Enhancing Circular Waste Management Behavior Through Adaptive Capacity With Structural Equation Modeling Framework in Bali, Indonesia

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ABSTRACT: This research examined the intricacies of circular waste management behaviors in Bali, Indonesia, using a Structural Equation Modeling (SEM) framework focused on adaptive capacity. Adaptive capacity was defined through five key dimensions: assets, flexibility, organization, learning, and agency. These elements were critical in shaping the intentions and behaviors associated with sustainable waste management practices. The study systematically explored how these interconnected dimensions of adaptive capacity either facilitated or impeded the adoption of practices aligned with the principles of the circular economy. The SEM approach was employed to map and validate the relationships between the dimensions of adaptive capacity and their impact on waste management behaviors. This analytical method provided a robust framework for understanding the complex dynamics at play, highlighting how different facets of adaptive capacity interacted to influence sustainable practices. Key findings underscored the critical role of individual empowerment, the effectiveness of organizational structures, and the impact of educational initiatives in driving sustainable waste management behaviors. These insights suggested that enhancing individual agency, optimizing organizational protocols, and expanding learning opportunities were pivotal in fostering more sustainable waste management practices.

KEYWORDS: Circular economy; waste management behavior; structural equation modeling; adaptive capacity; sustainability

1. Introduction

The rapid urbanization of Bali, Indonesia, particularly within the Sarbagita Metropolitan area, underscored the urgent need for sustainable waste management practices [1]. As urban populations swelled, the challenges of managing municipal waste grew [2], often outpacing the development of the necessary infrastructure and policy frameworks. This led to increased environmental degradation, affecting both land and marine ecosystems [3–5], which were

crucial to the region's economy and the well-being of its communities. The concept of a circular economy, which emphasized reducing waste, reusing resources, and recycling materials to keep them within the economy for as long as possible [6,7], offered a promising pathway to address these challenges. However, transitioning to a circular economy required more than just infrastructural changes; it demanded a shift in the behaviors and attitudes of individuals and organizations towards waste management [8, 9]. This was where the concept of adaptive capacity came into play, encompassing the abilities of individuals and communities to adjust their behaviors and practices in response to environmental policies and changes. Adaptive capacity in waste management was influenced by various factors, including assets, flexibility, organization, learning, and agency [10, 11]. These dimensions collectively contributed to the resilience of urban systems against environmental pressures and were pivotal in fostering sustainable waste management behaviors [12].

Understanding the factors that drove behavior change was crucial in sustainable waste management [9, 13]. Traditionally, research in this area predominantly relied on psychological models like the Theory of Planned Behavior (TPB), which focused on attitudes, subjective norms, and perceived behavioral control as determinants of behavior [14–17]. While TPB provided valuable insights into individual motivations, it fell short in addressing the broader systemic and adaptive capacities critical in a circular economy. The circular economy model emphasized reducing, reusing, and recycling materials to minimize waste and sustainably manage resources. However, the transition to such an economy was complex and required more than just individual behavior change; it demanded a systemic transformation involving adapting technologies, processes, and behaviors at multiple levels of society. This was where the concept of adaptive capacity became particularly relevant, encompassing the ability of a system, community, or individual to adjust practices, processes, and structures in response to changing conditions and to maintain or enhance its functionality [18, 19].

Despite the growing emphasis on adaptive capacity in sustainability research, a clear gap remained in understanding how its constituent elements interacted to shape waste management behavior within a circular economy framework. Existing studies predominantly examined adaptive capacity dimensions in isolation or emphasized infrastructure availability and individual attitudes, often drawing on theory-driven approaches such as the Theory of Planned Behavior (TPB) or infrastructure-centric performance indicators. As a result, the interdependencies among adaptive capacity components and their collective role in translating intention into actual behavior within a circular economy context were insufficiently addressed. The advancement of sustainable waste management under a circular economy framework extended beyond the mere provision of physical infrastructure [20, 21]. Prior empirical evidence suggested that infrastructure alone was often inadequate to produce sustained behavioral change, particularly in rapidly urbanizing and tourism-dependent regions [22, 23]. In response to this limitation, the present study adopted a multifaceted perspective, positioning adaptive capacity as a systemic construct composed of interrelated dimensions that jointly influenced behavioral outcomes. Specifically, assets, flexibility, organization, learning, and agency were conceptualized as complementary elements that collectively shaped the resilience and effectiveness of urban waste management systems. Rather than treating infrastructure as the dominant driver, this framework emphasized the synergistic interaction among adaptive capacity dimensions in enabling sustainable waste management practices [24].

Building on this conceptual foundation, the study developed an integrated adaptive capacity framework for circular waste management (Figure 1). Assets reflected the availability of physical and policy-related resources supporting waste management activities, aligning with the resource-based view that emphasized material and institutional readiness. Flexibility captured the ability of individuals and systems to adjust practices in response to changing environmental and regulatory conditions, consistent with dynamic capability theory. Organization represented the role of coordinated structures, routines, and governance mechanisms in guiding collective action, as highlighted in institutional theory. Learning referred to knowledge acquisition and dissemination processes that enhanced environmental awareness and competence, drawing on knowledge-based theory. Agency reflected individual and collective empowerment, emphasizing autonomy and perceived self-efficacy in initiating and sustaining pro-environmental action, as grounded in social cognitive theory.
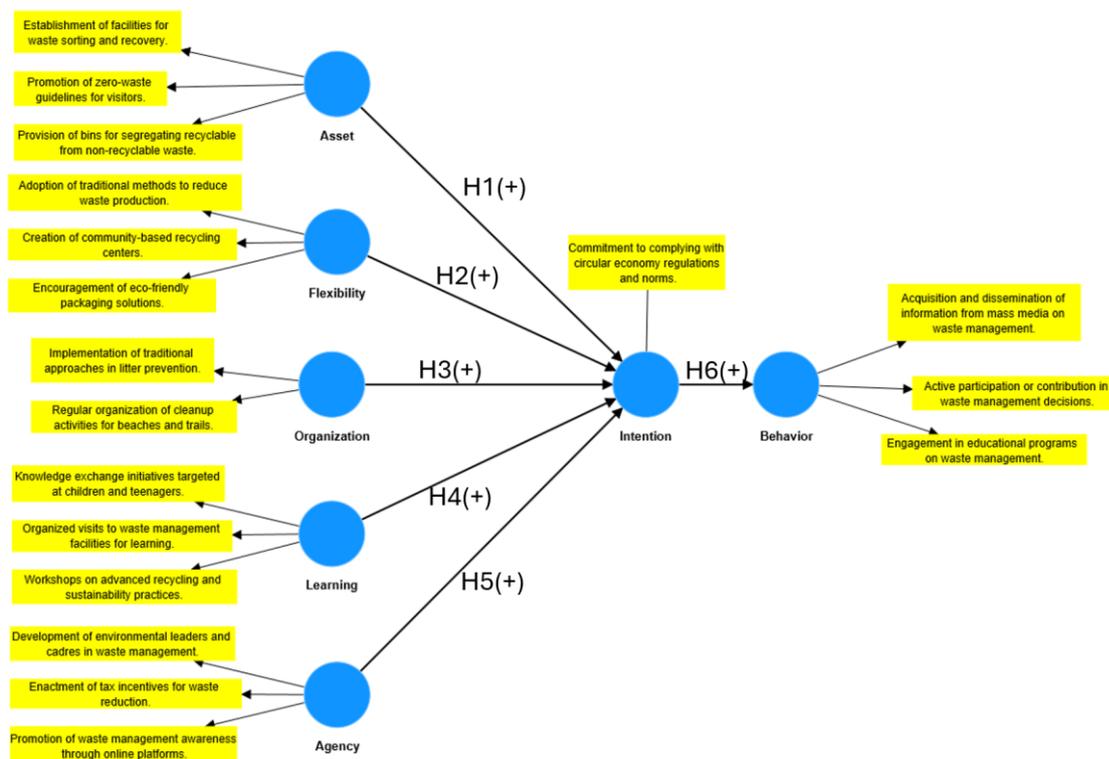
Figure 1. Adaptive capacity framework in circular economy for sustainable waste management.

