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Eco-Efficiency and Waste Management in Small-Scale Enterprises: Cost Efficiency and Environmental Management Roles

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ABSTRACT
This study was grounded in the growing importance of sustainable business practices among small-scale enterprises (SSEs), particularly in addressing environmental challenges through eco-efficiency. It aims to examine the effect of eco-efficiency on waste management in SSEs, with cost efficiency and environmental management as mediating factors. Additional analyses also assess whether these factors moderate the relationship between eco-efficiency and waste management. Drawing on the resource-based view (RBV), this study positions eco-efficiency as a strategic mechanism. A quantitative approach was employed using survey data collected from 101 SSEs and analyzed with PLS-SEM. The results showed that eco-efficiency does not directly translate into improved waste management. Instead, it strengthens cost efficiency and environmental management as internal capabilities that support waste management. Environmental management, as a higher-order capability, directly improves waste management by embedding sustainability into business operations. Cost efficiency, although important for resource optimization, does not directly influence waste management, indicating that financial efficiency alone was insufficient to drive sustainable waste practices. Further analysis showed that only environmental management mediates the eco-efficiency–waste management relationship, while only cost efficiency moderates it. The study suggests that SSE managers should prioritize environmental management systems alongside efficiency-oriented strategies to achieve sustainable waste management outcomes.

Keywords: Cost efficiency; Eco-efficiency; Environmental management; Small-scale enterprises; Waste management

INTRODUCTION

Prior studies in sustainability and waste management often adopt a linear perspective, assuming that eco-efficiency (*EE*) inherently translates into superior environmental outcomes without sufficiently addressing the structural and financial mechanisms that enable such a transformation (Besné et al., 2018; Maman et al., 2024; Vásquez et al., 2019). This oversimplification overlooks the reality that *EE*, while optimizing resource use and minimizing waste at the source, does not automatically lead to strategic waste management (*WM*) unless firms possess the necessary financial discipline (cost efficiency (*CE*)) (İncekara, 2022; Woodard, 2021), and governance frameworks (environmental management (*EM*)) (Cavicchi et al., 2023; Cordeiro et al., 2012) to convert efficiency gains into structured sustainability initiatives. The failure of prior literature to critically assess these interdependencies has led to an overreliance on the eco-efficiency paradigm as a standalone driver of waste reduction. They neglect the nuanced ways in which firms must operationalize sustainability beyond mere resource conservation (Gąsior et al., 2022; Özbuğday et al., 2020). In contrast, *EE*, *CE*, and *EM* must function as mutually reinforcing strategic assets, where *CE* serves as the financial conduit that reallocates efficiency-derived cost savings toward long-term *WM* (Gopalakrishnan et al., 2021; Richter et al., 2021), and *EM* ensures that these financial investments are institutionalized into corporate environmental strategies rather than remaining ad hoc responses to external pressures (Andeobu et al., 2021; Dey et al., 2018; Hafid et al., 2022).

Moreover, the lack of an integrative approach in prior studies has created a theoretical gap in how sustainability strategies are framed within the Resource-Based View (RBV) (Majid et al., 2023; Oduro, 2024). Traditional RBV applications have largely treated cost efficiency and environmental management as separate constructs (Chaudhuri et al., 2022; Oduro, 2024), failing to recognize their interactive effects in shaping waste management effectiveness. This disjointed perspective limits the explanatory power of RBV in sustainability contexts. It does not account for how firms must strategically coordinate financial and environmental resources to maximize waste reduction outcomes. This research addresses this gap by arguing that *CE* and *EM* are not merely independent drivers but act as complementary enablers that mediate and moderate the *EE-WM* relationship. Without *CE*, eco-efficiency may yield financial benefits that are absorbed into operational cost reductions rather than reinvested in waste management. Without *EM*, cost efficiency may be pursued in a manner that prioritizes short-term financial performance over long-term sustainability commitments. Thus, firms capable of integrating *EE*, *CE*, and *EM* not only improve waste management performance but also develop a sustainable competitive advantage by embedding waste reduction into their broader strategic framework. This perspective fundamentally challenges prior sustainability models that rely on simplistic efficiency-based arguments and underscores the need for a more resource-intensive, governance-driven approach to corporate waste management.

This study focuses on small-scale enterprises (SSEs) in emerging economies, a sector that plays a dominant role in economic activity but faces significant structural constraints. SSEs contribute substantially to employment and economic growth; however, they operate under persistent limitations in financial capacity, managerial capability, and access to technology (Andono et al., 2024). These constraints become particularly critical in the context of waste management, where SSEs are increasingly expected to comply with environmental standards while simultaneously maintaining operational efficiency. The urgency of examining SSEs stems from the growing pressure on this sector to adopt sustainable practices despite limited resources. Unlike large firms, SSEs often lack the financial flexibility to invest in advanced waste treatment technologies or sophisticated environmental management systems (Ning & Shen, 2024). At the same time, regulatory expectations and stakeholder demands for improved environmental performance continue to intensify, creating a tension between sustainability goals and resource availability.

The unique challenges faced by SSEs, particularly in relation to waste management, are often downplayed or oversimplified in prior studies. Many previous studies have tended to focus on large firms or developed economies, assuming that solutions for waste management, such as advanced technologies or sophisticated regulatory frameworks, can be directly applied to SSEs in emerging markets (Derhab & Elkhwesky, 2022; Gąsior et al., 2022; Maman et al., 2024). These studies often fail to recognize the resource constraints that small-scale enterprises face, which significantly limit their ability to adopt costly waste management systems or invest in the infrastructure needed for sustainability. Moreover, the focus in earlier research on technological solutions as panaceas for waste management (Gaur et al., 2024) overlooks the fact that non-technological factors, such as financial and environmental management, are equally critical. While advanced waste treatment technologies, automation, and digital monitoring systems can enhance efficiency, they are often financially unattainable for SSEs due to their high implementation and maintenance costs. As such, this situation adds the uniqueness of the current study by exploring an alternative approach, 'non-technological factors,' to manage *WM* for SSEs in emerging economies.

LITERATURE REVIEW

RBV Theory in Context

The theoretical foundation of this study is grounded in the Resource-Based View (RBV), which emphasizes that a firm's competitive advantage is derived from its ability to effectively utilize valuable, rare, inimitable, and non-substitutable (VRIN) resources. Within this perspective, eco-efficiency, cost efficiency, and environmental management are conceptualized as internal capabilities that enable firms, particularly small-scale enterprises (SSEs), to optimize resource utilization while maintaining operational performance. While the Natural Resource-Based View (NRBV) extends RBV by explicitly incorporating environmental concerns such as pollution prevention, product stewardship, and sustainable development, it primarily focuses on how environmental strategies contribute to long-term ecological sustainability and competitive positioning. In contrast, this study adopts RBV as a more suitable lens, given that the primary focus is not on environmental sustainability but on how firms leverage their internal resources and capabilities to achieve efficient waste management outcomes. Therefore, RBV provides a more direct and parsimonious framework to explain the strategic role of eco-efficiency and its associated mechanisms in driving both economic and operational efficiency within the context of SSEs.

