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WASTE REDUCTION STRATEGIES IN JEPARA FURNITURE SMEs: EVIDENCE FROM INDONESIA'S WOOD INDUSTRY CLUSTER

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ABSTRACT

Objective: This study aims to analyze the waste reduction strategies implemented by furniture companies in the Jepara Industrial Cluster and their impact on operational efficiency and environmental sustainability.

Research Design & Methods: This study employs a mixed-methods approach that combines quantitative survey data from 87 furniture SMEs in Jepara with qualitative in-depth interviews with 12 company managers. The data were analyzed using descriptive statistics, multiple regression analysis, and thematic analysis.

Findings: The results show that the implementation of lean manufacturing principles, material optimization techniques, and circular economy practices significantly reduced production waste by 23–38%. Companies that systematically implemented waste reduction programs reported a 17.4% increase in operational efficiency and a 21.2% reduction in raw material costs.

Contributions: This study provides empirical evidence supporting the implementation of waste reduction strategies in Indonesian furniture SMEs and offers practical recommendations for industry stakeholders and policymakers to promote green manufacturing in the Jepara cluster.

Novelty: Unlike previous studies that focused on large-scale manufacturing, this study integrates lean manufacturing, the circular economy, and SME-specific constraints within the unique socioeconomic context of the traditional Jepara furniture cluster.

Keywords: Waste Reduction, Furniture Industry, Circular Economy.

JEL codes: L73, Q53, M11

Article type: research paper

INTRODUCTION

The furniture industry in Jepara, Central Java, is one of the largest wood-based industrial clusters in Indonesia and has long been the backbone of the local economy. Jepara is internationally recognized as a center for carved furniture production, with products characterized by high artistic value and superior craftsmanship. This industry is dominated by small and medium-sized enterprises (SMEs) spread across nearly all subdistricts in Jepara Regency. Research indicates that more than 31% of SMEs in Jepara operate in the furniture sector, making it the most dominant economic sector in the region (Prahastia & Ismanto, 2022). Besides absorbing a large workforce, Jepara's furniture industry also contributes significantly to Indonesia's export activities through markets in Europe, the United States, the Middle East, and the Asia-Pacific region (Arifin et al., 2024). The existence of this industrial cluster not only serves as a source of foreign exchange for the country but also as a means of economic empowerment for the local community—a role it has played for several generations.

The high volume of waste generated during the production process is one of the main challenges facing the Jepara furniture industry. This waste includes wood scraps, sawdust, wood shavings, and other leftover materials that are often not utilized to their full potential. Various studies indicate that the wood-based furniture industry has a relatively low level of raw material utilization efficiency (Afifah et al., 2025; Hartini et al., 2021; Uliana et al., 2025). A recent study on the Indonesian furniture industry found that the production process can generate waste amounting to as much as 58.85% of the total raw materials used (Sudiryanto & Suharto, 2020; Yuniati et al., 2025). Even during the sawing stage, wood waste can exceed 56% due to mismatches in board dimensions, material shape, and the cutting techniques employed (Laksono et al., 2016). This situation results in significant economic losses because a large portion of high-value wood raw materials cannot be converted into

finished products. Furthermore, the widespread practice of open-air burning of sawdust waste has the potential to increase air pollution and carbon emissions, which negatively impact the environment.

The issue of waste in the furniture industry can be explained through the Lean Manufacturing theory developed by Womack and Jones (1997). The concept of waste in lean manufacturing is defined as any activity that does not add value for the customer but consumes the company's resources. This concept emphasizes the importance of eliminating waste through the optimization of production processes, the reduction of product defects, the efficient use of raw materials, and increased labor productivity. The application of lean manufacturing in the furniture industry has proven effective in reducing material waste while improving a company's operational efficiency (Hartini et al., 2021). Research by Wurjaningrum and Bhaskoro (2024) on the Indonesian furniture industry shows that the lean-green manufacturing approach is effective in identifying sources of waste and reducing the environmental impact of production processes.