Based on this framework, six hypotheses were formulated. Assets (H1), flexibility (H2), organization (H3), learning (H4), and agency (H5) were hypothesized to influence behavioral intention toward circular waste management, while intention was expected to mediate the relationship between adaptive capacity dimensions and actual behavior (H6). This integrative hypothesis structure was consistent with systems thinking, which emphasized that interactions among multiple system components generated emergent behavioral outcomes rather than linear, single-factor effects.

The novelty of this study lay in the development and empirical validation of an adaptive capacity–based measurement model that explicitly integrated five interdependent dimensions within a unified Structural Equation Modeling (SEM) framework. Unlike previous studies that focused on isolated predictors or direct behavior models, this research examined both direct and indirect pathways linking adaptive capacity, intention, and behavior. By operationalizing

adaptive capacity as a multi-dimensional latent construct and testing its mediated effects on behavior, the study provided a more comprehensive explanation of how circular waste management practices emerged in complex urban contexts. Accordingly, this study aimed to address the identified research gap by applying SEM to analyze the relationships between adaptive capacity, intention, and circular waste management behavior in the Sarbagita Metropolitan Area of Bali, Indonesia. This context was particularly relevant due to its high urban density, intense tourism activity, and environmental vulnerability, where effective waste management represented both an ecological necessity and an economic imperative. The findings contributed empirical insights for policymakers, urban planners, and community stakeholders by demonstrating how strengthening adaptive capacity beyond infrastructure provision alone, supported more resilient and sustainable waste management systems.

2. Material dan Method

2.1. Study location, study design, and hypothesis development.

The research was conducted in the Sarbagita Metropolitan Area of Bali, Indonesia, which comprises Denpasar City and the regencies of Badung, Gianyar, and Tabanan. Sarbagita represented a rapidly urbanizing metropolitan region characterized by high population density, intensive tourism activity, and increasing municipal solid waste generation. These dynamics posed persistent challenges for waste management governance, infrastructure performance, and community participation, particularly within a tourism-driven economy where environmental quality directly affected economic sustainability. A quantitative, cross-sectional survey design was employed to examine how adaptive capacity influenced circular waste management intention and behavior in this urban context. The circular economy perspective was especially relevant in Sarbagita due to high consumption rates, seasonal fluctuations in waste volume driven by tourism, and growing pressure on existing waste management systems. These conditions highlighted the limitations of infrastructure-centric approaches and underscored the importance of adaptive behavioral and institutional responses.

Adaptive capacity was conceptualized as a multidimensional construct consisting of five interrelated dimensions: assets, flexibility, organization, learning, and agency. To ensure conceptual clarity and empirical rigor, each dimension was operationalized into measurable indicators grounded in established theoretical frameworks and adapted to Sarbagita's local context. Assets reflected the availability and quality of physical infrastructure and policy instruments supporting waste management. Flexibility captured the ability of households and communities to adjust waste-related practices in response to regulatory changes, tourism pressure, and service variability. Organization represented the effectiveness of institutional coordination, routine waste management activities, and community-level organization. Learning reflected access to environmental education, knowledge exchange, and information related to circular economy practices. Agency captured individual and collective empowerment to participate in decision-making and initiate waste management actions. The operational definitions, measurement items, and theoretical foundations of these constructs were summarized in Table 1 to enhance transparency and methodological clarity.

Table 1. Operationalization of adaptive capacity constructs in circular waste management.

Construct	Definition	Example Survey Indicators	Theoretical Foundation
Assets	Availability and quality of physical infrastructure and policy instruments supporting waste management	Waste segregation bins, waste sorting facilities, zero-waste guidelines	Resource-Based View
Flexibility	Ability to adjust waste management practices in response to changing conditions	Adoption of traditional waste reduction methods, adaptive collection practices	Dynamic Capability Theory
Organization	Effectiveness of institutional coordination and routine waste management structures	Regular clean-up activities, organized community recycling centers	Institutional Theory
Learning	Access to and participation in environmental education and knowledge exchange	Workshops, school programs, facility visits	Knowledge-Based Theory
Agency	Individual and collective empowerment to initiate and participate in waste management actions	Environmental leadership, participation in decision-making, policy incentives	Social Cognitive Theory
Intention	Willingness and readiness to engage in circular waste management practices	Commitment to regulations, intention to participate	Behavioral and Systems Theory
Behavior	Actual engagement in circular waste management actions	Participation in programs, information dissemination	Behavioral Theory / Systems Thinking

Based on this framework, six hypotheses were developed and explicitly grounded in both theory and the Sarbagita context. H1 posited that assets positively influenced intention toward circular waste management behavior, drawing on the resource-based view, which emphasized the role of material and institutional resources in enabling sustainable practices. H2 hypothesized that flexibility positively influenced intention, consistent with dynamic capability theory, which highlighted adaptability as a key mechanism for responding to environmental and regulatory change in complex urban systems. H3 proposed that organization positively influenced intention, supported by institutional theory, which emphasized the role of governance structures, routines, and coordination in shaping collective behavior. H4 suggested that learning positively influenced intention, drawing on knowledge-based theory, which underscored the importance of information and education in promoting pro-environmental behavior. H5 hypothesized that agency positively influenced intention, grounded in social cognitive theory, which emphasized self-efficacy and perceived control as critical drivers of behavioral motivation. H6 proposed that behavioral intention mediated the relationship between adaptive capacity dimensions and actual circular waste management behavior, consistent with systems thinking and behavioral theories that emphasized the interaction of multiple system components in producing observable outcomes.