The RBV states that firms achieve sustained competitive advantage by leveraging unique, inimitable, and valuable resources (Varadarajan, 2023). In the context of waste management, this perspective necessitates a shift from traditional cost-minimization strategies to resource optimization. Although resource uniqueness and inimitability are central to RBV (El Nemar et al., 2025), waste management solutions often require collaborative ecosystems rather than firm-specific isolation (Journeault et al., 2021). *EE*, *CE*, and *EM* are conceptualized as internal capabilities that support the development of waste management strategies. Within the context of RBV (Varadarajan, 2023), these internal capabilities are seen as key resources that enable a firm to address operational challenges (Llanquileo-Melgarejo & Molinos-Senante, 2021; Sala-Garrido et al., 2024). However, *EE* alone does not inherently translate into *WM* improvements unless accompanied by structured cost and environmental governance mechanisms. *EE* optimizes resource use and minimizes waste at the source, but its effectiveness depends on the firm's ability to reinvest efficiency gains into sustainability initiatives (Sala-Garrido et al., 2024). Without *CE*, firms may prioritize short-term profitability over sustainable waste strategies, failing to institutionalize waste management as a core operational function (Gopalakrishnan et al., 2021; Richter et al., 2021). Similarly, without *EM*, *EE*-driven efficiencies may lack the necessary managerial oversight and strategic alignment needed to create lasting environmental impact. *EM* frameworks ensure that waste management practices are not isolated efforts but are aligned with broader environmental goals and regulations (B. J. Singh et al., 2023). Through well-structured environmental management, firms can ensure that waste management activities are systematically evaluated, monitored, and continuously improved, creating a feedback loop that drives further resource optimization and environmental performance.

Waste Management

WM in SSEs in emerging economies presents unique challenges and opportunities. Its practice is deeply affected by a constellation of structural, economic, cultural, and regulatory factors. These interconnected factors create complexities that often hinder sustainable practices. In the work of Pacheco et al. (2018) and Zahoor and Gerged (2021), many small-scale enterprises operate with limited resources, which may make it difficult for them to implement advanced waste management systems or technologies. According to Dey et al. (2018), waste handling in these firms is frequently reactive rather than proactive. It is driven by short-term cost considerations rather than long-term sustainability objectives. Dey et al. (2018). As a result, many SSEs resort to cost-cutting disposal methods that may not align with environmental best practices, such as informal dumping, burning waste, or outsourcing waste disposal to third parties without adequate oversight. Unlike large corporations that can leverage economies of scale to implement advanced waste treatment technologies, SSEs often rely on rudimentary disposal methods, exacerbating environmental degradation. This structural limitation is further exacerbated by insufficient awareness of the long-term economic benefits of waste minimization, including cost savings from resource efficiency and improved stakeholder relations (Cantú et al., 2021; Malik et al., 2022). Moreover, the lack of financial accessibility to green technologies (Zahoor & Gerged, 2021), coupled with an absence of tailored policy instruments such as tax incentives or subsidies (Rajapakse et al., 2022), renders waste reduction initiatives economically unfeasible.

Financial and Environmental Resources in SSEs

Unlike large corporations with dedicated sustainability divisions and substantial budgets, SSEs have constrained financial and human resources. SSEs need to balance environmental responsibility with the practical realities of running a small business on a tight budget. One way SSEs can achieve waste reduction without significant investment is by adopting eco-efficiency. This strategy focuses on reducing the environmental impact of production processes while improving operational efficiency (Vásquez et al., 2019). Eco-efficiency is based on the idea that doing more with less, whether that is using fewer materials, energy, or water, leads to both environmental and economic benefits (Llanquileo-Melgarejo & Molinos-Senante, 2021; Vásquez et al., 2019). For SSEs, this means optimizing resource use, minimizing waste generation, and improving overall productivity without the need for large capital expenditures.

Eco-efficiency in SSEs may not be fully optimized when *CE* and *EM* are treated as separate and isolated goals. These two strategies must be viewed as interconnected pillars within the broader business strategy. Conceptually, cost savings from efficient resource use can be reinvested in sustainability initiatives, such as energy-efficient technologies or waste-reduction programs (Richter et al., 2021). Similarly, effective *EM* practices, such as waste segregation or energy-efficient production methods (Andeobu et al., 2021), contribute to both reduced environmental impact and lower operational costs. This integration enables SSEs to achieve a dual benefit, where improvements in one area (e.g., *CE*) directly enhance performance in the other (e.g., *EM*), thereby creating a reinforcing cycle of eco-efficiency. Therefore, such a strategic alignment is expected to lead to more effective implementation, ensuring that sustainability is ingrained in the firm's daily operations, long-term goals, and competitive positioning in the marketplace.

The Influence of Eco-Efficiency on Waste Management

EE, as an operational philosophy, is a pivotal driver of waste management. It significantly shapes both environmental sustainability and organizational performance (B. J. Singh et al., 2023). Within the RBV, *EE* can be viewed as a strategic resource that enables firms to leverage their unique capabilities to achieve sustainable competitive advantage (Zorpas, 2020). In this sense, EE emerges as a resource that cultivates dynamic capabilities in waste management processes, fostering a culture of innovation and continuous improvement. This paradigm offers a different perspective on traditional waste management approaches, positioning the firm as a key player in driving industry-wide transformation (Pujara et al., 2019). As noted by Hafid et al. (2022), the unique capabilities developed through eco-efficient strategies, such as innovative waste-processing techniques and integrated waste-reduction practices, further enhance the firm's long-term viability in an increasingly competitive market. Consequently, firms that embrace eco-efficiency are expected to contribute to environmental preservation and enhance their operational efficiency, creating a virtuous cycle that strengthens their resource base and fortifies their market position.

H1: The higher the level of eco-efficiency, the greater the impact it has on optimizing waste management strategies.

The Influence of Eco-Efficiency on Cost-Efficiency

From the RBV perspective, *CE* is attributed to an outcome of financial prudence and a strategic capability embedded within a firm’s unique resources and competencies (Varadarajan, 2023). Studies have demonstrated that firms adopting eco-efficient strategies, such as energy-efficient manufacturing processes, closed-loop supply chains, and circular economy models, achieve cost efficiency by reducing material waste and energy expenditures (Kara et al., 2022; Yadav et al., 2024). Moreover, investment in eco-efficient technologies has been shown to generate long-term cost advantages by reducing dependency on non-renewable resources and mitigating price volatility in raw material markets (Sala-Garrido et al., 2024). Research further suggests that regulatory compliance costs, which often burden firms operating in highly regulated industries, are significantly reduced when businesses proactively implement eco-efficient practices (Vásquez et al., 2019). Additionally, eco-efficient firms benefit from improved reputational capital, which can translate into higher investor confidence, access to sustainable financing, and increased customer loyalty, all of which contribute to cost efficiency (Leonidou et al., 2016; Prashar, 2021). Therefore, the linkage between these constructs is articulated through causal mechanisms that explain how firms derive cost savings from eco-efficiency practices.

