



## Exploring household waste management behavior through the stimulus-organism-response model

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### ABSTRACT

Waste is one of the most pressing global issues that demands urgent action and innovative solutions, this problem growing and requires increased attention. This study proposed a conceptual framework based on the stimulus-organism-response model, incorporating waste sorting knowledge, awareness, and environmental concerns to understand this issue. The proposed framework was tested with structural equation modeling (SEM), and the internal validity and reliability of the measurements and measures were evaluated with confirmatory factor analysis (CFA). This research use data collected from 131 household in Banyuwangi, Indonesia, using a purposive sampling. The results reveal that knowledge significantly influences awareness ( $\beta = 0.679$ ,  $t = 8.232$ ) and environmental concern ( $\beta = 0.105$ ,  $t = 2.811$ ). However, its effect on waste-sorting behavior ( $\beta = -0.053$ ,  $t = -0.324$ ) is not supported. Waste-sorting behavior is determined by environmental concern ( $\beta = 0.883$ ,  $t = 3.37$ ) but not by awareness ( $\beta = 0.342$ ,  $t = 1.835$ ). Furthermore, the findings confirm the full mediation of environmental concern in the relationship between knowledge and waste-sorting behavior. This study provide insight driven from stimulus-organism-response model and its implication in household waste management behavior research in developing country. This research offers several theoretical and practical implications, contributing to the existing literature and aiding practitioners in designing effective intervention campaigns to promote household waste sorting.

### 1. Introduction

Waste is one of the most pressing global issues that demands urgent action and innovative solutions. The United Nations recognizes its significant impact on society, the environment, and the economy. To tackle this challenge, the UN has integrated waste management into the 17 Sustainable Development Goals, particularly SDG 11 and SDG 12 (Okayama et al., 2021). Household waste is a significant contributor to this problem and requires increased attention. It adversely affects the economy and exacerbates environmental degradation and pollution. (Wang et al., 2021). Wang et al. (2021) emphasize that promoting effective household waste management, including waste sorting, is

essential for minimizing the negative impacts of waste. The World Bank projects that global waste generation will increase by 70 % by 2025. However, the capacity of developing nations to address this issue remains limited, with only 4 % of the waste they produce recycled (Goh et al., 2022). Therefore, reducing waste generation and enhancing waste separation at the household level are critical steps toward decreasing the volume of waste sent to landfills.

In Indonesia, waste is a major problem that requires significant effort to prevent its consequences. The National Waste Management Law (Law No. 18/2008) and Waste Management Master Plan (2020-2024) are legal frameworks and strategies to address the waste problem across the country and promote waste separation, recycling, and responsible

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disposal. Besides, the National Action Plan targets a 70 % reduction in waste by 2025 (Ministry of Environment and Forestry, 2020). However, the successful execution of these noble goals relies on promoting household waste management, particularly waste separation, which is vital. Like most developing countries, 55 to 80 % of municipal solid waste is from households. In 2020, almost 40 % of the municipal waste generated in Indonesia flowed from the local community (Aprilia, 2021; Zhang, Hassan, & Sheikh, 2024). Due to inadequate infrastructure and insufficient waste treatment facilities, much of this ends up in landfills as a complex mix of food waste, paper, plastic, apparel, textiles, metal, and glass, complicating both waste management and resource recovery efforts. Household waste management can be defined as the activities taken by households to recover valuable resources from discarded materials, minimize and properly discard waste at home. Sorting is one of the most common household waste management's practices and encourages developing nations to reduce the waste discarded in landfills.

Besides the government initiatives, policies, and strategies, scientific research on household waste management behavior has consistently increased, specifically on waste separation or sorting, to understand the key factors that encourage households to manage their waste. For example, Wang et al. (2021) uses the theory of planned behavior (TPB) as a psychological framework to explain how individual attitudes, social influences and perceived control influence intention and behavior associated with household waste sorting, and Zhang, Li, and Lou (2024) adopted this model to understand household waste sorting in China. Similarly, Tang et al. (2023) use the TPB to explore the issue in Ghana. The theory was further extended by integrating it with the Norm Activation Model (NAM) to examine how personal norms, such as feelings of moral obligation, influence behavior, providing deeper insights into the phenomenon in Australia (Goh et al., 2022). Other studies use behavioral frameworks such as the Theory of Reasoned Action (TRA), which assumes that individuals make rational, deliberate decisions based on available information (Zhou & Qiong, 2022). Consequently, these studies show the dynamism of this issue across contexts, and it is imperative to gain additional understanding from many different perspectives and contexts to improve household waste management practices. Although several attempts exist to explain household management behavior, specifically waste sorting or waste separation, almost all

published investigations to date focus on developed nations and countries like China. Besides, most previous studies have used prominent behavioral and normative theories, including the theory of planned behavior and norm activation model, considering the importance of personal and individual characteristics and psychological factors in waste sorting behavior (Chia et al., 2024; Knickmeyer, 2020). However, some studies have argued that there is a need to extend the focus on cognitive variables such as knowledge and awareness of the adverse impact of household waste (Razali et al., 2020). Although most studies have examined how psychological and cognitive factors influence the intention to participate in waste management, there is a lack of research investigating how these factors influence actual behavior.