2.2. Survey execution and sampling design.

The survey was designed to collect quantitative data on community attitudes and behaviors related to circular economy–oriented municipal waste management in the Sarbagita Metropolitan Area, Bali. Data collection was conducted using face-to-face interviews in Bahasa Indonesia and Bahasa Bali to ensure clarity of interpretation and to capture local linguistic and cultural nuances associated with environmental stewardship. This approach

enhanced response accuracy and minimized misunderstandings related to technical waste management terminology.

A stratified random sampling strategy was applied to ensure representativeness across the Sarbagita metropolitan area, which consists of four administrative districts: Denpasar City, Badung Regency, Gianyar Regency, and Tabanan Regency. Stratification was conducted at the district level to account for differences in population density, urbanization intensity, and waste management characteristics. Within each district, respondents were randomly selected from residential areas to ensure balanced representation across socio-demographic groups.

The minimum required sample size was determined using the Slovin formula with a margin of error of 4%, which was selected to achieve higher precision while remaining feasible for field-based data collection in a large metropolitan population. This margin of error was considered appropriate for improving estimation accuracy in behavioral and perception-based studies conducted at the urban scale. Based on this calculation, a target sample size exceeding the minimum requirement was collected to ensure robustness for multivariate analysis. A total of 640 valid responses were obtained and included in the final analysis. The response rate was high due to the face-to-face survey approach, and incomplete or inconsistent questionnaires were excluded during data screening to maintain data quality. The final sample size satisfied the requirements for Confirmatory Factor Analysis and Structural Equation Modeling, thereby supporting reliable estimation of latent constructs and structural relationships. The survey instrument comprised twelve indicators representing five adaptive capacity dimensions relevant to circular economy implementation: assets, flexibility, organization, learning, and agency. Assets assessed the availability and quality of physical and infrastructural resources supporting waste management. Flexibility captured the ability of communities to adjust waste management practices in response to environmental or regulatory changes. Organization measured the effectiveness of institutional and community coordination mechanisms. Learning reflected access to and participation in educational activities related to waste management and circular economy principles. Agency represented individual and collective empowerment to initiate and sustain waste management actions.

Each indicator was operationalized through specific actions or initiatives designed to strengthen adaptive capacity. Respondents evaluated these indicators using Likert-scale questions. Satisfaction with waste management measures was rated from *Not Very Satisfying* to *Very Satisfying*, while engagement-related behaviors such as participation in educational programs, involvement in decision-making processes, and information acquisition through mass media were measured using agreement scales ranging from *Strongly Disagree* to *Strongly Agree*. This structured approach enabled a comprehensive assessment of adaptive capacity and provided a robust empirical foundation for subsequent CFA and SEM analyses.

2.4. Data analysis.

The data analysis was conducted in two sequential stages to align with the study's research objectives. The first stage focused on validating the proposed adaptive capacity measurement model, while the second stage examined the structural relationships between adaptive capacity dimensions, behavioral intention, and circular waste management behavior. Confirmatory Factor Analysis (CFA) was employed as the initial analytical step to validate the measurement model of adaptive capacity within the circular economy framework of municipal waste management in Bali. CFA assessed whether the observed survey indicators adequately

represented their respective latent constructs—assets, flexibility, organization, learning, agency, intention, and behavior—as specified in the conceptual framework. This procedure ensured that the measurement model was theoretically coherent and empirically robust before testing structural relationships. Indicator validity was evaluated through standardized factor loadings, which were required to be statistically significant and exceed commonly accepted thresholds.

Construct reliability was assessed using Cronbach's alpha to examine the internal consistency of the indicators associated with each latent variable. Higher Cronbach's alpha values indicated stronger consistency in measuring the underlying construct. In addition, convergent validity was evaluated using the Average Variance Extracted (AVE), which measured the proportion of variance captured by a construct relative to measurement error. AVE values exceeding 0.50 indicated satisfactory convergent validity and supported the adequacy of the measurement model.

Following measurement validation, Structural Equation Modeling (SEM) was applied to address the second research objective, which examined the hypothesized direct and indirect relationships among adaptive capacity dimensions, behavioral intention, and actual waste management behavior. SEM was selected because it allowed the simultaneous estimation of multiple interrelated dependence relationships while accounting for measurement error in latent constructs. This approach was particularly suitable for testing the mediating role of intention in translating adaptive capacity into observed behavior within a circular economy context. Model fit was evaluated using multiple goodness-of-fit indices to ensure an adequate representation of the observed data. The Standardized Root Mean Square Residual (SRMR) assessed the average discrepancy between observed and model-implied correlations, with values below 0.08 indicating acceptable fit. The Normed Fit Index (NFI) compared the estimated model with a null model, where values closer to 1 reflected better model performance. Together, these indices provided evidence that both the measurement and structural models were appropriate for testing the study's conceptual framework and research hypotheses.

3. Results and Discussion

The descriptive statistics in Table 2 revealed distinct patterns across infrastructure-related, behavioral, and engagement-oriented indicators, highlighting important nuances in community responses to circular waste management initiatives. Indicators associated with physical infrastructure and policy support, such as the provision of waste segregation bins, promotion of zero-waste guidelines, and establishment of waste sorting and recovery facilities, exhibited moderate mean values. This suggested that although such assets were available, their perceived effectiveness or utilization remained uneven across the community. The pattern implied that infrastructure availability alone did not automatically translate into strong behavioral commitment, reinforcing the need to examine adaptive capacity beyond material provision. In contrast, indicators reflecting behavioral engagement and personal involvement, including participation in educational programs, active contribution to waste management decision-making, and acquisition of information through mass media, demonstrated notably higher mean values. These results indicated that informational exposure, learning opportunities, and participatory mechanisms were more strongly internalized by respondents than infrastructural measures alone. The higher means observed for intention-related indicators, such as

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commitment to complying with circular economy regulations, further suggested that normative and cognitive factors played a central role in shaping waste management behavior within the study area.

Table 2. Survey indicators and actions for circular economy and waste management.