H2: The higher the level of eco-efficiency, the greater the impact it has on reducing costs and improving efficiency.

The Influence of Cost-Efficiency on Waste Management

Studies have demonstrated that firms focused on cost minimization actively seek alternative waste disposal methods, such as recycling, repurposing, and energy recovery, to avoid high landfill fees and regulatory penalties (Ahmad et al., 2020; Veleva & Bodkin, 2018). Operationally, SSEs are more likely to implement frugal innovation strategies, such as repurposing products, using waste as raw material inputs, and forming partnerships with local waste management cooperatives, to reduce both costs and environmental impact. These resource-conserving approaches may be attributed to the direct link between cost efficiency and waste management. Similarly, other scholars argue that *CE* enables SSEs to minimize losses from defective production processes, excess inventory, and inefficient resource allocation, which are common in low-margin business models (İncekara, 2022; Woodard, 2021). Additionally, firms that operate under stringent cost-efficiency frameworks tend to prioritize waste prevention over waste treatment, recognizing that preventing waste generation at the source is far more cost-effective than managing its disposal post-production (M. Singh et al., 2015). These findings suggest that cost efficiency not only influences waste management by reducing direct waste-related expenses but also fosters a strategic mindset that prioritizes sustainable resource utilization.

H3: The higher the level of cost efficiency, the greater the impact it has on enhancing waste management efficiency.

The Influence of Eco-efficiency on Environmental Management

In highly competitive markets, eco-efficiency enables firms to simultaneously improve operational performance and environmental management by optimizing the use of resources throughout the supply chain (Mahapatra et al., 2021; Wu et al., 2024). According to Famiyeh et al. (2018), Eco-efficiency emphasizes the creation of greater economic value while minimizing environmental impacts, encouraging firms to reduce energy consumption, material waste, and emissions during production processes. Through the implementation of eco-efficient practices, firms are more likely to adopt renewable energy, improve water efficiency, and utilize cleaner production technologies as part of their environmental management strategies. Previous studies also indicate that eco-efficient firms tend to invest in energy-efficient machinery, process automation, smart grid systems, and waste-reducing technologies, which contribute directly to improved environmental performance (Capozza et al., 2021). For example, firms that optimize their energy consumption through process automation, smart grid systems, and eco-friendly manufacturing techniques experience lower operational costs and reduced greenhouse gas (GHG) emissions.

H4: The higher the level of eco-efficiency, the greater the impact it has on improving environmental management strategies.

The Influence of Environmental Management on Waste Management

The relationship between *EM* and *WM* is fundamentally symbiotic. Without a structured and well-implemented environmental management system, small-scale enterprises face significant challenges in managing their waste effectively. It might be different from firms that adopt waste management practices due to market pressures or legal obligations. Businesses led by environmentally conscious entrepreneurs perceive sustainability as a moral and strategic imperative, resulting in the voluntary adoption of proactive waste-reduction initiatives (Crossley et al., 2021). Their strategic influence extends to investment choices, where they are more inclined to adopt eco-friendly production methods, utilize renewable materials, and implement closed-loop supply chain models that minimize waste generation (Capozza et al., 2021; Johnstone, 2021). Furthermore, such business owners recognize that waste is not just a cost to be managed but an opportunity for innovation, leading them to explore alternative revenue streams such as upcycling, industrial symbiosis, and biodegradable product development (Johnstone, 2021). Similarly, companies with strong sustainability leadership often establish internal waste management protocols, encourage employee-led green initiatives, and integrate environmental KPIs into performance evaluations (Arya et al., 2023).

H5: The higher the level of environmental management, the greater the impact it has on enhancing waste management efficiency.

The Mediating Role of Cost-Efficiency

Fostering cost efficiency, it enables firms to allocate financial resources more effectively toward sustainable waste-reduction solutions (Ferrazzi et al., 2025). Eco-efficient firms that reduce raw material consumption or energy waste can lower their environmental footprint and generate cost savings that can be redirected toward improved waste handling, recycling, and circular economy initiatives. Other scholars note that firms with high eco-efficiency often invest in closed-loop production systems that convert waste into reusable materials, thereby reducing overall waste disposal costs and reinforcing cost efficiency (Angelis-Dimakis et al., 2016). While such systems enhance sustainability efforts, their widespread adoption depends on the ability to generate cost savings that offset initial capital expenditures. Cost efficiency ensures that environmental sustainability aligns with financial imperatives, making waste management improvements both economically and operationally viable (Gopalakrishnan et al., 2021). For example, firms utilizing waste-to-energy technologies or material recovery processes can generate revenue from recycled materials while simultaneously reducing landfill costs. Additionally, cost-efficient eco-innovation enables firms to meet regulatory compliance requirements more effectively, mitigating the financial risks associated with environmental penalties (İncekara, 2022). In this way, cost efficiency serves as a reinforcing mechanism, amplifying the impact of eco-efficiency on waste management, transforming sustainability initiatives into financially feasible strategies that support long-term corporate success.

H6: The higher the level of eco-efficiency, the greater its impact on optimizing waste management strategies through improved cost efficiency.

The Mediating Role of Environmental Management

According to Xue et al. (2022), individuals with strong environmental management are more inclined to view waste management as an integral part of their firm's core value proposition rather than merely a regulatory requirement. This perspective leads to the development and implementation of long-term strategies that promote waste minimization and resource optimization. By adopting eco-efficiency practices such as lean manufacturing, design for the environment, and sustainable sourcing, business owners reduce waste at its source rather than relying on end-of-pipe solutions like recycling or disposal (Journeault et al., 2021). Implementing such practices requires careful planning and investment in technologies that support waste reduction, such as zero-waste initiatives, waste-to-resource programs, and closed-loop production cycles (Ball & Lunt, 2020). Business owners who understand environmental management principles are better equipped to identify opportunities for waste reduction across every aspect of their operations (Cagno et al., 2012; Simboli et al., 2014), making eco-efficiency an ongoing organizational commitment rather than a one-off project. As such, through their proactive strategies, they integrate sustainability deeply into the fabric of the firm's operations, ensuring that waste management practices are not only reactive but part of a forward-looking, integrated sustainability strategy.

H7: The higher the level of eco-efficiency, the greater its impact on optimizing waste management strategies through enhanced environmental management.