The Circular Economy theory, popularized by the Ellen MacArthur Foundation (2015), offers another perspective on waste reduction alongside the lean manufacturing approach. This theory emphasizes that waste should not be viewed as an end product to be discarded, but rather as a resource that can be reused through the processes of reuse, recycling, remanufacturing, and recovery. In the context of the furniture industry, the circular economy approach can be implemented by reusing wood scraps for small products, processing sawdust into biomass fuel, and developing derivative products with higher economic value. Recent literature indicates that the transition to a circular economy has become a strategic necessity for the global furniture industry, as it can reduce the consumption of natural resources while enhancing business sustainability (Yuniati et al., 2025). Research on the Jepara furniture industry also indicates that low wood utilization efficiency and limited waste utilization pose a threat to the industry's long-term sustainability (Malik & Hopewell, 2011).

Shifts in global market preferences are further underscoring the urgency of implementing waste reduction strategies in the furniture industry. International consumers today consider not only product quality and price but also the sustainability of the production process. Various export destination countries, particularly within the European Union, have begun implementing strict environmental standards regarding the legality of raw materials, carbon footprints, waste management, and the application of circular economy principles within the supply chain (Arifin et al., 2024). These conditions are forcing Indonesian furniture exporters to improve their environmental performance as part of a strategy to maintain access to international markets. Consequently, companies' ability to manage waste effectively has evolved from a mere environmental obligation into a strategic factor that determines their global competitiveness.

The importance of waste reduction has been widely discussed in the literature; however, research specifically examining waste reduction strategies in the Jepara furniture cluster remains relatively limited. Most previous studies have focused more on the economic performance of SMEs, product innovation, marketing strategies, and export competitiveness (Prahastia & Ismanto, 2022). Research on waste is generally conducted on specific companies with a narrow scope, so it has not yet been able to comprehensively describe the conditions of the Jepara furniture industry (Wurjaningrum & Bhaskoro, 2024). Furthermore, there are still few empirical studies that quantitatively measure the relationship between waste reduction strategies and improvements in operational efficiency, production cost savings, and business sustainability at the SME level. Studies such as Hartini et al., (2021) and Suhardi et al., (2019) demonstrate lean and circular economy interventions through single-company case studies in Indonesia, while Ince et al., (2025) and Sasso et al., (2025) examine lean-circular synergy in larger, more industrialized furniture and manufacturing firms outside Indonesia; none of these studies statistically test how lean manufacturing and circular economy adoption jointly predict waste reduction and cost outcomes across a representative sample of SMEs within a single traditional craft cluster. In other words, there remains a research gap regarding the identification of effective waste reduction practices and the measurement of their impact on the performance of furniture companies, particularly using quantitative, cluster-wide evidence rather than isolated case studies.

Based on the above discussion, this study was conducted to address a gap in the literature regarding waste management in the Jepara furniture industry. Specifically, this study aims to: (1) identify and categorize various waste reduction strategies implemented by furniture SMEs in Jepara; (2) measure the impact of these strategies on the efficiency of raw material use, production costs, and company productivity; and (3) formulate practical recommendations for business operators, industry associations, and local governments in developing a sustainable waste management system. The results of this study are expected to contribute theoretically to the development of research on lean manufacturing and the circular economy in the furniture sector, while also generating policy recommendations that support the transformation of Jepara's furniture industry toward a more efficient, competitive, and sustainable production model.

LITERATURE REVIEW

Lean Manufacturing

Lean manufacturing is a production management philosophy focused on identifying and eliminating waste

throughout the entire production process to improve efficiency and add value for customers. This concept was first popularized through the Toyota Production System (TPS), which identifies seven classic types of waste: overproduction, waiting time, transportation, excessive processing, excess inventory, unnecessary motion, and defects (Anoop G.M., 2020). In the context of the wood-based furniture industry, this waste generally takes the form of wood offcuts, sawdust, finishing defects, and waiting time between processes due to a suboptimal production layout.