In addition to the above evidence, there is a growing body of research in the context of Indonesian that investigated household waste management using TPB-based models, socio-economic analyses, and short-term interventions (Kokash et al., 2025; Rakhmawati et al., 2023; Raghu & Rodrigues, 2020; Ulhasanah & Goto, 2018) (Table 1). The existing literature remains fragmented in explaining how policy, infrastructure, and informational cues translate into effective and sustainable sorting behavior (Sembiring et al., 2024; Ulhasanah & Goto, 2018). Besides, the majority of the past research work focuses on intentional behavior to participate and engage in proper waste disposal or sorting, or willingness to pay, relies on cross-sectional or lab-based designs; these studies overlook the role of emotional or cognitive mediators beyond attitudes and norms (Fenitra et al., 2025; Setiawan et al., 2019). Therefore, this study addresses these gaps by applying the Stimulus–Organism–Response (SOR) framework (see Fig. 1.) to model the impact of waste management Knowledge through organism-level states (to observed behavioral responses, specifically proper sorting behavior (Yadav & Sijoria, 2025; Zhang, Li, & Lou, 2024). By integrating affective and cognitive mechanisms of household behavioral measures across diverse Indonesian contexts, this research aims to expand the theory beyond intentional behavior focus models. It offers actionable insights for implementing a successful waste management strategy. To address these gaps, this study focuses on how Indonesian households translate knowledge and environmental concern into actual waste-sorting practices, exploring beyond intention-focus investigation. This work builds the propose conceptual framework based on Stimulus–Organism–

**Table 1**

Overview of recent research applying behavioral and psychological theories to waste management practices.

Citation	Focus	Context	Theory	Limitations
Sembiring et al. (2024)	Investigate visual/verbal interventions on household waste sorting	Low-income households in Banyuwangi, Indonesia	Behavioral change & intervention design	Small sample (29), short-term, limited generalizability.
Fenitra et al., (2025)	Link gap between knowledge and practice in campus sorting	Indonesian higher education institutions	Knowledge-Attitude-Practice (KAP) model	Small sample (69), cross-sectional, limited to engineering students.
Raghu and Rodrigues (2020)	Systematic review of behavioral theories in SWM	Global (80 studies, mostly high-income countries)	TPB, TRA, NAT, VBN, SDT, SCT, SPT, TAM, DOI, etc.	Lack of evaluation studies; limited use of social/tech theories; mostly quantitative; few mixed methods.
Zhang (2025)	Empirical & simulation study on urban waste sorting behavior	Shanghai, China (554 residents)	COM-B model + SEM + SD	Limited to Shanghai; cross-sectional; lacks broader generalizability.
Yadav and Sijoria (2025)	Examines how social media content influences zero-waste (ZW) product purchase intention	India; Instagram users following ZW stores	Goal-Framing Theory (GFT), Stimulus–Organism–Response (SOR)	Limited to Instagram users; cross-sectional design; does not measure actual behavior.
Kokash et al. (2025)	Investigates digital engagement and environmental concern in circular product buying	Malaysia; digitally active consumers aged 18–45	Stimulus–Organism–Response (SOR), Theory of Planned Behavior (TPB), Diffusion of Innovations (DOI)	Cross-sectional; excludes older and rural populations; attitude had weak predictive power.
Setiawan et al. (2019)	Assesses how different types of information affect willingness to pay (WTP) for waste management improvements	Surabaya, Indonesia; household survey	Randomized Controlled Trial (RCT), Randomized Conjoint Analysis	Limited to one city; stated preferences may not reflect actual behavior; short-term info exposure.
Ding et al. (2024)	Explores factors influencing stakeholders' intention to use CDW recycling products	China; construction industry stakeholders	Stimulus–Organism–Response (S-O-R) model; TOE framework; TAM	Does not include negative factors like perceived risk; intention ≠ actual behavior
Ulhasanah and Goto (2018)	Evaluates readiness of citizens for waste separation-based system	Indonesia; Padang City	Theory of Planned Behavior (TPB); Structural Equation Modeling (SEM); Social Evaluation	Limited to one city; stated intentions may not reflect actual behavior; short-term exposure.

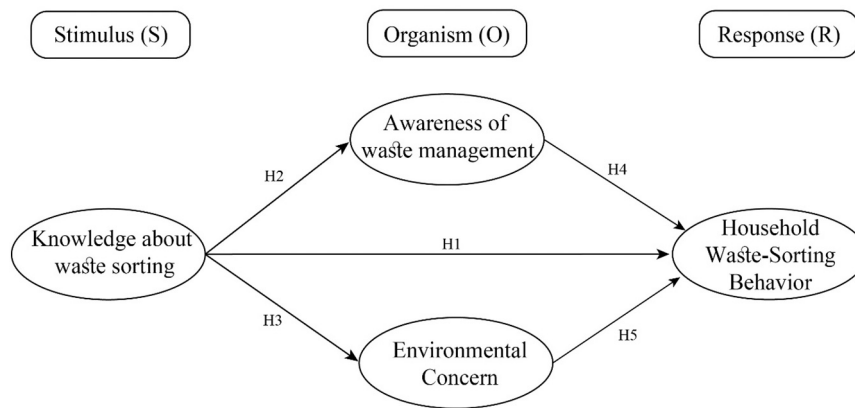


Fig. 1. Conceptual framework of waste management based on the Stimulus–Organism–Response (SOR) model.

Response to demonstrate how these internal cognitive and affective process collectively drive actual waste sorting behavior.

The major objectives of this work lie on four main aspects namely; this study explore household waste management in Indonesia, with a primary focus on waste-sorting behavior from a behavioral perspective. It examines the unique context of Indonesian households; this research enriches the existing literature and provides nuanced insights into waste-sorting practices in the region. This study employs the Stimulus–Organism–Response (SOR) model, to integrate waste-sorting knowledge, environmental concern, awareness, and waste-sorting behavior in a unified framework. Additionally, this study focusses on actual waste-sorting behavior, to explore how both cognitive and psychological factors simultaneously influence waste management practices an often-overlooked area. This study contributes to advancing current knowledge and offers practical implications for promoting effective household waste sorting practices. Specifically, by integrating both cognitive and psychological elements within the Stimulus–Organism–Response (SOR) framework and linking them to sorting behavior, this research broadens the knowledge beyond intention-centric models and offers a theoretically distinct contribution. In sum, this extended the existing literature and provides comprehensive understanding on how internal psychological processes translate into sustainable waste management practices.