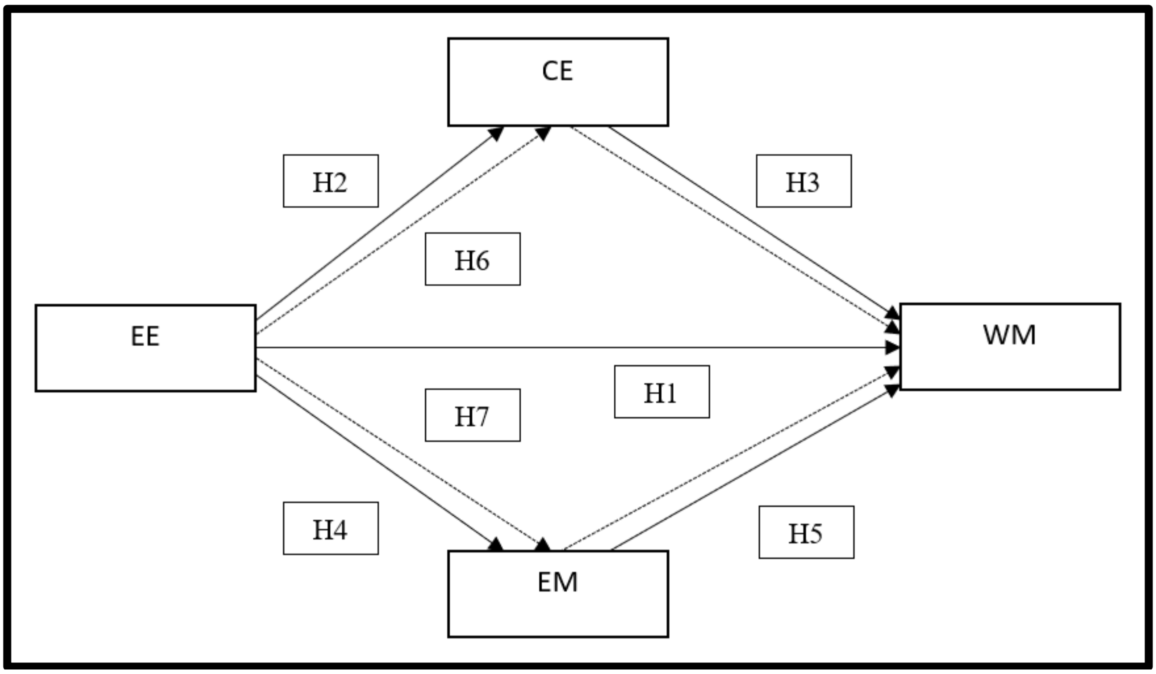

Figure 1. Research Model

Figure 1 shows the research model of this study. The conceptual framework proposes that eco-efficiency (*EE*) plays a central role in improving waste management (*WM*), both directly and indirectly through cost efficiency (*CE*) and environmental management (*EM*). Eco-efficiency is expected to directly enhance waste management by encouraging firms to optimize resource utilization, reduce waste generation, and minimize environmental impacts during production processes (*H1*). In addition, eco-efficiency positively influences cost efficiency (*H2*), as firms adopting eco-efficient practices are able to reduce operational costs through lower energy consumption, efficient material usage, and improved production processes. Cost efficiency subsequently contributes to better waste management performance (*H3*) because financially efficient firms are more capable of implementing waste reduction strategies and cleaner production technologies. Eco-efficiency is also proposed to positively affect environmental management (*H4*) by encouraging firms to adopt sustainable operational practices, pollution prevention initiatives, and environmentally responsible policies. Furthermore, environmental management positively influences waste management (*H5*), as effective environmental practices support recycling activities, waste minimization, and sustainable resource management. The framework also examines the indirect role of cost efficiency (*H6*) and environmental management (*H7*) in strengthening the relationship between eco-efficiency and waste management, indicating that eco-efficiency can improve waste management outcomes through enhanced operational efficiency and stronger environmental management practices.

RESEARCH METHOD

Research Procedure

The first page of the questionnaire clearly stated the research purpose and explained that the collected data would be used solely for academic purposes. It also informed participants that their responses would be treated anonymously and confidentially, with no personally identifiable information disclosed during the research process. Data-handling procedures were described to ensure the secure and ethical management of participants' information. The questionnaire also emphasized that participation was voluntary and that participants could withdraw at any time without any negative consequences.

Sampling and Data Collection

This study used purposive sampling to ensure that participants were business owners with direct experience in eco-efficiency and waste management. This method enabled the selection of participants possessing relevant knowledge and decision-making authority. This study was conducted in Surabaya, Indonesia. Surabaya is the most advanced city in East Java province, Indonesia, in terms of economic and business growth. The region provides a dynamic environment where businesses face competitive pressures and must optimize resources. Unlike other areas with less developed business networks, Surabaya offers a setting where sustainability practices can be observed in a growing economy. Business owners in this region are more likely to engage in strategic decision-making regarding cost efficiency and waste management. As such, the findings are expected to reflect enterprises operating in a competitive and evolving marketplace. More specifically, it focuses on business owners in the food production sector. This sector is highly relevant to waste management due to the large amounts of organic and non-organic waste it generates. Food production businesses must manage perishable raw materials, packaging waste, and food safety regulations (Raak et al., 2017). These challenges make them ideal for studying the impact of eco-efficiency on waste management. Additionally, this sector plays a vital role in Surabaya's local economy. Therefore, studying this sector helps explain how small businesses adopt sustainable practices while maintaining profitability.

Initially, the study targeted 176 business owners. However, language barriers led to the exclusion of 44 participants who could not read Indonesian fluently. Since the survey was conducted in Indonesian, it was essential for participants to fully understand the questions to ensure data accuracy. This exclusion was necessary to maintain the validity and reliability of the responses. After excluding individuals who experienced language difficulties, 132 eligible business owners remained available to participate in the study. Out of the 132 eligible participants, only 128 agreed to participate in the study. Despite this initial participation, data processing showed inconsistencies or incomplete responses in some surveys. Following data tabulation in Excel, 101 responses were identified as usable for analysis. Among the 101 valid respondents, 34 were women, and 67 were men. The detailed demographic profile of the respondents is presented in Table 1, which summarizes key characteristics, including gender, age of the business owner, years of operation, and business-related attributes.

Table 1. Demographic Respondents

Characteristic	Category	Frequency (n)	Percentage (%)
Gender	Male	67	66.34
	Female	34	33.66
	Total	**101**	**100.00**
Age of Business Owner	< 30 years	18	17.82
	30 – 40 years	42	41.58
	41 – 50 years	27	26.73
	> 50 years	14	13.86
	Total	**101**	**100.00**
Years of Operation	< 3 years	21	20.79
	3 – 5 years	33	32.67
	6 – 10 years	29	28.71
	> 10 years	18	17.82
	Total	**101**	**100.00**
Number of Employees	1 – 5 employees	39	38.61
	6 – 10 employees	34	33.66
	11 – 20 employees	18	17.82
	> 20 employees	10	9.90
	Total	**101**	**100.00**
Annual Revenue	< IDR 300 million	25	24.75
	IDR 300 million – 2.5 billion	46	45.54
	IDR 2.5 – 5 billion	19	18.81
	> IDR 5 billion	11	10.89
	Total	**101**	**100.00**
Type of Business	Snack production	37	36.63
	Food manufacturing	28	27.72
	Beverages	21	20.79
	Restaurant	15	14.85
	Total	**101**	**100.00**
Education Level	High school or below	29	28.71
	Diploma	21	20.79
	Bachelor’s degree	38	37.62
	Postgraduate	13	12.87
	Total	**101**	**100.00**
Ownership Type	Sole proprietorship	62	61.39
	Partnership	23	22.77
	Family-owned business	16	15.84
	Total	**101**	**100.00**

