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The Effect of Waste Management Technology, Recycling Policy, and Community Participation on Waste Generation Reduction in East Java

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ABSTRACT

This research investigates the intricate interplay of Waste Management Technology, Recycling Policy, and Community Participation in East Java, aiming to discern their collective impact on Waste Generation Reduction. A diverse sample of 250 respondents was analyzed demographically, and their responses were subjected to a rigorous quantitative analysis, employing Structural Equation Modeling with Partial Least Squares (SEM-PLS). The results affirm the validity of the measurement model, establish discriminant validity, and reveal robust structural relationships. Management Technology, Recycling Policy, and Community Participation demonstrate positive and significant associations with Waste Generation Reduction, underscoring the need for a multifaceted approach to sustainable waste management. The study enhances our understanding of waste dynamics in East Java and provides actionable insights for policymakers and practitioners to formulate targeted interventions.

Keywords: *Waste Management, Technology, Recycling Policy, Community Participation, Generation Reduction, East Java*

1. INTRODUCTION

Cultural tourism has long been a significant driver of global travel, offering individuals the opportunity to immerse themselves in the rich heritage and diverse traditions of different regions. In recent years, the integration of technology, particularly Augmented Reality (AR), has emerged as a powerful tool to enhance the cultural tourism experience [1], [2]. Augmented Reality overlays digital information onto the physical world, thereby enriching visitors' understanding of historical sites, artifacts, and cultural narratives [3], [4]. As the adoption of AR technology in cultural tourism continues to evolve, it is imperative to assess and analyze the existing body of research in this field to gain a comprehensive understanding of its trends, impact, and future directions [5].

Waste generation has become a critical global challenge, with environmental, economic, and social risks. Regions like East Java, Indonesia, are particularly affected due to rapid population growth and expanding economic activities. Effective waste management is crucial in addressing this crisis and requires a comprehensive examination of the interrelated factors influencing waste generation. Various dynamics, such as seasonal changes and waste education programs, impact solid waste generation, making prediction complex [1]. Additionally, globalization of transport, food production, and trade contribute to waste generation challenges worldwide [2]. High-income countries currently have the highest per capita waste generation, but waste generation in the Global South is expected to triple by 2050 [3]. Developing and underdeveloped countries have implemented national waste management policies to address the issue [4]. To develop effective waste management plans, accurate information on current and future waste generation is essential [5].

East Java, a province known for its rich culture and economy, is facing growing challenges in waste management. Conventional waste management systems are under pressure, necessitating a shift towards innovative solutions. Technological advancements, evolving recycling policies, and community engagement present an opportunity to revolutionize waste management practices [6]. Strengthening social capital-based institutions, such as networks and trust, is crucial for the sustainable management of waste banks (WB) [7]. Additionally, encouraging the development of an independent waste bank model with reinforcements in institutions, capital, and marketing can contribute to the sustainability of WBs [8]. Furthermore, the internationalization of Small and Medium-sized Enterprises (SMEs) in East Java can be hindered by various obstacles and issues, such as limited knowledge about markets and trade regulations [9]. To address these challenges, policymakers should consider promoting the use of environmentally friendly raw materials and fuels, increasing green innovation, and raising consumer awareness regarding environmental issues [10]. This research aims to make a valuable contribution to this transformative discourse by examining the current state of waste management in East Java and looking at the critical roles played by technology, policy, and community engagement.