Variable	Mean	Std. Error	Std. Deviation	Variance	Skewness	Kurtosis
Provision of bins for segregating recyclable from non-recyclable waste.	2.4703	0.05283	1.33652	1.786	0.764	-0.727
Promotion of zero-waste guidelines for visitors.	2.4516	0.0553	1.39891	1.957	0.781	-0.79
Establishment of facilities for waste sorting and recovery.	2.4047	0.05494	1.38976	1.931	0.728	-0.787
Adoption of traditional methods to reduce waste production.	2.3953	0.05254	1.32921	1.767	0.816	-0.603
Encouragement of eco-friendly packaging solutions.	2.4016	0.05348	1.35302	1.831	0.776	-0.709
Creation of community-based recycling centers.	2.4547	0.05281	1.33608	1.785	0.814	-0.614
Implementation of traditional approaches in litter prevention.	2.3859	0.04929	1.24701	1.555	0.783	-0.482
Regular organization of cleanup activities for beaches and trails.	2.3672	0.05141	1.30048	1.691	0.811	-0.547
Knowledge exchange initiatives targeted at children and teenagers.	2.4063	0.05234	1.32413	1.753	0.822	-0.562
Organized visits to waste management facilities for learning.	2.3734	0.05348	1.35299	1.831	0.844	-0.556
Workshops on advanced recycling and sustainability practices.	2.4188	0.05172	1.30832	1.712	0.803	-0.542
Promotion of waste management awareness through online platforms.	2.4156	0.05037	1.27418	1.624	0.788	-0.522
Development of environmental leaders and cadres in waste management.	2.3813	0.04982	1.26031	1.588	0.834	-0.382
Enactment of tax incentives for waste reduction.	2.3391	0.04924	1.2456	1.552	0.945	-0.199
Commitment to complying with circular economy regulations and norms.	4.1391	0.02774	0.70169	0.492	-0.363	-0.207
Engagement in educational programs on waste management.	4.175	0.0296	0.74892	0.561	-0.589	-0.112
Active participation or contribution in waste management decisions.	4.0562	0.03586	0.90726	0.823	-1.234	1.999
Acquisition and dissemination of information from mass media on waste management.	3.9406	0.03778	0.95579	0.914	-1.24	1.896
Gender (1=Female, otherwise=0)	0.5438	0.0197	0.49847	0.248	-0.176	-1.975
Income (1=More than minimum wage, otherwise=0)	0.8156	0.01534	0.38809	0.151	-1.632	0.664
Higher education (1=More than bachelors degree, otherwise=0)	0.6266	0.01914	0.4841	0.234	-0.525	-1.73
Age (1 more than 39 year old, otherwise=0)	0.2141	0.01623	0.41049	0.169	1.398	-0.047

Indicators related to community organization and learning, such as regular clean-up activities, environmental leadership development, and knowledge exchange initiatives, displayed relatively consistent means with moderate dispersion. This indicated shared recognition of collective action while also reflecting variation in the intensity of participation.

Such variation underscored the heterogeneous nature of adaptive capacity across households and communities in Sarbagita, where exposure to programs, governance arrangements, and local initiatives differed by location and socio-economic context. Several variables exhibited noticeable skewness and kurtosis, particularly those related to participation and information acquisition, indicating departures from normal distribution. These distributional characteristics reflected polarized responses, where a segment of respondents was highly engaged while others remained minimally involved. These patterns justified the application of latent-variable modeling approaches, as Structural Equation Modeling was well suited to capturing underlying constructs and accounting for measurement complexity beyond simple mean comparisons.

Figure 2 presented the Structural Equation Modeling (SEM) results for the adaptive capacity framework and its relationship with sustainable waste management behavior. The measurement model exhibited strong construct validity across all latent variables. Indicators associated with assets showed high standardized loadings, ranging from 0.933 to 0.948, indicating that infrastructure-related measures such as waste sorting facilities, zero-waste guidelines, and waste segregation bins were consistently perceived as representing the asset construct. Similarly, flexibility indicators loaded strongly on their latent construct, with values between 0.936 and 0.943, reflecting coherent measurement of adaptive waste reduction practices and eco-friendly packaging initiatives.
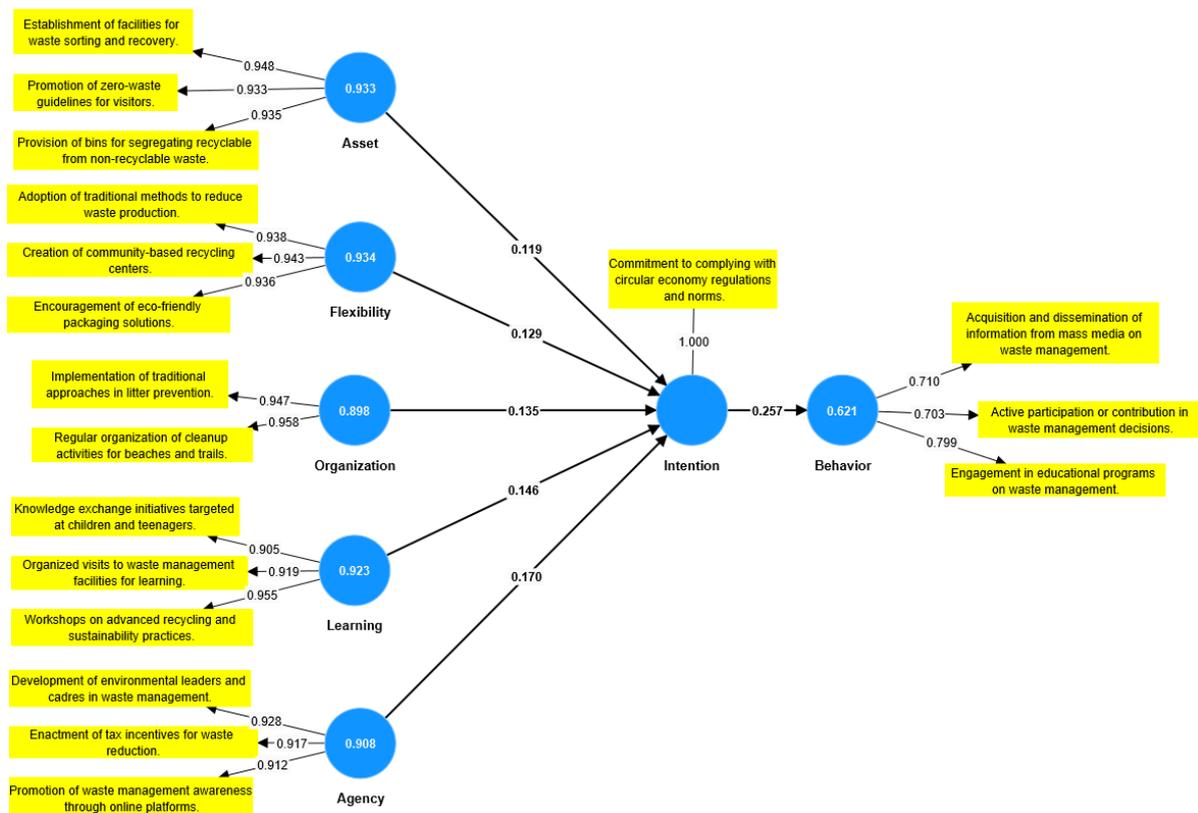
Figure 2. SEM results for adaptive capacity and sustainable waste management behaviors.