Measurement of Constructs

This study developed measurement items for *EE* based on Vásquez et al. (2019). Their framework provides a comprehensive approach to assessing resource optimization, reducing environmental impact, and promoting sustainable business practices. The measurement items for CE were adapted from Shah et al. (2019). Their study provides a structured narrative for evaluating how businesses optimize costs while maintaining operational effectiveness. The items assess various aspects, including cost-reduction strategies, resource-allocation efficiency, and financial sustainability. *EM* was measured using items developed from Dey et al. (2018), while *WM* was assessed using items from Ramos et al. (2020). These measures align well with the focus on small-scale enterprises that implement sustainability strategies despite resource constraints. For instance, Ramos et al. (2020) offer a comprehensive framework for assessing waste management practices, including waste reduction efforts, recycling initiatives, and compliance with environmental standards.

Data Analysis

The data were analyzed using Partial Least Squares Structural Equation Modeling (PLS-SEM) instead of Covariance-Based Structural Equation Modeling (CB-SEM). PLS-SEM is more suitable for the study because it focuses on prediction and explanation rather than theory confirmation (Dash & Paul, 2021). This approach enables the analysis of complex relationships between *EE*, *CE*, *EM*, and *WM*, even with a relatively small sample size. PLS-SEM is particularly useful for formative constructs rather than reflective ones (Hair Jr. et al., 2017). Another reason for choosing PLS-SEM is its ability to handle non-normal data distributions. Small-scale enterprises in emerging economies often exhibit high variability in their financial and operational data (Crossley et al., 2021; Gąsior et al., 2022). Traditional CB-SEM requires a large sample and assumes normality of the data (Hair Jr. et al., 2017). PLS-SEM, on the other hand, is more flexible and allows for robust analysis even when data distributions do not meet strict statistical assumptions (Hair Jr. et al., 2017). Furthermore, PLS-SEM is well-suited for exploratory research that seeks to develop new insights rather than confirm existing theories (Dash & Paul, 2021; Hair Jr. et al., 2017). Since this study examines the mediating role of CE and EM in the relationship between *EE* and *WM*, a predictive approach is more appropriate.

RESULTS AND DISCUSSION

Descriptive Statistics

Before analyzing the measurement model assessment, it is important to examine the descriptive statistics. Table 2 shows that the average scores are mostly above 4.00, meaning respondents gave positive ratings. The highest score is 4.277 (*EE2*), and the lowest is 3.960 (*WM1*), but the differences are small. The standard deviations are low, indicating consistent responses. *CE1* shows the greatest variation (0.844), while EM4 shows the least (0.568). Overall, the data is reliable and suggests good quality.

Table 3 shows the descriptive statistics for latent variables. The median values are close to zero, meaning the data is balanced. The minimum and maximum values suggest a reasonable spread of data. The standard deviation is the same (1.000) for all variables, indicating normalized data. The excess kurtosis values are negative, meaning the distributions are flatter than normal. Skewness values are close to zero, suggesting the data is fairly symmetric. In general, the data appear well distributed.

Table 2. Descriptive Statistics

Items	Mean	SD
CE1	3.980	0.844
CE2	4.158	0.714
CE3	4.089	0.631
CE4	4.040	0.782
CE5	4.109	0.716
EE1	4.050	0.776
EE2	4.277	0.719
EE3	4.069	0.787
EE4	4.198	0.630
EM1	4.139	0.745
EM2	4.079	0.754
EM3	4.218	0.684
EM4	4.208	0.568
WM1	3.960	0.730
WM2	4.079	0.727
WM3	4.000	0.731
WM4	4.059	0.701

Table 3. Latent Variable Descriptive Statistics

Variables	Median	Min	Max	Excess Kurtosis	Skewness
CE	-0.133	-1.852	1.586	-0.834	0.035
EE	-0.250	-1.876	1.376	-1.054	0.067
EM	-0.279	-2.069	1.510	-0.729	-0.041
WM	-0.036	-1.705	1.633	-0.715	-0.008

Table 4 shows the correlations between latent variables. All values are positive, indicating a positive relationship between the variables. *CE* and *EE* have the strongest association (0.559), suggesting that greater Cost-Efficiency (*CE*) is associated with greater Eco-Efficiency (*EE*). *EM* and *WM* also have a strong connection (0.650), indicating that higher Environmental Management (*EM*) aligns well with Waste Management (*WM*). Other correlations, though smaller, still show positive relationships. Taken together, this suggests that the variables reinforce each other meaningfully. From Tables 2, 3, and 4, these results suggest that the data is well-structured and suitable for further analysis.

Table 4. Latent Variable Correlations

Variables	CE	EE	EM	WM
CE	1.000	0.559	0.232	0.322
EE	0.559	1.000	0.287	0.315
EM	0.232	0.287	1.000	0.650
WM	0.322	0.315	0.650	1.000

Measurement Model Assessment

The guidance provided by Hair et al. (2019) was followed in evaluating the Measurement Model Assessment, with emphasis on convergent and discriminant validity.

The findings of the divergent validity analysis are shown in Tables 5 and 6, while the discriminant validity results are presented in Tables 7, 8, and 9.

Table 5. Factor Loading and VIF

Items	Factor Loading	VIF
CE1	0.733	1.537
CE2	0.897	3.676
CE3	0.729	1.626
CE4	0.753	1.802
CE5	0.831	3.076
EE1	0.941	4.889
EE2	0.799	1.923
EE3	0.696	1.501
EE4	0.928	4.354
EM1	0.786	2.005
EM2	0.834	1.725
EM3	0.888	3.603
EM4	0.673	2.278
WM1	0.787	1.786
WM2	0.824	2.022
WM3	0.919	2.706
WM4	0.735	1.547

As shown in Table 5, most factor loadings are above the recommended threshold of 0.70. Although *EE3* and *EM4* have factor loadings slightly below 0.70, these indicators were retained because their values remain within an acceptable range and the overall construct reliability and AVE values satisfy the recommended criteria. In addition, all VIF values are below 5, indicating that multicollinearity is not a concern. These results support the adequacy of the measurement model and are further reinforced by the construct reliability and validity results presented in Table 6 (Hair et al., 2019). The Cronbach's Alpha, *rho_A*, and Composite Reliability values for all variables exceed the recommended threshold of 0.70, indicating good internal consistency and reliability (Hair et al., 2019). Additionally, all AVEs exceed 0.50, confirming adequate convergent validity (Hair et al., 2019). As suggested, Table 6 provides strong evidence that the constructs are reliable and valid, further supporting the quality of the data.

