positive attitudes towards waste segregation through awareness campaigns and educational programs. Improving waste classification knowledge is equally important, as it empowers individuals to make informed decisions about waste segregation. Organized waste collection systems are critical for translating intentions into action. Investments in infrastructure, such as door-to-door collection

services and separate bins for wet and dry waste, are essential to enable households to effectively segregate waste. It not only affects behavior but also positively promotes people's intention of waste segregation equally.

The findings of this study is limited by its limited sample size of surveyed households and participants centric responses of the questionnaire. A combination of psychological and structural interventions may be helpful in better assessment of both motivational and practical barriers to waste segregation. In future, awareness campaigns should be complemented by the provision of convenient waste collection facilities to ensure that individuals can act according to their intentions.

Abbreviations

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Santwana Sneha: Conceptualization, Methodology, Analysis, Data Curation, Manuscript Preparation, Ashish Ranjan Sinha: Supervision.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

Data Availability

The data used to support the research findings are available from the corresponding author upon request.

Declaration of Artificial Intelligence (AI) Assistance

AI-assisted tools were used only for language editing and grammar improvement, and the authors take full responsibility for the content of the manuscript.

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