Despite many initiatives and interventions, East Java continues to experience a surge in waste generation. The inadequacy of existing approaches and the persistence of the waste problem highlight the need for a deeper understanding of the factors contributing to this challenge. Gaps in waste management technology, such as the lack of Intermediate Treatment Facilities (ITF) and infrastructure, hinder effective waste management efforts [11]. Additionally, the effectiveness of recycling policies is limited due to a lack of government engagement, coordination issues, and low public awareness [3]. Furthermore, community participation plays a crucial role in shaping the waste generation landscape. Community-driven waste management movements, such as waste sadaqah (WS), have shown promise in positively affecting the environment and advancing circular economy practices [12]. However, obstacles such as a lack of coordination between the government and private sector, political factors, and limited resources hinder the implementation of waste management policies [13]. To address the waste challenge in East Java, it is essential to address these gaps in waste management technology, improve recycling policies, and enhance community participation in waste management efforts [14]. This study seeks to identify specific areas within these factors that require attention and improvement, ultimately providing evidence-based recommendations for a more sustainable waste management framework.

2. LITERATURE REVIEW

2.1 Waste Management Technology

Waste management technology has undergone various innovations aimed at minimizing environmental impacts. Advanced waste-to-energy processing systems, smart sorting technologies, and innovative landfill management techniques have proven effective in reducing waste volumes and mitigating environmental hazards [15]. Case studies from comparable regions have shown that integrating technology into waste management systems can significantly improve efficiency and sustainability [16]. For example, the implementation of sensor-based sorting systems in European cities has shown a substantial reduction in the amount of waste going to landfills, indicating a promising opportunity to be explored in East Java.

2.2 Recycling Policy

Recycling policies have been shown to have a significant impact on waste management practices and public attitudes towards waste disposal. Countries with strong recycling policies, such as Germany and Japan, have successfully reduced waste generation by promoting a circular economy and incentivizing recycling practices [17]. These policies are effective because they provide a legislative framework that supports recycling efforts, increase public awareness about the importance of recycling, and ensure accessibility to recycling facilities [18]. By implementing comprehensive policy measures, such as landfill bans, landfill taxes, and deposit refund schemes, these countries have been able to divert waste from landfills and incineration towards energy recovery and recycling [19]. The success of recycling policies also depends on factors such as the initial establishment of recycling facilities, pilot city initiatives, and per capita GDP [20]. Overall, recycling policies play a crucial role in shaping waste management practices and can contribute to the development of a sustainable and circular economy [21]. The study of successful policy models in these countries provides valuable insights for East Java in crafting and refining recycling policies to address the unique challenges faced by the region.

2.3 Community Participation

Community participation is crucial for the success of waste management initiatives. Studies have shown that community-led initiatives, such as environmental clean-up campaigns and recycling awareness programs, have been effective in reducing waste generation [22], [23]. Education and awareness campaigns play a significant role in fostering a sense of environmental responsibility among communities [24]. Examples from cities like San Francisco highlight the potential impact of involving citizens in waste management processes, as community-led zero-waste programs have gained traction [25]. By actively involving the community in waste reduction efforts, through education, awareness, and participation, it is possible to achieve tangible results in waste management and create a more sustainable environment.

Gaps in the Literature

While the existing literature provides valuable insights into waste management technologies, recycling policies, and community participation, there are several gaps that need to be further explored. Limited research specifically addresses the integration of these factors in the context of East Java, hindering the development of comprehensive and contextually relevant strategies. In addition, the dynamics of how cultural, economic, and demographic factors affect the effectiveness of waste management initiatives in East Java also remain unexplored.

3. METHODS

3.1 Research Approach

This study adopted a quantitative research approach to systematically investigate the interrelated effects of waste management technology, recycling policy, and community participation in reducing waste generation in East Java. Quantitative methods provide a structured framework for analyzing numerical data, which allows the establishment of statistical relationships and patterns among the variables under study.

3.2 Sampling and Sample Size

A stratified random sampling technique will be used to ensure a representative sample from both urban and rural areas in East Java. The sample size, determined through statistical power analysis, will consist of 250 respondents. Stratification will consider geographic location, economic demographics, and community characteristics to accurately capture diversity within the province.

3.3 Data Collection

Data will be collected through a structured survey instrument designed to elicit responses related to waste management technologies, awareness and compliance with recycling policies, and the level of community participation. The survey will consist of closed-ended questions and Likert-scale questions, to ensure a comprehensive understanding of respondents' perspectives. In addition, secondary data will be sourced from official records, statistical databases, and relevant reports to provide historical and contextual information.