## 2. Literature review

### 2.1. Stimulus-organism-response

Mehrabian and Russell (1974) developed the Stimulus–Organism–Response (SOR) framework to understand psychology and behavior related to ecology. This paradigm has been adapted across various disciplines and contexts, including waste management behavior, and it is relevant to understanding the formation of waste sorting behavior. The framework explains that stimulus (S) enhances organism (O), which in turn triggers response (R). These three dimensions work together to shape cognitive and human behavior processes. This means that, when people are exposed to a stimulus, they will develop an emotion or cognitive internal response that pushes them to act or engage in a particular way. *Stimulus* (S) refers to the external factors that might evoke an internal emotional state in an individual. *Organism* (O) refers to an individual's emotional and cognitive state triggered by an external factor. *Response* (R) is the outcome behavior or action undertaken by an individual that is reinforced by their affective state. In this study, knowledge about waste sorting (Stimulus) elicits awareness and environmental concern (Organism), which then pushes households to engage in waste sorting (Response). Although several variables in the framework resemble constructs from the Norm Activation Model (NAM), this study adopts the Stimulus–Organism–Response (SOR) model to provide a broader lens. The SOR framework enables

integration of both cognitive and affective dimensions of behavior, allowing the analysis to go beyond normative obligations emphasized in NAM and capture a more holistic view of household waste management behavior.

#### 2.1.1. Stimulus

##### *Knowledge about waste sorting:*

Waste sorting knowledge refers to the cognitive and practical ability to classify or separate waste correctly, including understanding the consequences of improper sorting of waste. Several research papers highlight the critical role of knowledge in shaping waste-sorting behavior. For example, Wang et al. (2020) found that individuals with higher knowledge about waste sorting are more likely to engage in the behavior. Wang et al. (2021) emphasized the importance of procedural knowledge in effective waste management practices. Rakhmawati et al. (2023) argued that increased knowledge about waste enhances waste-sorting behavior. Furthermore, a recent study on waste sorting underscores the positive link between knowledge and behavior (Zhang, 2025). Collectively, this evidence supports the hypothesis:

**Hypothesis 1.** *Knowledge about waste sorting significantly influences waste-sorting behavior.*

Furthermore, Debrah et al. (2021) emphasize the relationship between waste management knowledge and awareness and argue that knowledge can predict awareness. Empirical studies show that knowledge can fuel awareness about the impact of waste generation. In the survey conducted in Theran, Marques and Teixeira (2022) demonstrated that there is a positive relationship between knowledge and awareness. Numerous empirical behavioral studies on waste management have found the significant role of knowledge in predicting awareness. Bhatia and Sharma (2023) discuss the significant link between knowledge and awareness, and assert that awareness can be improved by providing relevant knowledge through education. Moreover, Babaei et al. (2015) suggest that increasing household waste management knowledge enhances household awareness. The findings indicate that cognitive information and abilities can positively influence affective states. Specifically, when households gain sufficient knowledge about proper waste sorting or are exposed to comprehensive information on how to sort waste correctly, their awareness of the potential adverse consequences of improper waste management will likely be heightened. Therefore, this study asserts that the higher the knowledge about waste sorting, the higher their awareness. Thus, this study proposes the following hypothesis:

**Hypothesis 2.** *Knowledge about waste sorting has a significant influence on waste management awareness.*

Additionally, several studies, including pro-environmental and waste management studies, show that knowledge can stimulate environmental

concerns (He et al., 2020; Rakhmawati et al., 2023). For instance, Kwakye et al. (2024) discuss how knowledge of solid waste management is linked to household perceptions and the adverse consequences it has on local communities, particularly in terms of environmental quality. This link is imperative in a behavior related to waste management. A higher degree of knowledge is crucial as it enhances an individual's cognitive and emotional state, leading them to consider and be more concerned about the environment. This is because they understand the significant effects their actions can have if they fail to sort their waste correctly. Visschers et al. (2016) supported this argument, finding a positive correlation between knowledge and environmental concern with data collected among households in Switzerland in the context of sorting food waste. Thus, this study proposes:

**Hypothesis 3.** *Knowledge about waste sorting significantly influences environmental concerns.*

### 2.1.2. Organism

**2.1.2.1. Awareness of waste management.** Awareness of waste sorting has been widely discussed by prior studies in the meta-analysis related to household waste sorting (Rousta et al., 2020). Awareness of waste sorting is a key determinant of waste management behavior. Prior studies underscore the importance of awareness in promoting waste sorting. Pongpunpurt et al. (2022) stressed that increasing awareness of waste sorting's benefits is crucial for behavior change. In particular, Debrah et al. (2021) found that greater awareness leads to higher recycling participation. Pongpunpurt et al. (2022): Stressed that increasing awareness of waste sorting is crucial for behavior change. Moreover, Pedersen and Manhice (2020) argue that the more people are aware of the importance or the benefits of sorting waste, the more likely they engage in waste sorting. Similarly, in the context of household waste management, including sorting waste, awareness plays a vital role in reinforcing waste-sorting behavior (Miltojević et al., 2017). In sum, awareness of waste sorting is a key determinant of waste management behavior. Prior studies underscore the importance of awareness in promoting waste sorting. Thus, this study proposes the following hypothesis:

**Hypothesis 4.** *Awareness of waste management significantly influences waste-sorting behavior.*

#### *Environmental Concern:*

Environmental concern is widely recognized as a critical driver of pro-environmental behavior, including waste sorting. Studies demonstrate its direct and indirect impact on behavior. He et al. (2020) Highlighted the mediating role of environmental concern in waste management behavior. Adjei et al. (2023) Identified environmental concern as a key factor influencing recycling behavior in Ghana. Rakhmawati et al. (2023) found that greater environmental concern among Indonesian households increases waste-sorting behavior. In conclusion, environmental concern is pivotal in driving pro-environmental behaviors, including waste management. Specifically, higher environmental concern in households increases the likelihood of engaging in waste sorting. Based on this evidence, the study proposes:

**Hypothesis 5.** *Environmental concern significantly influences waste-sorting behavior.*

### 2.1.3. Response

**2.1.3.1. Waste-sorting behavior.** Waste-sorting behavior has garnered significant scholarly attention as an essential component of effective waste management. As primary waste generators, households play a critical role in minimizing environmental impact through proper sorting practices (Pierini et al., 2021). Research identifies various antecedents and motivators of waste-sorting behavior, including, Shabanali et al.

(2019) highlighted the importance of situational and personal factors. Arkorful et al. (2023) found that subjective norms and perceived behavioral control influence waste sorting. Oke et al. (2022) emphasized the need to understand household-level drivers to design effective waste management practices. Therefore, the existing evidence highlights that waste-sorting behavior can be influenced by both external and internal factors, triggering reactions and emotional responses. This study builds on these findings to explore how knowledge, awareness, and environmental concern collectively shape household waste-sorting behavior using the following conceptual framework. Regarding the above evidence, it also suggests the intervention role of environmental consciousness and awareness on the link between knowledge and behavior. Thus, the hypothesis is as follows,

**Hypothesis 6.** *a) Environmental awareness and b) Consciousness mediate the influence of waste sorting knowledge on household waste sorting behavior.*

## 3. Methods

Banyuwangi, located on the southern coast of Java, faces a severe waste crisis that mirrors Indonesia's broader plastic pollution problem. (Kelly et al., 2025) reported that only about half of the nation's 42 million tonnes of annual municipal waste is formally collected. In this regard, massive waste leaks into rivers and seas, making densely populated Java, including Banyuwangi, a major hotspot. Limited waste management infrastructure and underfunded local systems further exacerbate the issue, making Banyuwangi highly vulnerable to both locally generated waste and plastic inflows from across Java. This setting was selected site due to its growing challenges in waste management and its relevance as a representative case for exploring household-level practices. Low participation in waste sorting in the area required a study to understand the current behavior. While previous studies have primarily focused on urban and metropolitan cities, there is a gap in research regarding the communities in periurban areas (Rakhmawati et al., 2023). With a community-based quantitative discovery nature, among of its limitations is the access to the respondents. As consequence the sample size of this study were 131 households in Banyuwangi, it met the minimum requirement for Structural Equation Modeling (SEM) (Wolf et al., 2013), and satisfied the rule of thumb of a 1:5 ratio between indicators and observations recommended by Hair et al. (2009). Following these given rules, the sample size meets the minimum required sample size acceptable range for the 14 items. Thus, the sample size also reflects practical limitations in accessing respondents in the field. Moreover, to minimize the small sample size bias and how it might limit the generalizability of the findings, besides the internal validity test, this research also performs test the structural model using bootstrapping with 5000 resamples. This process was considered to provide a stable and significant path coefficient estimates.

The data were collected through survey questionnaires using a purposive sampling technique to ensure an adequate response rate. The respondents received assistance from the investigator when completing the questionnaires. The survey questionnaires were designed using the Indonesian language and consist of 3 sections: the first section includes a brief introduction of the purpose of the survey and a verbal statement about the privacy policy and consent of the respondents. The second section contains the demographic profile of the respondents. The third section consists of self-reported behavioral questions. The self-reported questions used in this study were developed using borrowed and adjusted questions from prior studies. Knowledge about waste sorting refers to the extent to which households understand how to separate and categorise their waste correctly; it was measured with three items from Wang et al. (2020). Environmental concern refers to the degree to which households are concerned about environmental problems and the adverse impact of household waste. Five items from He et al. (2020) and Rakhmawati et al. (2023) were used to measure this variable. Waste management awareness refers to the recognition of the importance of



sorting waste. Three items from [Thakur and Onwubu \(2024\)](#) were used to measure this variable. Lastly, waste sorting behavior refers to the extent to which households participate in and engage with waste sorting. Three items from [\(Wang et al., 2021\)](#) were used to measure this variable. Each item was measured using a 5 likert scale range from 1 strongly disagree, 2 disagree, 3 neutral, 4 Agree, 5 strongly agree.

The Statistical Package for the Social Sciences (SPSS) and Amos software were used to analysis the data. Following [Anderson and Gerbing's \(1988\)](#) suggestions for conducting Structural Equation Modeling (SEM). These techniques require a two-stage approach: Confirmatory Factor Analysis (CFA), which assesses the validity and reliability of the measure and measurements. The second stage is SEM, which tests the coefficient between the given hypothesis.

This study ensured that the self-reported cross-sectional data were free from Common Method Bias (CMB) to overcome potential biases. First, the questions were thoroughly developed following the guidelines for minimizing CMB in survey research questionnaire recommended by [\(MacKenzie & Podsakoff, 2012; Podsakoff et al., 2003\)](#). The items used in the questionnaires were clear, concise and unambiguous to avoid a potential socially desirable bias or inconsistency. A statistical analysis was conducted to evaluate multicollinearity. A surrogate variable was created as a dummy dependent variable; then, regression analysis was performed to test whether each variable was associated with the others. Correspondingly, the Variance Inflation Factor (VIF) value was used to evaluate the presence of CMB with the VIF of multicollinearity with a threshold of 50 %. Herman's single-factor test results show that every factor has variance power below the threshold, which explains that the VIF met the required threshold, confirming that CMB was not a significant concern in this study [\(Podsakoff et al., 2003\)](#).