The organization construct demonstrated robust indicator loadings, ranging from 0.947 to 0.958, suggesting that coordinated activities such as clean-up programs and litter prevention practices were well captured. Indicators for learning also showed high loadings (0.905–0.955), confirming that knowledge exchange initiatives, educational visits, and recycling workshops reliably represented learning-related adaptive capacity. The agency construct was strongly

measured, with factor loadings between 0.912 and 0.928, indicating that leadership development, policy incentives, and online awareness campaigns consistently reflected empowerment and self-efficacy dimensions. Behavioral indicators loaded adequately on the behavior construct (0.703–0.799), while the construct reliability value for behavior (0.621) indicated acceptable consistency for exploratory behavioral research.

At the structural level, the SEM results revealed differentiated effects of adaptive capacity dimensions on behavioral intention. Agency exerted the strongest positive influence on intention (standardized path coefficient = 0.170), highlighting empowerment as the most influential driver of commitment to circular waste management practices. Learning also showed a positive relationship with intention (0.146), although the magnitude was relatively modest. In contrast, assets exhibited a negative relationship with intention (−0.119), indicating that increased infrastructure availability did not enhance, and may have reduced, individual motivation to engage in sustainable waste management. Flexibility (0.129) and organization (−0.135) displayed weak and non-significant relationships with intention, suggesting limited direct motivational effects within the Sarbagita context. Behavioral intention demonstrated a strong and positive effect on actual behavior (path coefficient = 0.257), confirming its central mediating role in translating adaptive capacity into observable waste management actions. The coefficient of determination for intention was fixed at 1.000 in the model, while the explained variance for behavior was 0.621, indicating that intention accounted for a substantial proportion of behavioral variation.

Table 3 presented the goodness-of-fit indices for the Structural Equation Modeling (SEM) analysis, comparing the saturated model and the estimated model. These indices were reported to evaluate how well the proposed adaptive capacity framework represented the observed data. Multiple fit measures were used to provide a comprehensive assessment of model adequacy, including the Standardized Root Mean Square Residual (SRMR), discrepancy measures (d_ULS and d_G), the Chi-square statistic, and the Normed Fit Index (NFI). Together, these indicators offered complementary evidence regarding the overall fit and robustness of the measurement and structural models. The results indicated that the estimated model achieved an acceptable level of fit. The SRMR value of 0.081 for the estimated model remained within the commonly accepted threshold for SEM applications, while the NFI value of 0.864 suggested a satisfactory comparative fit relative to the null model. Although the Chi-square statistic increased slightly in the estimated model, this outcome was expected given the model's complexity and sample size and did not undermine the overall adequacy of the model fit.

Table 3. Goodness-of-fit measured.

Parameters	Saturated model	Estimated model
SRMR	0.053	0.081
d_ULS	0.484	1.13
d_G	0.465	0.485
Chi-square	1739.342	1784.894
NFI	0.867	0.864

Table 4 reported the Confirmatory Factor Analysis (CFA) results for the adaptive capacity measurement model, including standardized factor loadings, t-values, and p-values for all observed indicators. For the asset construct, all infrastructure- and policy-related indicators demonstrated high standardized loadings (ranging from approximately 0.933 to

0.948) with p < 0.001 and large t-values. These results confirmed that the provision of waste segregation bins, zero-waste guidelines, and waste sorting or recovery facilities consistently and reliably represented the latent asset dimension. The statistical significance of these loadings indicated that respondents clearly associated these physical and regulatory elements with the concept of waste management assets. Importantly, this strong measurement validity suggested that the subsequently observed negative relationship between assets and intention in the structural model did not result from weak or ambiguous measurement but reflected a substantive behavioral phenomenon.

Table 4. Factor loadings for adaptive capacity in circular economy.

Variable	Loadings	Sample mean	Standard deviation	T-value	p-values
Acquisition and dissemination of information from mass media on waste management. ← Behavior	0.71	0.695	0.079	9	< 0.001
Active participation or contribution in waste management decisions. ← Behavior	0.703	0.686	0.078	8.981	< 0.001
Adoption of traditional methods to reduce waste production. ← Flexibility	0.938	0.936	0.02	46.198	< 0.001
Creation of community-based recycling centers. ← Flexibility	0.943	0.943	0.02	47.342	< 0.001
Development of environmental leaders and cadres in waste management. ← Agency	0.928	0.927	0.011	87.728	< 0.001
Enactment of tax incentives for waste reduction. ← Agency	0.917	0.917	0.013	72.3	< 0.001
Encouragement of eco-friendly packaging solutions. ← Flexibility	0.936	0.933	0.021	44.293	< 0.001
Engagement in educational programs on waste management. ← Behavior	0.799	0.803	0.059	13.624	< 0.001
Establishment of facilities for waste sorting and recovery. ← Asset	0.948	0.948	0.018	51.991	< 0.001
Implementation of traditional approaches in litter prevention. ← Organization	0.947	0.945	0.014	66.299	< 0.001
Knowledge exchange initiatives targeted at children and teenagers. ← Learning	0.905	0.898	0.033	27.253	< 0.001
Organized visits to waste management facilities for learning. ← Learning	0.919	0.913	0.029	31.195	< 0.001
Promotion of waste management awareness through online platforms. ← Agency	0.912	0.911	0.014	65.52	< 0.001
Promotion of zero-waste guidelines for visitors. ← Asset	0.933	0.93	0.023	40.971	< 0.001
Provision of bins for segregating recyclable from non-recyclable waste. ← Asset	0.935	0.933	0.02	47.571	< 0.001
Regular organization of cleanup activities for beaches and trails. ← Organization	0.958	0.958	0.012	77.735	< 0.001
Workshops on advanced recycling and sustainability practices. ← Learning	0.955	0.957	0.018	52.366	< 0.001