Table 6. Construct Reliability and Validity

Variables	Cronbach's Alpha	rho_A	Composite Reliability	AVE
CE	0.849	0.857	0.893	0.626
EE	0.864	0.900	0.909	0.717
EM	0.812	0.862	0.875	0.639
WM	0.835	0.882	0.890	0.671

In terms of the discriminant validity, Table 7 shows the Fornell-Larcker Criterion. The diagonal values (*0.791 for CE, 0.847 for EE, 0.799 for EM*, and *0.819 for WM*) represent the square root of the AVE for each construct, and they are all higher than the off-diagonal values in their respective columns. This confirms that each construct is more strongly related to its own indicators than to other constructs. These demonstrate good discriminant validity, indicating that the constructs are distinct from each other (Hair et al., 2019).

Table 7. Fornell-Larcker Criterion

Variables	CE	EE	EM	WM
CE	0.791			
EE	0.559	0.847		
EM	0.232	0.287	0.799	
WM	0.322	0.315	0.650	0.819

Furthermore, Table 8 presents the cross-loadings, which help assess discriminant validity by assessing whether items load more strongly on their respective constructs than on other constructs (Hair et al., 2019). As shown in the table, each item has the highest loading on its corresponding construct. For example, *CE1* has the strongest loading on *CE* (0.733), *EE1* on *EE* (0.941), *EM2* on *EM* (0.834), and *WM3* on *WM* (0.919). These values confirm that the items are well-associated with their respective constructs. As such, these support the measurement model's discriminant validity, as presented in Table 7.

Table 8. Cross Loadings

Items	CE	EE	EM	WM
CE1	*0.733*	0.525	0.243	0.272
CE2	*0.897*	0.487	0.135	0.280
CE3	*0.729*	0.442	0.129	0.103
CE4	*0.753*	0.364	0.237	0.330
CE5	*0.831*	0.357	0.159	0.264
EE1	0.558	*0.941*	0.230	0.325
EE2	0.379	*0.799*	0.235	0.311
EE3	0.407	*0.696*	0.173	0.104
EE4	0.529	*0.928*	0.318	0.292
EM1	0.042	0.275	*0.786*	0.380
EM2	0.243	0.295	*0.834*	0.688
EM3	0.192	0.189	*0.888*	0.526
EM4	0.242	0.122	*0.673*	0.388
WM1	0.227	0.210	0.479	*0.787*
WM2	0.167	0.197	0.467	*0.824*
WM3	0.295	0.283	0.715	*0.919*
WM4	0.366	0.344	0.398	*0.735*

Additionally, the Heterotrait-Monotrait Ratio (HTMT) was used as an additional analysis to assess discriminant validity, as illustrated in Table 9. According to the rule of thumb, an HTMT value below 0.85 indicates that the constructs are sufficiently distinct. In Table 9, all HTMT values are well below 0.85: *CE* and *EE* (0.639), *CE* and *EM* (0.276), *EE* and *EM* (0.327), and *EM* and *WM* (0.728). These values suggest that the constructs are adequately differentiated from one another. Therefore, Table 9 supports the measurement model's discriminant validity.

Table 9. Heterotrait-Monotrait Ratio (HTMT)

Variables	CE	EE	EM	WM
CE				
EE	0.639			
EM	0.276	0.327		
WM	0.386	0.362	0.728	

Regression Results

Panel A of Table 10 presents the results of hypothesis testing for direct effects. The findings show that three hypotheses are supported: *H2 (EE → CE, β = 0.559, p < 0.001), H4 (EE → EM, β = 0.287, p = 0.003), and H5 (EM → WM, β = 0.598, p < 0.001)*, indicating strong and significant relationships. However, *H1 (EE → WM) and H3 (CE → WM)* are not supported. This is because their p-values exceed the significance threshold (*p > 0.05*). These results suggest that while *EE* influences *CE* and *EM*, *EM* strongly affects *WM*, but the direct effects of *EE* on *WM* and of *CE* on *WM* are not significant. Moreover, Panel B of Table 10 presents the results of hypothesis testing for indirect effects. The findings indicate that H7 (*EE → EM → WM; β = 0.171, p = 0.005*) is supported, indicating that *EE* has an indirect positive influence on *WM* through *EM*. However, *H6 (EE → CE → WM)* is not supported, as the p-value is above 0.05 (*p = 0.135*). This suggests that while *EE* does not significantly impact WM through CE, it does have a meaningful indirect effect via *EM*.

Table 10. Hypothesis Testing Results

Paths	β	Mean	SD	Sig.	2.5%	97.5%	Note
Panel A: Direct effects							
H1: EE → WM	0.059	0.046	0.103	0.566	-0.155	0.237	Not supported
H2: EE → CE	0.559	0.576	0.073	0.000	0.425	0.718	Supported
H3: CE → WM	0.150	0.155	0.096	0.119	-0.030	0.335	Not supported
H4: EE → EM	0.287	0.289	0.095	0.003	0.110	0.462	Supported
H5: EM → WM	0.598	0.609	0.071	0.000	0.458	0.739	Supported
Panel B: Indirect effects							
H6: EE → CE → WM	0.084	0.088	0.056	0.135	-0.018	0.207	Not supported
H7: EE → EM → WM	0.171	0.176	0.061	0.005	0.067	0.296	Supported

Additional Analysis

Further analysis differentiated male and female respondents to examine whether similar differences existed in waste management. The model presented in Table 10 was re-estimated through separate regressions for each gender group. The results are illustrated by Tables 11 and 12.

Table 11. Regression for Males

Paths	β	Mean	SD	Sig.	2.5%	97.5%
Panel A						
EE → WM	-0.046	-0.052	0.137	0.737	-0.319	0.212
EE → CE	0.453	0.487	0.104	0.000	0.287	0.663
CE → WM	0.102	0.108	0.114	0.371	-0.136	0.320
EE → EM	0.154	0.177	0.133	0.248	-0.093	0.422
EM → WM	0.568	0.588	0.084	0.000	0.398	0.723
Panel B						
EE → CE → WM	0.046	0.050	0.058	0.423	-0.075	0.169
EE → EM → WM	0.088	0.103	0.079	0.268	-0.058	0.251

In Table 11, Eco-Efficiency (*EE*) does not have a significant direct effect on waste management (*WM*) (*β = -0.046, p = 0.737*), while its influence on cost efficiency (*CE*) is positive and significant (*β = 0.453, p < 0.001*). However, *CE* does not significantly affect *WM* (*β = 0.102, p = 0.371*), resulting in a non-significant indirect effect of *EE* on *WM* through *CE*. Similarly, although *EE* positively affects environmental management (*EM*), the relationship is insignificant (*β = 0.154, p = 0.248*), despite *EM* having a strong positive effect on *WM* (*β = 0.568, p < 0.001*). Consequently, the mediating role of *EM* is also insignificant in Table 11. In contrast, Table 12 demonstrates stronger and more significant relationships. *EE* significantly affects both *CE* (*β = 0.736, p < 0.001*) and *EM* (*β = 0.479, p < 0.001*), while *EM* shows a very strong positive effect on *WM* (*β = 0.760, p < 0.001*). Although the direct effect of *EE* on *WM* and the mediating role of CE remain insignificant, the indirect effect of *EE* on *WM* through *EM* becomes significant (*β = 0.364, p < 0.001*). These findings indicate that environmental management plays a more substantial mediating role in Table 12 compared to Table 11, suggesting a stronger integration of environmental practices in enhancing waste management outcomes.