## 4. Data analysis

### 4.1. Descriptive characteristics of the sample

Most of the sample was female, representing 93.9 %, and males only represented 6.1 %, which may lie as a limitation of the gender dominance of the results. Regarding education background, most of the sample completed primary school (58.8 %), 19.8 completed junior high school, 11.5 % completed senior high school, 6.9 were not attending school, and only four respondents had a bachelor's degree. Regarding the monthly income, most of the sample did not disclose their income; 22.9 % earned below 1 million Rupiah, and 35.9 % earned between 1 and 2 million. The age of the participants ranges from 16 years old to 58 years old [\(Table 2\)](#).

### 4.2. Confirmatory factor analysis

The validity was assessed with a loading factor greater than 0.5 and an Average Extracted Variance (AVE) exceeding 0.5 [\(Fornell & Lacker, 1981\)](#). For Reliability, composite reliability above 0.7 was considered

**Table 2**  
Sample's demographic profile.

Features	Type	Frequency	Percentage
Gender	Male	8	6.1
	Female	123	93.9
Education	Bachelor Degree	4	3.1
	Primary School	77	58.8
	Senior High School	15	11.5
	Junior School	26	19.8
	not attending school	9	6.9
Income (Monthly in IDR) 1USD = 15,576 IDR	n/a	51	38.9
	Below 1.000.000	30	22.9
	1.000.000–2.000.0000	47	35.9
	2.000.001–3.000.0000	1	0.8
	3.000.001–5.000.0000	2	1.5
Total		131	100.0

[\(Cheung et al., 2023\)](#). The CFA results show that the loading of the 20 items ranged from 0.52 to 0.925, with an AVE between 0.520 and 0.725. Moreover, all-composite reliability exceeded the threshold criteria [\(Alumran et al., 2014; Cheung et al., 2023\)](#). The result indicated that this study's measures and measurements were accurate and appropriate [\(Table 3\)](#).

### 4.3. Model fit

In this study, the Confirmatory Factor Analysis (CFA) and Structural Equation Modeling (SEM) model fit was conducted to evaluate the degree of satisfaction with the model fit. The Model fit was estimated using the model fit indices Chi-square Minimum Discrepancy (CIMN), baseline comparison, and Root Mean Square Error of (RMSEA) [\(Table 4\)](#). [Table 4](#) shows the CFA and SEM Model fit. The result indicated that each index's criteria was more significant than the minimum threshold; therefore, CFA and SEM fit moderately [\(Fan et al., 2016; Shen et al., 2019\)](#).

**Table 3**  
Confirmatory factor analysis results with factor loadings, Cronbach's  $\alpha$ , AVE, and survey items.

Variables	Questions	Items Code	$\lambda$	C.R	AVE
Awareness about waste management	"I think the municipality has a role to play in managing household waste in this area."	AW3	0.52	0.729	0.520
	"I am eager to know more about how to manage my household waste."	AW2	0.752		
	"I am aware of the benefits of separating my household waste (glass, plastic, paper, etc.)."	AW1	0.852		
Knowledge about waste sorting	"I think I have sufficient knowledge about the value of sorting waste."	WSK3	0.794	0.851	0.725
	"I think I have sufficient knowledge about how to sort waste correctly."	WSK2	0.856		
	"I think I have sufficient knowledge about the negative effects of waste."	WSK1	0.901		
Environmental concern	"Humans must live in harmony with nature if we wish to survive."	EC1	0.615	0.883	0.687
	"I am concerned with the environment."	EC2	0.925		
	"I think humans and nature should live in harmony."	EC3	0.822		
	"I think environmental pollution is a threat to me and my family."	EC4	0.849		
	"I think environmental problems have become more serious in recent years."	EC5	0.897		
Household waste sorting behavior	"I often sort our household waste."	WSB1	0.784	0.749	0.616
	"I often participate in related activities of household waste separation."	WSB1	0.827		
	"I often recommend others to sort household waste."	WSB3	0.743		

Note: Loading Factors ( $\lambda$ ) threshold >0.5, Composite reliability (C.R) threshold >0.7, Average variance extracted (AVE) threshold >0.5.

**Table 4**  
Model Fit Confirmatory Factor Analysis and Structural Equation Modeling.

	Indices	Criteria	CFA	SEM
Chi-square Minimum Discrepancy	$\chi^2$		106.194	107.129
	df		71	72
	$p$		0.004	0.005
	$\chi^2/df$	< 3	1.496	1.488
Baseline comparison	NFI	> 0.90	0.908	0.907
	IFI	> 0.95	0.967	0.967
	TLI	> 0.95	0.957	0.958
	CFI	> 0.90	0.967	0.967
	RMSEA	< 0.08	0.062	0.061

Note: Normed Fit Index (NFI); Incremental Fit Index (IFI); Incremental Fit Index (TLI); Comparative Fit Index (CFI); Root Mean Square Error of Approximation (RMSEA); Confirmatory Factor Analysis (CFA); Structural Equation Modeling (SEM).

#### 4.4. Discriminant validity

Discriminant validity ensures that each variable used in the model is distinct. Specifically, it is conducted to guarantee that each variable does not represent an overlapping dimension with the other variable. Table 5 demonstrates the results of discriminant validity, which indicated that the correlation coefficient value between variables (0.207–0.75) was below 0.8 (Hu et al., 2009). This test also refers to Fornell and Lacker (1981), suggesting that each correlation value between variables should not exceed the squared root of the average extracted variance. The results show that each value did not exceed the maximum required criteria. Therefore, no discriminate validity issue was found, and the analysis can proceed.