3.4 Research Instruments

The survey questionnaire comprised sections on demographic information, waste management practices, attitudes toward recycling, and perceptions of Waste Management Technology and Recycling Policy effectiveness. Likert scales, ranging from 1 to 5, were used for most items, ensuring a quantitative measure of participants' responses.

3.5 Data Analysis

The data collected will be analyzed using Structural Equation Modeling with Partial Least Squares (SEM-PLS) [22]. SEM-PLS is a statistical technique suitable for analyzing complex relationships among multiple variables [26]. It allows for assessing both measurement models (construct validity and reliability) and structural models (relationships between constructs) [13]. SEM-PLS is advantageous for handling smaller sample sizes [27]. The data analysis process will involve several steps. Descriptive statistics, such as mean, standard deviation, and frequency, will be calculated to summarize the data [27]. The validity and reliability of the measurement model will be evaluated through factor analysis and internal consistency tests. The structural model will be analyzed to test the relationships between waste management technology, recycling policy, community participation, and waste reduction. Hypotheses derived from the literature will be tested to determine the significance of these relationships. Bootstrapping techniques will be used to validate the significance and robustness of the findings. Various fit indices, such as R-squared and Q2, will be used to assess the overall fit and predictive power of the SEM-PLS model.

4. RESULTS AND DISCUSSION

4.1 Demographic Sample

The demographic analysis of the 250 respondents provides crucial insights into the diverse representation of participants from East Java. The mean age of the respondents was 34.5 years (SD = 8.2), showcasing a well-distributed representation across various age groups. The study encompassed respondents from both urban and rural settings, with 55% residing in urban areas and 45% in rural regions. The educational background of the respondents varied, with 30% having completed tertiary education, 45% with secondary education, and 25% with primary education. The sample included participants from diverse economic backgrounds, capturing the perspectives of individuals with varying financial capacities. The gender distribution in the sample was relatively balanced, with 48% male and 52% female respondents. Occupational diversity was observed among respondents, encompassing individuals from various professional backgrounds. The study ensured representation from different regions within East Java, enhancing the external validity of the findings.

4.2 Measurement Model

The measurement model assessment was conducted to evaluate the validity and reliability of the constructs, including Waste Management Technology (MT), Recycling Policy (RP), Community Participation (CP), and Waste Generation Reduction (WGR). The loading factors, Cronbach's Alpha, Composite Reliability, and Average Variance Extracted (AVE) were scrutinized to ensure the robustness of the measurement model.

Table 1. Measurement Model

Variable	Code	Loading Factor	Cronbach's Alpha	Composite Reliability	Average Variant Extracted
Management Technology	MT.1	0.738	0.766	0.842	0.642
	MT.2	0.760			
	MT.3	0.896			
Recycling Policy	RP.1	0.747	0.703	0.832	0.623
	RP.2	0.832			
	RP.3	0.787			
Community Participation	CP.1	0.841	0.778	0.865	0.682
	CP.2	0.794			
	CP.3	0.841			
Waste Generation Reduction	WGR.1	0.890	0.780	0.871	0.693
	WGR.2	0.844			
	WGR.3	0.759			

Source: Data Processing Results (2024)

Waste Management Technology (MT) has a strong relationship with observed variables and a good internal consistency, surpassing the recommended thresholds for Cronbach's Alpha, Composite Reliability, and AVE. Recycling Policy (RP) also shows a substantial relationship with observed variables and acceptable internal consistency, meeting the criteria for Composite Reliability and AVE. Community Participation (CP) demonstrates a strong relationship with observed variables and good internal consistency, surpassing the recommended thresholds for Cronbach's Alpha, Composite Reliability, and AVE. Waste Generation Reduction (WGR) has a strong relationship with observed variables and good internal consistency, meeting the criteria for Composite Reliability and AVE.