Table 12. Regression for Females

Paths	β	Mean	SD	Sig.	2.5%	97.5%
Panel A						
EE → WM	0.215	0.211	0.165	0.194	-0.150	0.489
EE → CE	0.736	0.737	0.083	0.000	0.532	0.868
CE → WM	0.082	0.073	0.124	0.509	-0.187	0.324
EE → EM	0.479	0.495	0.130	0.000	0.202	0.720
EM → WM	0.760	0.760	0.109	0.000	0.512	0.947
Panel B						
EE → CE → WM	0.060	0.055	0.095	0.525	-0.149	0.259
EE → EM → WM	0.364	0.367	0.083	0.000	0.178	0.520

Furthermore, the roles of *CE* and *EM* were further re-analyzed as moderating variables. Table 13 presents alternative paths to explain the relationships between *EE*, *CE*, *EM*, and *WM*, complementing the prior findings. Panel A suggests that the interaction between *EE* and *CE* (*β = 0.159, p = 0.044*) has a significantly positive effect on *WM*, whereas *EE* and *EM* (*β = 0.092, p = 0.296*) do not significantly impact *WM*. These results align with Table 10, which found that the direct effect of *EE* on *WM* was not supported (*β = 0.059, p = 0.566*), indicating that *EE*'s influence on *WM* is conditional on other factors. Panel B further strengthens this argument, showing that the interaction between *CE* and *EM* (*β = 0.531, p = 0.000*) and the three-way interaction (*EE*CE*EM*) (*β = 0.186, p = 0.011*) significantly contribute to *WM*. Finally, Panel C shows that *EE* indirectly affects *WM* through the interaction between *CE* and *EM* (*β = 0.333, p = 0.000*).

Table 13. Alternative Paths

Paths	β	Mean	SD	Sig.	2.5%	97.5%
Panel A						
EE*CE → WM	0.159	0.145	0.079	0.044	-0.014	0.292
EE*EM → WM	0.092	0.097	0.088	0.296	-0.078	0.273
Panel B						
CE*EM → WM	0.531	0.530	0.090	0.000	0.348	0.689
EE*CE*EM → WM	0.186	0.174	0.073	0.011	0.032	0.309
Panel C						
EE → CE*EM → WM	0.333	0.339	0.072	0.000	0.203	0.494

Discussion

The findings of this study provide critical evidence of the widely assumed linkages between *EE* and *WM*. This study reveals a complex, non-linear dynamic that necessitates a reassessment of prior theoretical postulations. The results revealed no direct relationship between *EE* and *WM*, regardless of the business owner's gender. This indicates that eco-efficiency-driven improvements do not inherently generate improved waste management outcomes. This result does not support prior studies that have often posited that firms adopting eco-efficiency measures may naturally experience enhanced waste management outcomes (Majid et al., 2023; Maman et al., 2024; Prashar, 2021). Conceptually, the result is acceptable. *EE* is inherently a production-centric concept that emphasizes doing more with less – reducing energy and material inputs while maintaining or improving output quality (Özbuğday et al., 2020). As such, this does not necessarily extend to waste management, which involves handling by-products, post-production waste treatment, and the implementation of circular economy principles. The fundamental distinction between EE and waste reduction lies in their core objectives: *EE* seeks to enhance operational performance by reducing input waste, whereas *WM* requires deliberate strategies to minimize, repurpose, or properly dispose of waste materials after production processes. As such, firms that adopt *EE* strategies will not naturally extend their effects to *WM*. *EE* does not inherently address the fate of waste materials. Additionally, *EE*-driven firms often prioritize cost efficiency, and if waste management efforts do not offer immediate financial returns, they may be overlooked or deprioritized.

Clearly, the observed positive influence of *EE* on *CE* and *EM* reinforces the argument that firms prioritizing resource efficiency tend to achieve economic and environmental gains. However, the gendered dimension of this relationship highlights a structural asymmetry, wherein male-owned businesses fail to exhibit the same positive *EE-EM* correlation, raising questions about gender-based managerial approaches or strategic environmental orientations. As shown in this study, female business owners who demonstrate a consistent positive *EE-EM* link may indicate a stronger inclination toward environmental stewardship, heightened awareness of long-term sustainability risks, or greater responsiveness to external regulatory and stakeholder pressures. This supports prior studies showing that women in leadership positions are often more risk-averse in financial decision-making (Dobija et al., 2022; García-Meca et al., 2022) and more proactive in addressing environmental and social risks. They may recognize that failure to integrate sustainability considerations into business operations can have long-term reputational and financial consequences. This suggests that female business owners may view eco-efficiency as more than just a cost-saving mechanism; rather, they are likely to see it as an integral part of a broader commitment to responsible business practices. By contrast, the lack of correlation in male-owned businesses may signal a more profit-driven or operationally focused approach to eco-efficiency, where efficiency gains are seen as a means to enhance competitiveness rather than as a vehicle for broader environmental responsibility.

The role of *EM* as a direct driver of *WM* introduces another layer of complexity, underscoring the need for proactive environmental governance mechanisms that go beyond efficiency-driven strategies (Andeobu et al., 2021; Crossley et al., 2021). *EM*'s positive influence on *WM* suggests that structured environmental policies and sustainability-oriented leadership are more consequential in shaping waste-reduction outcomes than mere efficiency optimizations. Given that waste management is a fundamental aspect of corporate environmental responsibility, firms that engage in robust *EM* practices are naturally positioned to adopt more effective and sustainable waste management strategies. This is supported by prior studies that firms with strong environmental management systems consistently demonstrate superior waste management performance (Aslam et al., 2021; Dey et al., 2018; Ferrazzi et al., 2025). Furthermore, the non-significance of *CE* in influencing *WM*, regardless of business owner gender, further destabilizes the assumption that financial prudence necessarily translates into better waste management. Essentially, this contradicts the dominant logic in the sustainability literature, which often presupposes that firms, when faced with cost-saving opportunities, will adopt environmentally responsible behaviors as a by-product of economic optimization (Gopalakrishnan et al., 2021). Instead, the results suggest that financial motivations alone do not necessarily translate into improved waste management outcomes, suggesting that firms may perceive sustainability as a secondary concern unless explicitly mandated through regulatory, institutional, or stakeholder pressures. This calls into question the effectiveness of market-driven environmental strategies that assume economic self-interest will naturally align with sustainable corporate practices, reinforcing the need for stronger governance mechanisms and policy interventions to bridge the gap between eco-efficiency and waste management performance.