### 5. Result and discussion

Table 6 demonstrates the hypothesis testing results. Results indicated that three of the five proposed hypotheses were accepted, and two were rejected. The influence of waste-sorting knowledge on household waste-sorting behavior was rejected. The statistical results show  $\beta = -0.053$ ,  $t = -0.324$ , and  $p = 0.761$ . Hence,  $H_1$  was rejected. The influence of knowledge about waste sorting on waste awareness was significant, with  $\beta = 0.679$ ,  $t = 8.232$ , and  $p < 0.001$ . Thus,  $H_2$  was accepted. The influence of knowledge about waste sorting on environmental concerns was statistically significant, with  $\beta = 0.105$ ,  $t = 2.811$ , and  $p = 0.005$ . This influence was positive. Thus,  $H_3$  was accepted. Hypothesis 4 tested the positive influence of awareness on waste sorting behavior. However, the statistical results rejected this hypothesis with  $\beta = 0.342$ ,  $t = 1.835$ , and  $p = 0.084$ . Thus,  $H_4$  was rejected. The positive influence of environmental concern on waste sorting behavior was significant. The statistical result shows a standardized effect  $\beta = 0.883$ ,  $t = 3.37$ , and  $p < 0.001$ . Hence,  $H_5$  was accepted.

During the analysis, a nonparametric bootstrap procedure including 2000 bootstrap samples and a Bias-corrected percentile method 90 % confidence interval (CI) was performed to assess the degree of significance of the path. The table describes the total, direct, and indirect effects and shows that both direct and indirect effects are found among variables. The direct impact of knowledge of environmental concern, knowledge of awareness, and environmental concern on waste sorting

**Table 5**  
Correlation matrix showing relationships among variables.

Variables	1	2	3	4
Knowledge about sorting waste	<b>0.851</b>			
Awareness about waste management	0.75	<b>0.722</b>		
Environmental concern	0.275	0.207	<b>0.829</b>	
Household waste sorting behavior	0.285	0.355	0.403	<b>0.785</b>

Note: Diagonal values in bold italics are the squared root value of the average variance extracted required to be larger than the correlation value.

**Table 6**  
Structural model estimation and hypothesis testing results.

Hypothesis	$\beta$	S.E.	t	p	Results
H1: knowledge about waste sorting - > waste sorting behavior	-0.053	0.162	-0.324	0.746	Rejected
H2: knowledge about waste sorting - > awareness about waste management	0.679	0.082	8.232	***	Accepted
H3: knowledge about waste sorting - > environmental concern	0.105	0.037	2.811	**	Accepted
H4: waste awareness - > waste sorting behavior	0.342	0.186	1.835	0.066	Rejected
H5: environmental concern - > waste sorting behavior	0.883	0.262	3.37	***	Accepted

Note: Significant level at, Waste sorting behavior (R-squared = 0.24), environmental knowledge (R-squared = 0.56), waste management awareness (R-squared = 0.80), Coefficient ( $\beta$ ), Standard Error (S.E.), t-statistic (t), p-Value (p).  
\*\*\* < 0.001.  
\*\* < 0.01.

behavior was significant. The direct effect of waste sorting knowledge and understanding of waste sorting behavior was insignificant. Moreover, the result found an indirect effect of waste sorting knowledge on waste sorting behavior, and environmental concerns potentially mediate this indirect link (Table 7).

The conceptual framework was developed based on the stimulus-organism-response model, incorporating waste sorting knowledge, waste awareness, and environmental concerns. This work examines the factors influencing household waste management behavior, mainly sorting, using the Stimulus Organism Model. Since the majority of the prior studies were based on the theory of planned behavior, the theory of reasoned action, and normative theory. To broaden the understanding, this study is among the few to explore this phenomenon through the Stimulus-Organism-Response (SOR) framework within the Indonesian context. The structural equation modeling (SEM) results indicate that three of the five proposed hypotheses were validated, while two were rejected. This study also confirms the relevance of the SOR model within this context.

The study did not support this relationship, which contradicts previous empirical evidence (He et al., 2020; Rakhmawati et al., 2023; Wang et al., 2020; Wang et al., 2021; Zhou & Qiong, 2022). Household waste management interventions often emphasize education, aiming to provide a direct solution to improve waste management practices. However, the current findings indicate that prioritizing knowledge to improve waste sorting behavior directly may not significantly enhance overall waste management practices. It implies that the absence of a direct effect suggests that knowledge alone is insufficient to activate these internal mechanisms. Given that only 24 % of the variance in waste management behavior was explained by the independent variable, it is crucial to consider additional factors, such as structural elements (e.g., facilities and collection services) (Thakur & Onwubu, 2024). Since the findings show that knowledge about household waste management does not influence waste sorting practices, it suggests that while knowledge is considered important in waste sorting in general, in this context, it does not directly improve waste sorting behavior. Therefore, regardless of how much an individual knows about household waste management practices, the presence of adequate facilities and infrastructure might be essential for translating that knowledge into effective practices is necessary to reinforce this behavior (Dhokhikah et al., 2015). These findings emphasize that, in the Indonesian context, having sufficient knowledge about waste management does not necessarily translate into practice; regardless of how much households know, it does not automatically result in waste-sorting behavior.