The application of lean manufacturing principles in furniture SMEs is believed to reduce the volume of production waste through several mechanisms. First, the implementation of 5S (Seiri, Seiton, Seiso, Seiketsu, Shitsuke) promotes better organization of materials and workspaces, thereby reducing cutting errors and damage to raw materials (Santos et al., 2023). Second, Value Stream Mapping (VSM) helps artisans identify points of waste along the production flow so that targeted improvements can be made (Suhardi et al., 2019; Wang et al., 2024). Third, the just-in-time principle and the pull system minimize overproduction and excess inventory of wood raw materials, which are at risk of quality degradation (Ince et al., 2025). Various studies in the small- and medium-scale manufacturing sector indicate that the degree of lean practice adoption is positively correlated with a reduction in the waste-to-output ratio, although the magnitude of this effect varies depending on the maturity level of implementation and the characteristics of the raw materials used. Based on this discussion, lean manufacturing is positioned as the primary predictor variable (constant) in this study, which is hypothesized to contribute directly to a reduction in production waste within the Jepara wood industry cluster.

Circular Economy Practices

The circular economy is an economic model that emphasizes extending the life cycle of products and materials through the principles of reduce, reuse, recycle, and recover, as an alternative to the linear "take-make-dispose" economic model (Goyal et al., 2018; Hom, 2024; Jahan et al., 2022). In the context of the wood industry, circular economy practices may include repurposing wood scraps into derivative products (such as small handicrafts or composite panels), using sawdust as biomass fuel or briquettes, partnering with suppliers to manage sustainably certified raw materials, and implementing take-back systems for defective products or production waste (Braghiroli & Passarini, 2020).

At the industrial cluster level, as observed in Jepara, circular economy practices are characterized by a symbiotic relationship among business actors, in which one business unit's waste can serve as an input for another business unit within the same cluster (industrial symbiosis). This mechanism has the potential to strengthen the effectiveness of waste reduction strategies by providing an economically viable outlet for the residual materials generated by lean manufacturing practices, thereby not only reducing waste generation but also converting it into additional economic value. Recent literature on the integration of lean and the circular economy (lean-circular synergy) indicates that these two paradigms are complementary: lean serves to reduce waste at its source, while the circular economy serves to optimize the value of unavoidable residues; thus, their interaction has the potential to yield greater performance impacts than the separate implementation of each approach (Sasso et al., 2025; Yazan & Fraccascia, 2020).

The Relationship Between Lean Manufacturing, the Circular Economy, and Cost Performance

The relationship between lean manufacturing, the circular economy, and cost performance has become an increasingly important issue in the furniture industry due to the high proportion of wood raw material costs in the production cost structure. From a lean manufacturing perspective, waste reduction is achieved by eliminating activities that do not add value, improving process efficiency, reducing product defects, and optimizing the use of raw materials. The implementation of this strategy is theoretically capable of lowering production costs by reducing material waste, rework costs, and waste disposal costs. Thus, the more effective a company's waste reduction strategy is, the greater its chances of achieving better cost performance. However, various studies indicate that the magnitude of the economic benefits derived from waste reduction strategies is not always the same across companies, as it is influenced by a company's ability to manage leftover materials that still hold economic value.

The circular economy is viewed as a factor that can strengthen the link between waste reduction strategies and a company's cost performance. The concept of the circular economy emphasizes the reuse of resources through reuse, recycling, remanufacturing, and recovery, so that materials previously considered waste can be returned to the production cycle or utilized to produce value-added products. Companies that only implement waste reduction tend to benefit from cost savings resulting from reduced material waste. Conversely, companies that combine waste reduction strategies with circular economy practices not only reduce waste but are also able to create new economic value from production residues—such as by converting wood dust, wood scraps, or furniture waste into derivative products or alternative fuels. Therefore, the higher the level of circular economy implementation, the stronger the impact of waste reduction strategies on improving a company's cost performance.