Similarly, indicators associated with flexibility, including traditional waste reduction methods, community-based recycling centers, and eco-friendly packaging solutions, showed very strong loadings (approximately 0.936–0.943) with p < 0.001. These results demonstrated that adaptive behavioral practices were coherently perceived as part of a single latent construct. The high statistical significance suggested that respondents consistently recognized flexibility as the ability to adjust waste management practices in response to changing conditions. Consequently, the non-significant structural path between flexibility and intention could not be attributed to measurement error but rather to contextual or motivational factors within the

Sarbagita setting. The organization construct also exhibited uniformly high and statistically significant loadings (p < 0.001), particularly for indicators related to litter prevention practices and the regular organization of cleanup activities. These results confirmed that institutional coordination and routine collective actions were well defined empirically. The strong significance of organizational indicators suggested that respondents clearly understood and recognized organized waste management activities. Therefore, the lack of a significant effect of organization on intention in the SEM analysis reflected a disconnect between institutional presence and individual motivational processes, rather than a failure to measure organizational capacity accurately. For the learning construct, all education- and knowledge-related indicators—including school-targeted knowledge exchange initiatives, visits to waste management facilities, and sustainability workshops—loaded strongly and significantly (p < 0.001) on the latent variable. These findings indicated that learning opportunities were consistently perceived as a coherent dimension of adaptive capacity. The strong statistical support for learning as a construct suggested that information and education were present and recognized by respondents, even though their influence on intention remained modest in the structural model. This outcome implied that awareness alone was insufficient to generate strong behavioral motivation without complementary empowerment or participatory mechanisms.

The agency construct demonstrated particularly robust measurement properties, with all indicators—such as environmental leadership development, tax incentives for waste reduction, and online awareness campaigns—exhibiting high standardized loadings and p < 0.001. The strong statistical significance underscored that empowerment, perceived control, and opportunities for initiative were clearly and consistently captured. This measurement strength aligned closely with the structural results, where agency emerged as the most influential driver of behavioral intention. The convergence of strong measurement validity and significant structural effects reinforced the central role of agency in translating adaptive capacity into action. Finally, indicators associated with the behavior construct—namely engagement in educational programs, participation in waste management decision-making, and acquisition and dissemination of information through mass media—were all statistically significant at p < 0.001. Although the standardized loadings for behavior were lower relative to other constructs, their statistical significance indicated that these indicators reliably reflected actual waste management behavior. The lower magnitude of loadings and the relatively modest Cronbach's alpha for behavior reflected the heterogeneous and situational nature of observed behavior rather than measurement invalidity. Behavioral engagement varied considerably across respondents, which was consistent with real-world differences in opportunity, access, and motivation. Notably, no indicators exhibited non-significant loadings (p > 0.05), indicating that all survey items met accepted statistical criteria for inclusion in the measurement model. This comprehensive statistical support confirmed that the CFA model was well specified and that all constructs were empirically distinct and meaningful. As a result, the interpretation of non-significant or counterintuitive structural relationships—such as the negative asset–intention path or the weak effects of flexibility and organization—was grounded in substantive behavioral dynamics rather than deficiencies in measurement quality. This distinction was critical for ensuring the validity of subsequent theoretical interpretation and policy implications.

Table 5 reported the reliability and validity metrics for the circular economy constructs included in the Structural Equation Modeling analysis. The assessment focused on internal consistency reliability using Cronbach's alpha, convergent validity using the Average Variance Extracted (AVE), and construct-level associations to evaluate the adequacy of the measurement model prior to interpreting the structural relationships. The results indicated strong internal consistency for most adaptive capacity constructs. Agency, asset, flexibility, learning, and organization exhibited Cronbach's alpha values exceeding the recommended threshold of 0.70, demonstrating reliable and consistent measurement of their respective latent constructs. In particular, agency ($\alpha = 0.908$), asset ($\alpha = 0.933$), flexibility ($\alpha = 0.934$), and learning ($\alpha = 0.923$) showed excellent reliability, confirming that empowerment, infrastructure availability, adaptive practices, and educational engagement were coherently captured within the Sarbagita context. Convergent validity was supported by the AVE values, all of which exceeded the minimum recommended threshold of 0.50. High AVE values for agency (0.845), asset (0.881), flexibility (0.882), and learning (0.859) indicated that these constructs explained a substantial proportion of variance in their observed indicators. This result confirmed that the indicators were strongly associated with their intended latent constructs and that the measurement model demonstrated satisfactory convergent validity.

Table 5. Reliability and validity metrics for circular economy constructs.

Variable	Agency	Asset	Behavior	Flexibility	Intention	Learning	Organization
Agency	1						
Asset	0.78	1					
Behavior	0.15	0.22	1				
Flexibility	0.74	0.81	0.2	1			
Intention	0.18	0.12	0.3	0.13	1		
Learning	0.71	0.79	0.17	0.76	0.14	1	
Organization	0.69	0.77	0.18	0.73	0.14	0.75	1
	Cronbachs alpha	Average variance extracted (AVE)					
Agency	0.908	0.845					
Asset	0.933	0.881					
Behavior	0.621	0.546					
Flexibility	0.934	0.882					
Intention	-	-					
Learning	0.923	0.859					
Organization							

The behavior construct exhibited a lower Cronbach's alpha value ($\alpha = 0.621$), which fell below the conventional 0.70 threshold. This limitation was acknowledged and interpreted cautiously. The lower reliability reflected the heterogeneous nature of observed waste management behaviors, which were influenced by situational factors such as access, opportunity, and variability in participation intensity across respondents. Despite this limitation, the AVE value for behavior (0.546) exceeded the acceptable minimum, indicating that the construct retained adequate convergent validity for exploratory behavioral analysis. These results suggested that while behavioral indicators consistently captured the underlying construct, future studies could enhance reliability by incorporating additional behavioral items or objective behavioral measures. Several construct-level association values exceeded unity

when interpreted as simple correlations. These values were instead understood as model-derived association estimates rather than conventional Pearson correlation coefficients. Importantly, the overall pattern of reliability and convergent validity indicators demonstrated that the constructs were empirically distinct and statistically sound. No evidence suggested that multicollinearity or measurement instability undermined the integrity of the measurement model.

Table 6 reported the structural path coefficients and effect decomposition results examining the relationships between adaptive capacity dimensions, behavioral intention, and sustainable waste management behavior. At the direct effect level, agency exhibited a strong and statistically significant positive influence on intention ($\beta = 0.43$, $p = 0.001$), providing clear empirical support for Hypothesis H5. This result indicated that empowerment-related factors—such as leadership development, incentives, and perceived autonomy—played a central role in motivating commitment to circular waste management practices.