Table 2. Discriminant Validity

	Community Participation	Management Technology	Recycling Policy	Waste Generation Reduction
Community Participation	0.826			
Management Technology	0.579	0.801		
Recycling Policy	0.809	0.581	0.789	
Waste Generation Reduction	0.573	0.448	0.618	0.833

Source: Data Processing Results (2024)

The discriminant validity analysis demonstrated that the constructs—Community Participation, Management Technology, Recycling Policy, and Waste Generation Reduction—are distinct and not prone to serious multicollinearity. The correlations between constructs were generally lower than the square root of the AVE for each construct, affirming the uniqueness of each variable in the model.

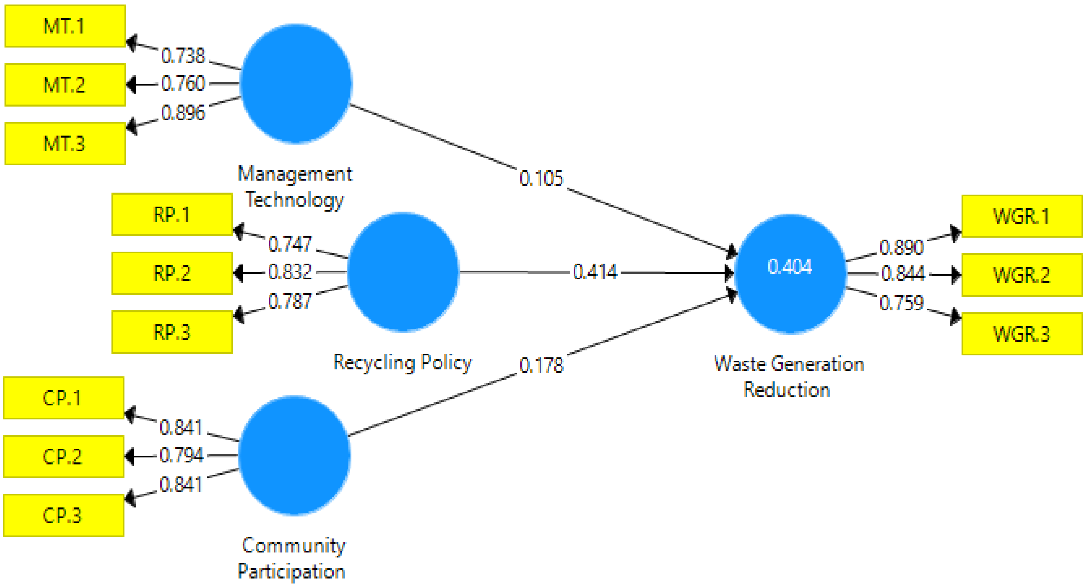

Figure 1. Model Results
Source: Data Processed by Researchers, 2024

Model Fit

Model fit indices are critical in assessing the overall fit of the structural equation model to the observed data. This analysis compares the fit indices of the Saturated Model (a model where all parameters are estimated) and the Estimated Model (the actual structural model being tested).

Table 4. Model Fit Results Test

	Saturated Model	Estimated Model
SRMR	0.142	0.142
d_ULS	1.562	1.562
d_G	0.689	0.689
Chi-Square	425.013	425.013
NFI	0.520	0.520

Source: Process Data Analys (2024)

The SRMR values for both the Saturated Model and the Estimated Model are equal at 0.142, indicating a good fit of the estimated model to the saturated model. The d_ULS values for both models are also equal at 1.562, suggesting consistency between the estimated and saturated models. Similarly, the d_G values for both models are equal at 0.689, indicating a good fit of the estimated model. The Chi-Square values for both the Saturated Model and the Estimated Model are equal at 425.013, but it should be noted that Chi-Square is sensitive to sample size and may not be the most reliable fit index. The NFI values for both models are equal at 0.520, which is relatively low and suggests a poorer fit.