In addition to these main variables, this study includes firm size and length of business experience as control variables to enhance the validity of the research model. Firm size—measured by the number of employees, production capacity, or revenue—reflects the availability of financial, technological, and managerial resources that enable the more systematic implementation of lean manufacturing and circular economy practices. Meanwhile,

length of business experience reflects the accumulation of knowledge and operational capabilities that a company has gained over the years in managing raw materials, controlling production processes, and addressing various sources of waste. More experienced companies generally have a better ability to optimize resource use compared to companies that have only recently begun operations. By controlling for these two variables, this study aims to ensure that the impact of waste reduction and circular economy strategies on cost performance can be observed more accurately without being distorted by differences in the companies' underlying characteristics.

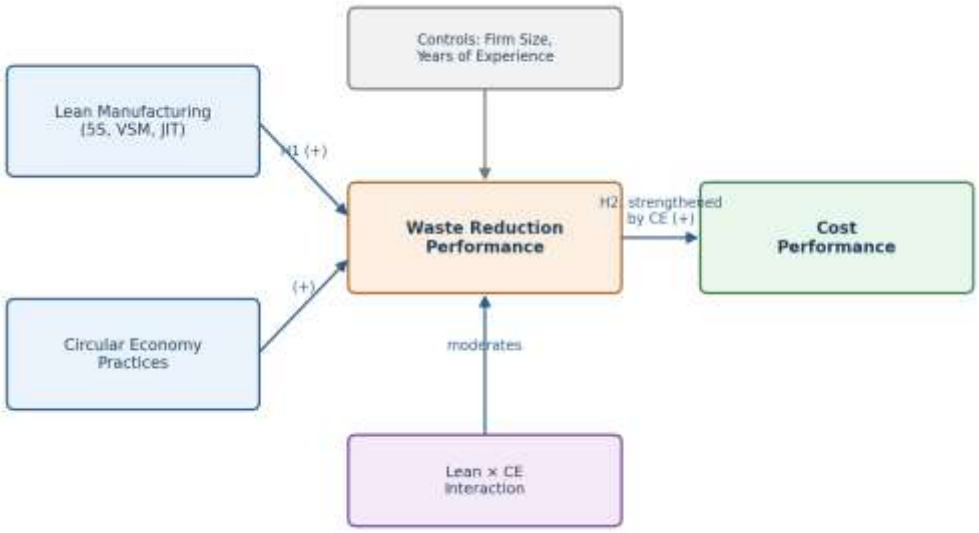

Figure 1. Conceptual framework of the relationships among lean manufacturing, circular economy practices, waste reduction performance, and cost performance

Hypothesis Development

H1: The implementation of lean manufacturing principles is significantly and positively correlated with a reduction in production waste at Jepara furniture SMEs.

This hypothesis is based on the argument that lean principles—such as the elimination of waste, the reorganization of workflows through value stream mapping, and the application of 5S—directly target the sources of waste generation in the wood furniture production process. The higher the degree to which a business unit applies lean principles, the greater the potential for reducing the volume of material scraps, production defects, and process inefficiencies, which ultimately results in a lower ratio of waste to production output.

H2: The adoption of circular economy practices positively moderates the relationship between waste reduction strategies and a company's cost performance.

This hypothesis is based on the argument that the economic benefits of waste reduction strategies will be maximized if remaining production residues can be reused through circular economy mechanisms, whether through internal utilization or symbiosis among business actors within a cluster. In other words, in companies with a high level of circular economy adoption, the impact of waste reduction strategies on production cost savings will be stronger than in companies with low circular economy adoption.

METHODS

This study employed a sequential explanatory mixed-methods design (Creswell & Clark, 2017), which combined a quantitative survey phase with a qualitative interview phase. The quantitative phase targeted furniture manufacturing SMEs registered with the Jepara Branch of the Indonesian Furniture and Handicrafts Industry Association (ASMINDO). The sampling frame included 423 registered member companies, from which 87 companies were selected through stratified random sampling based on company size (micro, small, medium) and product type (indoor furniture, outdoor furniture, custom/contract furniture). A structured questionnaire was administered to company owners or production managers, collecting data on waste reduction practices, production input-output ratios, cost structures, operational efficiency indicators, and environmental management practices. All multi-item constructs were measured on five-point Likert scales adapted from established lean manufacturing and circular economy instruments in prior studies, and the questionnaire was refined through a pilot test with 15 furniture SME respondents outside the final sample, after which items with weak item-total correlations were revised for clarity. Content validity was assessed by three academic and industry experts, and construct reliability for the lean manufacturing, circular economy, and waste reduction performance scales met the conventional threshold of