The results reveal that knowledge strongly, significantly, and

**Table 7**  
Summary of total, direct, and indirect effects in the structural model.

Effect sources	estimate	Bootstrapping standard error	Bias-corrected percentile method (90 %)		Two-Tailed Significance (BC)
			Lower Bounds (BC)	Upper Bounds (BC)	
<i>Total effect</i>					
KNW->BHV	0.272	0.142	0.11	0.465	0.009
KNW->BHV	0.679	0.099	0.555	0.821	0.001
KNW->ENVC	0.105	0.049	0.048	0.174	0.001
AWR->BHV	0.342	0.307	0.018	0.768	0.083
ENVC->BHV	0.883	0.337	0.476	1.411	0.001
<i>Direct effect</i>					
KNW->BHV	0.246	0.246	-0.387	0.249	0.788
KNW->AWR	0.099	0.099	0.555	0.821	0.001
KNW->ENVC	0.049	0.049	0.048	0.174	0.001
AWR->BHV	0.307	0.307	0.018	0.768	0.083
ENVC->BHV	0.337	0.337	0.476	1.411	0.001
<i>Indirect Effects</i>					
H6: KNW->BHV	0.324	0.084	0.084	0.622	0.025

Note: awareness about waste management (AWR), Knowledge about waste sorting (KNW), Environmental Concern (ENVC), Household waste sorting behavior (BHV).

positively influences awareness. Consistent with prior evidence from Babaei et al. (2015) and Bhatia and Sharma (2023). The present findings indicate that as households' knowledge of waste separation increases, their awareness of the benefits of properly managing household waste also increases. Meaning that when household are exposed to relevant information and knowledge about waste sorting, they would become more aware of the necessity of the waste management practices. Correspondingly, enhancing households' understanding of waste sorting can increase awareness. The results imply that educational initiatives and intervention campaigns focused on proper waste sorting could effectively increase household awareness of waste management issues.

The results are consistent with previous studies, which suggest that greater household knowledge of waste sorting is linked to higher levels of environmental concern (Visschers et al., 2016). In this context, knowledge about waste management operates as a critical stimulus that trigger effective response on the environmental concern, these results outline that when household acquire better understanding of waste sorting, through internalizing the ecological implications, they develop stronger environmental concern. Specifically, become more concern about the environmental problem that caused by the household waste.

These findings suggest that enhancing households' knowledge about waste separation could strengthen their environmental concerns. Furthermore, the importance of waste sorting knowledge in fostering environmental awareness has been empirically validated across various contexts. This study recommends that providing relevant information on proper waste sorting practices may enhance households' concern for the environment. Thus, information and knowledge-based intervention can effectively trigger emotional and value responses to household waste related issue.

Contrary to existing evidence (Debrah et al., 2021; Miltojević et al., 2017; Pedersen & Manhice, 2020) this study did not find support for this relationship. Although existing literature emphasizes the significant role of awareness in waste management practices, it has been shown across various contexts that increasing awareness can enhance waste management behaviors. In this context, however, households may not perceive awareness as a critical factor influencing their waste-sorting behavior. It suggests that awareness of the waste management practices is not necessarily translate into an actual waste sorting practice. The influence of awareness on sorting behavior may be limited by several factors, including the lack of visible, immediate impacts of improper waste sorting. Respondents may not perceive a need to act on their awareness if the environmental or health consequences are not apparent in their daily lives. Additionally, when waste management facilities are inadequate, individuals may perceive their sorting efforts as futile, even if they are well aware of the impact of their actions (Dhokhikah et al., 2015). Furthermore, the context of the site of this study lacks binding regulations or enforcement mechanisms that would encourage consistent sorting practices. Without penalties or rewards, individuals may feel little motivation to adhere to waste-sorting behaviors, regardless of their awareness of the benefits (Suryani, 2022). Thus, this may be attributed to several factors, including socio-economic conditions, regulatory incentives, and other external factors.

The results indicate a significant and positive effect: as households become more concerned about the environment, their participation in waste sorting increases. This finding aligns with prior studies (Adjei et al., 2023; Rakhmawati et al., 2023), which assert that environmental concern influences waste management behaviors. When the household internalize environmental value, they tend to be more emotionally driven to perform or engage in particular way specifically sorting their household waste, meaning that they would transform concern into an actual action relates to waste management. The results suggest that a household's level of environmental concern plays a critical role in enhancing waste-sorting practices. Encouraging households to engage in various ecological activities can help increase their awareness of the natural environment's benefits, impacts, and importance. This increased concern will likely reinforce their waste-sorting behavior, fostering greater involvement and participation in these efforts. Practically, strengthening the emotional response and behavioral link through experiential learning can therefore increase the participation of household to separate the waste.

The results highlight that there is no direct effect of waste sorting knowledge on the waste sorting behavior, which contradicts past studies, such as Zhang (2025); Wang et al. (2020; 2021); Rakhmawati et al. (2023). These findings indicate that environmental concern fully mediates the relationship between knowledge and behavior, suggesting that a strong sense of environmental concern enables households to translate knowledge into practice. Further, the influence of waste management awareness on waste sorting behavior was not supported, whereas environmental consciousness positively impacts waste sorting. These findings emphasize that environmental consciousness fully mediates the relationship, while waste-sorting awareness does not play a mediating role. In sum, the results highlight that strengthening households' environmental consciousness can help translate waste-sorting knowledge into effective waste-sorting practices. Interventions needed to be informed and cultivate environmental concern, as it is one of the essential psychological elements that transform knowledge into an

effective waste sorting practice.

## 6. Conclusion

This research enhances the understanding of households' waste-sorting behavior. This work applied the Stimulus-Organism-Response (SOR) framework to household waste sorting in Indonesia. This work broadens the existing knowledge in the waste management behavior literature, by exploring the association between waste sorting knowledge, waste management awareness, environmental concern, and waste sorting behavior. This work illustrates the influence of knowledge on waste behavior through awareness and environmental concern. This work expands the existing literature through a quantitative approach, providing insights into this issue from the perspective of Indonesian households. This work establishes that environmental concern fully mediates the link between knowledge and sorting behavior. Specifically, the result reveals a direct effect of knowledge on environmental concern and awareness and a direct effect of environmental concern on waste sorting behavior. However, there was no direct impact of waste sorting expertise and understanding of the need for waste sorting behavior. Additionally, indirect effects of knowledge on behavior were identified, with environmental concerns as a mediating factor. When designing an intervention campaign for household waste management, it is crucial to consider both the type of intervention and the information or message being conveyed. Providing informative and educational materials to households can significantly enhance their awareness about the benefits of waste sorting practices and the environmental issues particularly from household waste. Knowledge about proper waste sorting and its associated benefits is crucial, and it should be accompanied by clear explanations of how waste sorting directly impacts environmental health and quality. Research shows that an understanding of waste sorting improves environmental concerns. Therefore, practitioners and policy-makers should focus on promoting effective household waste management through education, as it not only raises environmental concerns but also encourages active participation in waste separation. Therefore, campaigns should be carefully designed, and the messages should align with the desired outcomes.