Table 6. Path coefficients and effects of adaptive capacity on sustainable behaviors.

Variable	Original sample	Sample mean	Standard deviation	T-value	p-values
Path coefficients					
Agency → Intention (H5)	0.43	0.419	0.126	3.419	0.001
Asset → Intention (H1)	-0.338	-0.321	0.146	2.307	0.021
Flexibility → Intention (H2)	-0.12	-0.108	0.146	0.825	0.409
Intention → Behavior (H6)	0.257	0.261	0.043	5.993	< 0.001
Learning → Intention (H4)	0.193	0.186	0.138	1.4	0.161
Organization → Intention (H3)	-0.012	-0.019	0.125	0.095	0.924
Total indirect effects					
Agency → Behavior	0.111	0.11	0.038	2.887	0.004
Asset → Behavior	-0.087	-0.085	0.043	2.028	0.043
Flexibility → Behavior	-0.031	-0.029	0.039	0.79	0.43
Learning → Behavior	0.05	0.05	0.039	1.285	0.199
Organization → Behavior	-0.003	-0.005	0.033	0.093	0.926
Specific indirect effects					
Flexibility → Intention → Behavior	-0.031	-0.029	0.039	0.79	0.43
Learning → Intention → Behavior	0.05	0.05	0.039	1.285	0.199
Organization → Intention → Behavior	-0.003	-0.005	0.033	0.093	0.926
Agency → Intention → Behavior	0.111	0.11	0.038	2.887	0.004
Asset → Intention → Behavior	-0.087	-0.085	0.043	2.028	0.043
Total effects					
Agency → Behavior	0.111	0.11	0.038	2.887	0.004
Agency → Intention	0.43	0.419	0.126	3.419	0.001
Asset → Behavior	-0.087	-0.085	0.043	2.028	0.043
Asset → Intention	-0.338	-0.321	0.146	2.307	0.021
Flexibility → Behavior	-0.031	-0.029	0.039	0.79	0.43
Flexibility → Intention	-0.12	-0.108	0.146	0.825	0.409
Intention → Behavior	0.257	0.261	0.043	5.993	< 0.001
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Learning → Intention	0.193	0.186	0.138	1.4	0.161
Organization → Behavior	-0.003	-0.005	0.033	0.093	0.926
Organization → Intention	-0.012	-0.019	0.125	0.095	0.924

In contrast, assets showed a statistically significant negative relationship with intention ($\beta = -0.338$, p = 0.021), supporting Hypothesis H1 in direction but revealing a counterintuitive effect. This finding suggested that increased availability of infrastructure and policy instruments did not enhance motivational commitment and instead weakened intention, likely reflecting infrastructure dependency, underutilization, or reduced perceived individual responsibility within the Sarbagita context.

Other adaptive capacity dimensions did not exhibit statistically significant direct effects on intention. Flexibility ($\beta = -0.12$, p = 0.409), learning ($\beta = 0.193$, p = 0.161), and organization ($\beta = -0.012$, p = 0.924) all showed non-significant paths, indicating that adaptive practices, educational exposure, and institutional organization alone were insufficient to directly shape behavioral intention. These results suggested that while such dimensions were well measured, their influence on motivation was indirect or conditional rather than immediate.

Consistent with Hypothesis H6, behavioral intention exerted a strong and highly significant positive effect on actual behavior ($\beta = 0.257$, p < 0.001). This result confirmed intention as the primary transmission mechanism through which adaptive capacity influenced observed waste management actions. The strength and significance of this path underscored the importance of motivational processes in converting capacity into behavior. The indirect effect analysis further clarified these dynamics. Agency demonstrated a significant positive indirect effect on behavior through intention ($\beta = 0.111$, p = 0.004), confirming that empowerment influenced behavior primarily by strengthening intention. In contrast, assets exhibited a significant negative indirect effect on behavior ($\beta = -0.087$, p = 0.043), reinforcing the interpretation that infrastructure availability reduced behavioral engagement by weakening motivational commitment. These mediated effects indicated that intention fully carried the influence of both agency and assets to behavior.

Other indirect pathways were not statistically significant. The indirect effects of flexibility ($\beta = -0.031$, p = 0.43), learning ($\beta = 0.05$, p = 0.199), and organization ($\beta = -0.003$, p = 0.926) on behavior through intention were weak and non-significant. These results suggested that adaptive practices, knowledge acquisition, and organizational routines did not independently motivate sustained behavioral engagement unless accompanied by empowerment and perceived agency. The total effects mirrored these patterns. Agency remained the most influential positive determinant of behavior (total effect $\beta = 0.111$, p = 0.004), while assets retained a significant negative total effect ($\beta = -0.087$, p = 0.043). All other adaptive capacity dimensions showed non-significant total effects on behavior, highlighting the dominant role of empowerment and intention formation over infrastructure provision or informational exposure alone.

The study investigated the influence of physical infrastructure, referred to as assets in the context of waste management, on the propensity of community members to engage in environmentally sustainable practices. The initial hypothesis, H1, posited a positive correlation between robust waste management infrastructure and an increased intention among the community to adopt sustainable waste disposal behaviors. This hypothesis was based on the presumption that infrastructure acts as a catalyst [25–27], propelling the community toward a more environmentally conscious mindset and practice. Contrary to the anticipated positive association, the empirical findings presented a counterintuitive narrative: assets exhibited a negative path coefficient. This unexpected outcome suggested that the mere availability of waste management infrastructure did not necessarily translate into a heightened intention to

participate in sustainable behaviors. Such a result prompted a reevaluation of the conventional assumption, which typically asserts a straightforward positive relationship between infrastructural assets and sustainability intentions.

One plausible explanation for this discrepancy may lie in the nuanced dynamics of human-environment interactions [28]. While the physical apparatus for waste management, such as recycling bins, composting facilities, and specialized disposal units, undeniably constituted the backbone of waste management systems, they may not inherently inspire individuals to use them purposefully or effectively. The result implied that the mere existence of assets was only one piece of a larger puzzle; without awareness programs, motivational incentives, and community engagement initiatives, infrastructure alone may fall short in fostering a sustainable behavioral shift. This paradoxical outcome contrasted with previous literature that typically underscored the critical role of infrastructure in environmental behavior change [9]. For instance, studies examining the impact of accessibility to recycling facilities on recycling rates often assumed that better infrastructure equates to improved sustainability outcomes [29,30]. However, the current study's findings challenged this assumption, highlighting the complexity of behavioral change and the potential for infrastructure to remain underutilized or misused without complementary measures to engage and educate the community. The negative coefficient raised critical questions about the factors driving sustainable behavior, prompting a broader view that includes psychological, social, and educational dimensions as integral components of environmental stewardship. Future research may need to consider these additional elements to fully understand the intricate influences that drive transitions toward sustainable waste management practices.