Cronbach's alpha above 0.70. Quantitative data were analyzed using IBM SPSS 26 with descriptive statistics, Pearson's correlation analysis, and multiple linear regression to test the stated hypotheses. The qualitative phase consisted of in-depth semi-structured interviews with 12 company managers who were purposively selected to represent a variety of company profiles within the survey sample. The interviews were conducted in Indonesian, audio-recorded with the participants' consent, transcribed verbatim, and analyzed using NVivo 12 software through thematic analysis following the framework of Braun and Clarke (2006). The qualitative findings were used to contextualize and explain the quantitative results in a sequential explanatory manner Braun and Clarke (2006).

RESULT

The survey sample consisted of 87 furniture SMEs, of which 41.4% were classified as micro-enterprises (< 10 employees), 43.7% as small enterprises (10–49 employees), and 14.9% as medium-sized enterprises (50–249 employees). Most respondents (68.9%) produce teak furniture primarily for the export market. The average production experience is 16.3 years, indicating a mature manufacturing base, though one that remains largely traditional.

Table 1 summarizes the prevalence of waste reduction strategies identified among the surveyed companies. Lean manufacturing practices, particularly 5S workplace organization and just-in-time material procurement, were the most widely adopted, reported by 62.1% and 57.5% of respondents, respectively. Circular economy measures, such as collecting sawdust for energy and selling wood scraps to secondary processors, are practiced by 44.8% and 38.0% of companies, respectively. Formal environmental management systems (ISO 14001 or equivalent) remain rare, reported by only 8.1% of companies. The multi-item Likert-scale constructs used to derive the lean manufacturing, circular economy, and waste reduction performance scores in the regression analysis below all exceeded the conventional reliability threshold (Cronbach's alpha > 0.70), supporting the internal consistency of the measures.

Table 1. Prevalence of Waste Reduction Strategies Among Furniture SMEs in Jepara (n=87)

Waste Reduction Strategies	n	%
5S Workplace Organization	54	62,1%
Just-in-Time Material Procurement	50	57,5%
Optimized Cutting Plans (CNC/Manual)	47	54,0%
Reuse of Wood Offcuts for Secondary Products	43	49,4%
Collection of Sawdust for Energy/Sale	39	44,8%
Waste Awareness Training for Employees	36	41,4%
Sale of Wood Offcuts to Other Manufacturers	33	38,0%
Digital Production Planning System	21	24,1%
ISO 14001 / Environmental Management System	7	8,1%