An additional critical implication of this study lies in the mediating mechanisms – or lack thereof – between *EE* and *WM*. The finding suggests that only *EM* serves as an intermediary between *EE* and *WM*, whereas *CE* does not. This is conceptually sound and supported by both theoretical frameworks and practical outcomes in the field of sustainability. From a theoretical perspective, *EM* ensures that efficiency-driven waste reductions translate into actual improvements in *WM* practices (Woodard, 2021). As previously mentioned, while *EE* focuses on reducing waste at the input stage through resource optimization (Sala-Garrido et al., 2024), it does not inherently address how the remaining waste should be managed. *EM* bridges this gap by embedding sustainability principles into firm governance (M. Singh et al., 2015; Wu et al., 2024), ensuring that waste minimization efforts extend beyond efficiency improvements to include proper waste handling, recycling, and disposal. So, through regulatory compliance (M. Singh et al., 2015), *EM* creates accountability structures that compel firms to implement waste management strategies rather than merely achieving production efficiency. This oversight is crucial because, without *EM*, efficiency gains might reduce waste generation without necessarily leading to better waste treatment, potentially resulting in continued environmental harm. In this sense, eco-efficiency goes beyond cost-cutting measures; it fosters a mindset that integrates sustainability across the entire value chain, including waste management. Moreover, the lack of *CE* mediation reinforces the argument that financial optimization, when pursued in isolation, does not guarantee environmental progress. This study, therefore, critiques the overreliance on economic rationality in sustainability studies, exposing the limitations of market-driven sustainability strategies that rely on cost efficiency as a primary driver of environmental performance (Cagno et al., 2012; Zhao et al., 2024).

When the mediating effects of *EM* and *CE* on *the EE-WM* relationship are disaggregated by gender, the findings show an intriguing contrast. Specifically, the mediation effect was not significant in male-led firms, whereas it was significant in female-led firms. This suggests that while male-led firms may implement environmental and cost efficiency measures, these mechanisms do not play a substantial role in translating eco-efficiency improvements into better waste management practices. In contrast, female-led firms demonstrate a clearer pathway in which *EM* effectively mediates the *EE-WM* relationship. It indicates that female-led firms are more likely to embed environmental management practices into their corporate strategies rather than treating them as peripheral or reactive measures. Unlike cost efficiency, whether a firm is male- or female-led does not significantly alter the mediating role of *CE* in the *EE-WM* relationship. Cost efficiency is a highly strategic, data-driven domain in which firms rely on industry benchmarks and cost-benefit analyses to shape their sustainability strategies. As a result, decision-making in this area is less likely to be influenced by gender-specific leadership styles and more likely to be driven by technical expertise, financial incentives, and compliance considerations. This result supports previous research emphasizing gender diversity in business leadership, not necessarily for gendered strategic benefits, but to foster diverse perspectives in decision-making (Ran et al., 2021). Gender diversity in leadership has been widely recognized for its role in improving corporate governance, ethical decision-making, and long-term sustainability planning (Dobija et al., 2022).

Finally, the study found that the *CE* becomes a more powerful mechanism for linking *EE* to *WM* when treated as a mediating factor. The fundamental premise of *EE* is that optimizing resource use leads to cost savings. However, without a structured financial approach, these savings may be absorbed by other operational priorities rather than being reinvested in sustainability initiatives. If firms lack a mechanism like *CE* to quantify the financial benefits of *EE* and translate them into a structured reinvestment strategy, these initiatives may be deprioritized in favor of more immediate financial gains. Moreover, the interaction between *CE* and *EM* was found to fundamentally transform the relationship between *EE* and *WM*. This dual role suggests that *CE* and *EM* do not operate in isolation but instead create a reinforcing mechanism that strengthens the pathway through which *EE* influences *WM*. This study extends prior work by demonstrating that financial and environmental resources must be strategically integrated to achieve sustainable waste management outcomes. For instance, Richter et al. (2021) argue that firms with superior resources, such as financial capital from *CE* or *EM*, gain a competitive advantage. However, these findings suggest that *CE* and *EM* must function together as mutually reinforcing resources to unlock EE's potential to drive waste management outcomes fully. In this study, *CE* and *EM* are not static assets but rather dynamic enablers that enhance a firm's ability to develop internal alignment between economic incentives and environmental commitments.

CONCLUSION

The findings of this study reveal a nuanced, non-linear relationship between eco-efficiency and waste management in small-scale enterprises. Contrary to conventional expectations, eco-efficiency does not directly influence waste management practices. Instead, its impact operates through more complex organizational mechanisms. Eco-efficiency is shown to significantly enhance cost-efficiency, indicating that firms adopting environmentally efficient practices can reduce operational costs. However, cost efficiency itself does not translate into improved waste management, nor does it mediate the relationship between eco-efficiency and waste management. This suggests that financial or cost-driven motives alone are insufficient to encourage firms to adopt effective waste-handling practices.

In contrast, eco-efficiency has a significant positive effect on environmental management, which in turn strongly influences waste management. Furthermore, environmental management fully mediates the relationship between eco-efficiency and waste management. These results highlight the critical role of structured environmental management systems as a bridging mechanism that transforms efficiency-oriented practices into concrete waste management outcomes. Overall, this study underscores that while eco-efficiency can serve as a strategic resource, its effectiveness in improving waste management depends heavily on the presence of formal environmental management practices. Without such structures, efficiency gains are more likely to remain confined to cost reduction rather than extending to broader environmental responsibilities.

The findings of this study offer some key managerial implications for businesses aiming to integrate *EE* with *W*M. First, firms should recognize that *EE* improvements alone do not guarantee better *WM* outcomes and must implement structured *EM* frameworks to bridge this gap. Second, business leaders, especially in male-led firms, should adopt a more proactive approach to embedding sustainability into corporate strategies rather than viewing *EE* purely as a cost-saving measure. Third, companies should leverage the complementary roles of *EM* and *CE* to ensure that financial gains from efficiency improvements are reinvested in sustainable waste-reduction initiatives. Finally, policymakers and corporate decision-makers must design stronger regulatory and incentive structures that compel firms to align *EE* efforts with effective waste management practices, ensuring long-term environmental and economic benefits.

One limitation of this study is its focus on SSEs in a single emerging economy, which may limit the generalizability of findings to other regions or larger firms with different regulatory and financial environments. Future research could explore similar models in diverse geographic and industrial contexts to enhance external validity. Another limitation is the reliance on self-reported survey data, which may introduce bias due to social desirability or misunderstanding of questions. Subsequent studies should incorporate qualitative interviews or longitudinal case studies for deeper insights. Additionally, while this study examines eco-efficiency, cost efficiency, and environmental management, it does not consider external factors such as regulatory pressures or consumer demand, which may significantly influence waste management practices. Future research should therefore integrate these external determinants.

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