Hypothesis H2 was based on the premise that flexibility would significantly predict an individual's intention to perform sustainable behaviors. It was anticipated that those who could readily adjust their waste management behaviors to new information or changing conditions would be more inclined to adopt sustainability practices consistently [9]. However, the structural equation model did not find a significant path coefficient for flexibility, suggesting that its role in shaping intentions might not be as pivotal as initially thought. This absence of a significant relationship indicated that flexibility, while conceptually valuable, may be overshadowed by other more influential factors in the study context. Such factors could include deeply ingrained cultural values or economic incentives directly affecting an individual's cost-benefit analysis when deciding whether to engage in waste management behaviors. These findings challenged previous research that emphasized adaptability as a critical driver of environmental intentions. Studies in environmental psychology and sustainability have often demonstrated that individuals with a higher capacity for adaptability report stronger intentions to engage in pro-environmental behaviors [31–33].

Hypothesis H3 investigated the influence of organization on individual intentions to engage in sustainable behaviors. The study expected to find a positive relationship, positing that well-structured and coherent community or institutional waste management systems would create collective intention toward sustainability. However, the analysis revealed that the organization's role might not be as directly impactful on intentions as theorized. The absence of a significant path coefficient implied that while organizational structures were an essential backdrop for sustainable practices, they did not necessarily translate into individual behavioral intentions. This finding contrasted with prior studies that highlighted the significance of organizational structures in promoting pro-environmental behavior [34,35]. Research has

emphasized that political actors, organizations, or institutional support cultivate a shared ethos of sustainability [36]. In this study's setting, unique cultural or operational dynamics may have diminished the direct influence of organizational frameworks on personal intentions.

Hypothesis H4 anticipated a positive relationship between learning and behavioral intention, based on the assumption that environmental education and knowledge dissemination would strengthen individuals' motivation to engage in sustainable waste management. Although the estimated path coefficient was positive, the relationship was not statistically significant. This finding diverged from existing literature documenting a direct link between environmental knowledge and pro-environmental intention. The result suggested that knowledge alone was insufficient to motivate behavioral commitment in the Sarbagita context. Instead, learning appeared to function as a supporting condition requiring integration with stronger motivational and enabling mechanisms. From a policy perspective, this implied that educational programs needed to move beyond awareness-raising and incorporate actionable guidance, practical incentives, and visible outcomes connecting learning to tangible behavioral benefits.

In contrast, Hypothesis H5 received clear empirical support, demonstrating the central role of agency in shaping behavioral intention. The positive and significant effect of agency confirmed that individuals' perceived ability to make autonomous decisions and influence outcomes was a critical determinant of their willingness to adopt circular waste management practices. This result aligned with a substantial body of behavioral research emphasizing perceived control and empowerment as key drivers of sustainable action [37]. When community members believed their actions mattered and that they had real opportunities to participate, their intention to engage in sustainable behavior strengthened substantially.

These findings carried direct implications for policy and practice. Waste management strategies focusing solely on infrastructure provision or information dissemination were unlikely to produce sustained behavioral change. Effective interventions needed to prioritize empowerment-oriented approaches [38–40]. Practical measures included participatory governance mechanisms that actively involved residents in waste management decision-making, incentive schemes recognizing and rewarding consistent sustainable practices, and community-based platforms enabling peer learning and collective action. Such interventions enhanced individual and collective agency by reinforcing competence, ownership, and accountability, thereby increasing the likelihood that sustainable intentions translated into action.

Building on Hypothesis H6, the study confirmed that behavioral intention served as a critical mediator between adaptive capacity and actual waste management behavior. The strong and significant relationship between intention and behavior demonstrated that motivation was a necessary condition for sustained engagement in circular economy practices. The findings highlighted the adaptive nature of intention, defined as the readiness to adjust behaviors in response to changing environmental, technological, or regulatory conditions. This adaptability was particularly relevant in dynamic urban environments such as Sarbagita, where waste management systems were continuously influenced by tourism flows, policy reforms, and technological innovation.

From a policy standpoint, this underscored the importance of designing interventions that not only encouraged initial commitment but also strengthened individuals' capacity to adapt their behavior over time. Policies supporting continuous learning, flexible regulatory

frameworks, and incremental adoption of new waste management technologies were more likely to sustain long-term behavioral change. For example, individuals with strong adaptive intentions were better positioned to incorporate emerging recycling or composting technologies into their daily routines as these options became available. Such adaptability was especially critical in dense urban settings, where conventional waste management solutions often faced spatial and operational constraints.

4. Conclusion

This study's exploration of adaptive capacity dimensions within urban waste management in a circular economy in Bali provided valuable insights into the complex interplay between infrastructure, individual and community capacities, and sustainability practices. The findings challenge traditional assumptions about the sufficiency of assets alone to drive sustainable behaviors and underscore the nuanced roles of flexibility, organization, learning, and agency in shaping intentions and behaviors toward waste management. Significantly, the study revealed that while assets are crucial, they do not inherently guarantee an increase in sustainable intentions or behaviors. Instead, the effectiveness of these assets is mediated by the adaptive capacities of individuals and communities to utilize them in response to changing environmental conditions. The unexpected negative association between assets and intention highlights the potential for resources to be underutilized if not supported by adequate flexibility, organizational structure, and opportunities for learning and personal agency. The results suggest that flexibility and organization, while important, do not directly impact sustainability intentions as significantly as hypothesized, pointing to the influence of other social, economic, or cultural factors. On the other hand, agency proved to be a critical factor, with a significant positive impact on sustainability intentions, emphasizing the importance of empowering individuals and communities to take proactive steps toward sustainability. The strong correlation between intention and actual sustainable behavior reaffirms the foundational principles of the Theory of Planned Behavior, highlighting intention as a crucial determinant of behavior. This reinforces the need for strategies that aim to build infrastructure while fostering strong intention and the capability to use such infrastructure effectively.

Acknowledgments

Author Contributions

I Wayan Koko Suryawan conceived the research idea, developed the conceptual framework, designed the methodology, supervised the research process, and led the manuscript writing and revision. Ari Rahman supported methodological implementation and assisted in data

interpretation. Mega Mutiara Sari contributed to revision of the contextual discussion. All authors reviewed, edited, and approved the final version of the manuscript.

Funding

Competing Interests

The authors declare that they have no competing financial or non-financial interests relevant to the content of this article.

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