Source: Primary data, 2026

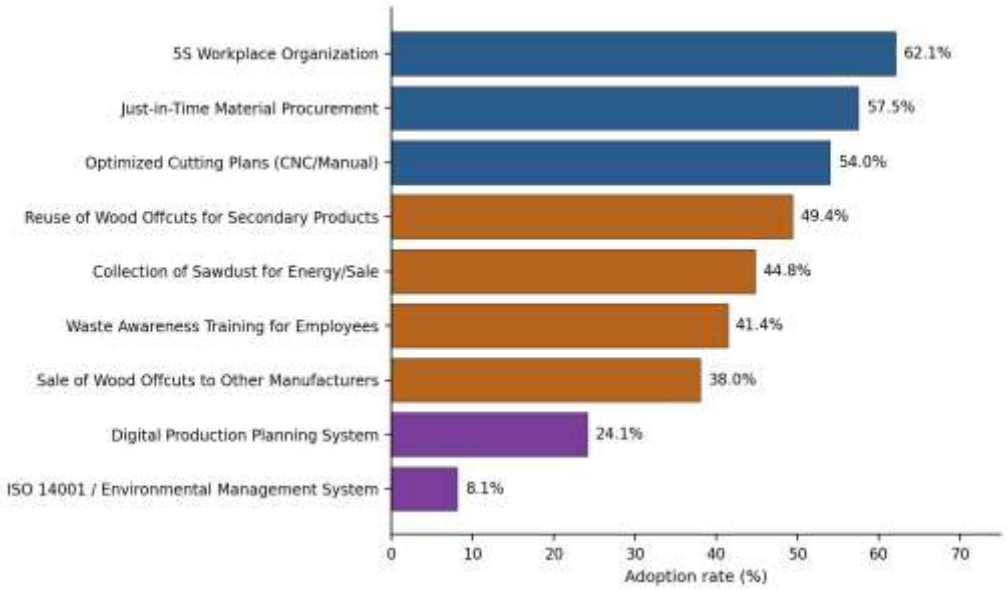

Figure 2. Adoption rates of waste reduction strategies among surveyed furniture SMEs (n = 87)

The results of the multiple regression analysis (Table 2) show that the adoption of lean manufacturing (β = 0.412, p < 0.001) and circular economy practices (β = 0.287, p < 0.01) are both significant positive predictors of waste reduction performance, accounting for 54.3% of the variance (R^2 = 0.543, F = 49.7, p < 0.001). The interaction term between lean practices and CE adoption was also significant (β = 0.198, p < 0.05), indicating a positive synergistic effect when the two approaches are combined.

Table 2. Multiple Regression Results: Predictors of Waste Reduction Performance

Variable	β	Std. Error	t-value	p-value
Constant	2,341	0,312	7,503	< 0,001
Lean Manufacturing (H1)	0,412	0,089	4,629	< 0,001
Circular Economy Practices (H2)	0,287	0,094	3,053	0,003
Lean × Circular Economy Interaction	0,198	0,076	2,605	0,011
Company Size (Control)	0,103	0,071	1,451	0,150
Years of Experience (Control)	0,076	0,065	1,169	0,246

Source: Primary data analysis, 2026. R^2 = 0.543, Adjusted R^2 = 0.521, F = 49.7 (p < 0.001)

In terms of measurable outcomes, companies with high lean implementation scores (top quartile) reported an average production waste ratio of 16.3%, compared to 38.7% for companies in the bottom quartile—a statistically significant difference (t = 8.34, p < 0.001). Cost savings from waste reduction programs averaged Rp 124.7 million per year for small businesses and Rp 487.3 million for medium-sized businesses.

DISCUSSION

The findings of this study provide strong empirical support for both hypotheses. The significant positive relationship between the adoption of lean manufacturing and waste reduction (H1 confirmed, β = 0.412, p < 0.001) is consistent with previous literature from the furniture manufacturing context in Brazil de Oliveira and Junior (2019) and Vietnam Quang (2025). 5S workplace organization and just-in-time purchasing—the most widely adopted lean tools in our sample—address fundamental sources of waste in wood processing: disorganized workspaces that lead to damage and material loss, as well as the purchase of large quantities of materials that create excess inventory and storage-related damage.

The significant contribution of circular economy practices (H2 confirmed, β = 0.287, p < 0.01) indicates that value recovery from wood residues—particularly through the energy conversion of sawdust and the sales network for wood scraps—is a meaningful complement to upstream waste prevention. These findings extend the theoretical work of Kutnar and Hill (2014) to the context of Indonesian SMEs, demonstrating that the principles of the circular economy are not exclusive to large integrated corporations but can be meaningfully implemented by traditional craft-based producers.

The significant interaction effect between lean practices and the circular economy (CE) is particularly noteworthy, indicating a synergistic dynamic in which companies that combine both approaches achieve waste reduction results that exceed what each approach delivers independently. This interaction may reflect the complementarity between prevention-oriented lean strategies, which minimize waste generation at the source, and recovery-oriented CE strategies, which extract maximum value from unavoidable residues. Future research should examine the mechanisms underlying this synergy in greater depth.