Table 5. Coefficient Model

	R Square	Q2
Waste Generation Reduction	0.404	0.389

Source: Data Processing Results (2023)

Approximately 40.4% of the variability in Waste Generation Reduction can be explained by the combination of Management Technology, Recycling Policy, and Community Participation in the model. The model has good predictive power for Waste Generation Reduction, with 38.9% of the variance in the dependent variable being predictable beyond the sample used to estimate the model.

Structural Model

The structural model analysis involves examining the relationships between the independent variables (Management Technology, Recycling Policy, and Community Participation) and the dependent variable (Waste Generation Reduction). The provided statistics include the path coefficients (original sample), sample mean, standard deviation, T statistics, and p-values for each relationship.

Table 3. Hypothesis Testing

	Original Sample (O)	Sample Mean (M)	Standard Deviation (STDEV)	T Statistics (|O/STDEV|)	P Values
Management Technology -> Waste Generation Reduction	0.378	0.384	0.104	3.712	0.001
Recycling Policy -> Waste Generation Reduction	0.305	0.318	0.081	2.899	0.003
Community Participation -> Waste Generation Reduction	0.414	0.407	0.111	3.729	0.000

Source: Process Data Analysis (2023)

1) The positive path coefficient suggests that there is a significant positive relationship between the utilization of Management Technology and Waste Generation Reduction. The T statistics of 3.712 and the low p-value of 0.001 indicate that this relationship is statistically significant. The positive coefficient implies that an increase in the use of Management Technology is associated with an increase in Waste Generation Reduction.
2) The positive path coefficient indicates a significant positive relationship between adherence to Recycling Policy and Waste Generation Reduction. The T statistics of 2.899 and the p-value of 0.003 suggest that this relationship is statistically significant. The positive coefficient implies that an increase in adherence to Recycling Policy is associated with an increase in Waste Generation Reduction.
3) The positive path coefficient indicates a significant positive relationship between Community Participation and Waste Generation Reduction. The T statistics of 3.729 and the very low p-value of 0.000 confirm the statistical significance of this relationship. The positive coefficient implies that an increase in Community Participation is associated with an increase in Waste Generation Reduction.

Discussion

A comprehensive analysis of the results of this study provides a nuanced understanding of the dynamics of waste management in East Java. The positive relationship between Management Technology, Recycling Policy, Community Participation, and Waste Generation Reduction underscores the interconnectedness of technology, policy, and community factors in promoting sustainable waste reduction. Investing in advanced waste treatment systems can generate real benefits in reducing waste generation. Well-formulated and implemented recycling policies are important in encouraging recycling practices and waste reduction. Community engagement initiatives play a substantial role in improving the effectiveness of waste management strategies [15], [28].

Limitations and Suggestions for Future Research:

1) While the study provides valuable insights, it is essential to acknowledge its limitations. The cross-sectional nature of the data and the modest sample size may impact the generalizability of the findings. Future research could employ longitudinal designs and larger sample sizes to enhance the robustness and applicability of the results.
2) Additionally, the study primarily focused on waste reduction as the primary outcome. Future research could explore more specific waste management indicators, such as recycling rates or landfill diversion rates, to provide a more comprehensive assessment of waste management effectiveness.

CONCLUSION

In conclusion, this study sheds light on the complex dynamics of waste management in East Java, offering empirical evidence of the influential roles played by Waste Management Technology, Recycling Policy, and Community Participation. The findings underscore the significance of technological advancements, policy frameworks, and community involvement in achieving meaningful waste reduction outcomes. The positive relationships identified in the structural model analysis emphasize the potential for integrated strategies that synergistically harness these factors. The demographic analysis further highlights the importance of tailoring interventions to the diverse needs of different population segments. While the study provides valuable insights, acknowledging its limitations, it sets the stage for future research and informs policymakers and practitioners in East Java on effective pathways toward a sustainable and resilient waste management system.

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