### 6.1. Theoretical and practical implications

This research offers several theoretical and practical implications. From a theoretical perspective, it validates the applicability of the stimulus-organism-response model in the context of waste management behavior. As the first study to utilize this framework to explore this phenomenon, it confirms the relevance of this theory to the topic. It provides insights into the potential for incorporating additional factors into the model in future research. Moreover, this work enriches the existing knowledge from the perspective of households in Indonesia. In terms of practical implications, this study highlights the roles of knowledge, awareness, and environmental concerns in enhancing waste sorting behavior. It suggests that – in periurban areas in Indonesia, like Banyuwangi – investments to improve knowledge on waste sorting or increase awareness of the benefits of this practice might be less effective in nudging waste sorting behavior than concerns people have for the environment. That said, it was not investigated whether awareness may worsen environmental concerns. The findings serve as guidelines for policy and strategy formation and for designing campaigns to improve households' waste-sorting behavior. Furthermore, environmental concerns have a positive influence on waste sorting behavior, while awareness of waste management alone does not have the same effect. This highlights the greater importance of how much households value environmental issues when promoting waste management practices. It suggests that campaigns and household waste management policies should place a stronger emphasis on the environmental impact of waste management and the associated benefits to the environment, rather than focusing solely on waste management itself.

### 6.2. Limitation and recommendation

Nevertheless, it is essential to note that despite the contributions and insights gained from this work, it also has some limitations. The limitation of this study is the sample size and characteristics, the sample used was relatively small and consisted only of lower- and middle-class households in Banyuwangi. Thus, future studies on this topic are encouraged to use a larger sample that includes a more heterogeneous mix of social classes. Comparing different classes would provide additional insights and enhance the generalizability of the results. Besides, the data used in this study were collected through self-reported survey questionnaires, which may not fully capture actual behaviors or accurately assess the respondents' level of waste sorting knowledge. Since the respondents come from lower-income backgrounds, their literacy and education levels may also be limited. As a result, Likert scale questionnaires may not be the most effective choice, as participants might struggle to comprehend the questions and express their preferences without assistance from researchers. To obtain more reliable information, future researchers might consider conducting field observations or experimental studies to gain deeper insights into participants' behaviors regarding waste sorting. Moreover, the proposed conceptual framework in this study only incorporates several variables relevant to intervention campaigns aimed at enhancing environmental behaviors. However, to gain a broader insight, future studies should also consider external variables such as incentives, regulations, and socio-cultural factors to understand this phenomenon comprehensively from multiple perspectives. Another possible limitation of this research also is that the majority of respondents (93 %) were female. In the Indonesian context, women are generally more responsible for managing household activities, including waste, which explains their higher representation in the sample. Nevertheless, this may limit the generalizability of the findings and opens opportunities for further exploration of gender dynamics. Future studies could conduct comparative analyses across genders or include gender as a control variable alongside factors such as household income and education.

Additionally, this study did not measure actual knowledge directly; instead, this work assessed participants' self-perceived knowledge. What individuals believe they know may not be sufficient to reach the necessary level of awareness, and it could include incorrect or incomplete information. Specifically, the assessment of knowledge relied on self-reported evaluations, which may not fully reflect the actual knowledge of households. Therefore, the implication of this finding that some of the hypothesis was not supported is that the respondents may have struggled to assess their own knowledge accurately. Additionally, this study did not clarify which specific knowledge or how much of it is necessary to influence waste sorting behavior. Therefore, to gain a profound understanding in this regard, future studies should consider using observational or experimental methods to capture better the true level of knowledge and understanding regarding household waste sorting practices. Furthermore, since the present study focuses on household waste sorting behavior, future research should simultaneously examine household waste management practices such as recycling, reusing or reducing household waste. This approach will provide insights into the relative importance of each factor across different types of behavior. Lastly, Future research could adopt novel theoretical perspectives, such as the Theory of Reasoned Goal Pursuit, and incorporate additional innovative factors. Expanding the study with a larger and more representative sample in justifiable locations would also enhance the robustness and novelty of the findings.

### CRediT authorship contribution statement

**Emenda Sembiring:** Writing – review & editing, Validation, Supervision, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Rakotoarisoa Maminirina Fenitra:** Writing – original draft, Methodology, Formal analysis. **Aisya**



**Rahmania Dangkoa:** Investigation, Data curation. **Zayinaton Biladiyah Al Khoeriyah:** Project administration, Investigation, Data curation. **Anouk Zeeuw Van Der Laan:** Data curation. **Yueyun Fan:** Data curation. **Fabrizio Ceschin:** Supervision, Data curation. **Susan Jobling:** Funding acquisition.

## Ethical statement

The authors declare no conflicts of interest related to the completion of this work. All research procedures complied with ethical standards, and the study was conducted in accordance with the Declaration of Helsinki. The research materials and protocols were approved by the appropriate Ethics Committee.

## Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Susan Jobling reports financial support was provided by UK Research and Innovation. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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## Data availability

The datasets used in the current study are available from the corresponding author on reasonable request.

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