Qualitative interview data provide important contextual nuances to these statistical findings. Several managers emphasized that cultural factors within Jepara's traditional woodworking community both facilitate and constrain the adoption of waste reduction. On the one hand, a strong tradition of craftsmanship instills a deep respect for materials and values of craftsmanship that align naturally with waste-conscious production. On the other hand, resistance to formal management systems—including documented cutting plans and production scheduling—was noted as a barrier, particularly among the older generation of master craftsmen (empu), who prefer production methods based on intuition and experience.

Notably, neither company size ($\beta = 0.103$, $p = 0.150$) nor years of experience ($\beta = 0.076$, $p = 0.246$) emerged as significant predictors of waste reduction performance once lean manufacturing and circular economy adoption were accounted for. This suggests that, within the Jepara cluster, the decision to adopt waste-reducing practices is driven less by the resource advantages that typically accompany larger or more established firms and more by managerial commitment and cluster-level knowledge diffusion. Qualitative interviews support this interpretation: several micro-enterprise owners reported adopting 5S and cutting-plan optimization after observing neighboring workshops or receiving informal guidance through ASMINDO networks, rather than through formal capacity investments tied to firm size or tenure. This finding is consistent with prior lean-adoption research suggesting that in tightly clustered, artisan-based industries, social learning and peer imitation can substitute for the internal resources that larger firms would otherwise rely on, which helps explain why size and experience add little explanatory power beyond the two focal constructs.

The low adoption rate of formal environmental management systems (8.1%) reflects broader challenges in the sustainability of Indonesian SMEs: the gap between awareness and certified compliance. Although many companies practice informal waste reduction measures, translating these practices into a recognized environmental management framework requires institutional support, capacity building, and often external certification costs that are prohibitive for micro and small enterprises. Policy interventions targeting this gap—such as subsidized ISO 14001 audits for SME clusters—could substantially accelerate the adoption of formal sustainability practices in Jepara's furniture sector.

CONCLUSION

This study investigates waste reduction strategies at 87 furniture SMEs in the Jepara industrial cluster, Central Java, Indonesia. The findings show that lean manufacturing practices and the circular economy approach are both significant positive predictors of waste reduction performance, with a synergistic interaction effect when combined. Companies in the top quartile of lean implementation achieved a production waste ratio of 16.3%, compared to 38.7% in the low-lean group, representing cost savings of up to Rp 487 million per year for medium-sized businesses.

Theoretically, this study extends Lean Manufacturing theory and Circular Economy theory by demonstrating that their combined explanatory power exceeds what either framework achieves independently in an SME cluster setting. Whereas prior lean manufacturing research has centered on internal process efficiency within individual firms, and circular economy scholarship has emphasized resource-recovery flows at the level of large corporations or supply chains, this study shows that the two frameworks interact synergistically even among resource-constrained, artisan-based micro and small enterprises. The significant interaction effect between lean adoption and circular economy practices suggests that these are not competing but complementary strategies for waste governance—lean principles curb waste at the point of generation, while circular economy practices recover value from what remains—and that this complementarity operates at the cluster level through mechanisms such as industrial symbiosis, not merely within single firms. By showing that company size and years of operation do not independently predict waste reduction outcomes once these two practice bundles are accounted for, the study also nuances resource-based views of SME sustainability, indicating that managerial adoption behavior and cluster-level knowledge diffusion can substitute for the internal resource advantages that larger or more established firms typically hold.

This study has several practical implications. For SME owners and managers, the findings highlight 5S workplace organization, optimized cutting plans, and disciplined material procurement as high-impact, low-cost entry points for waste reduction programs. For industry associations such as ASMINDO Jepara, the results point to opportunities for cluster-level waste management infrastructure, including a collective wood-offcuts trading platform and shared sawdust processing facilities, which leverage cluster economies to address the resource constraints of individual SMEs. For the government, the data supports targeted investments in SME capacity-

building programs that integrate lean tools and circular economy principles within the existing Indonesian Green Industry certification framework.

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