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RESEARCH ARTICLE

Tool for Evaluating the Level of Circularity in Peruvian Micro and Small Enterprises

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Abstract

This study aimed to develop and validate an analytical tool for assessing the circularity level of Micro and Small Enterprises (MSEs), applying it to five businesses located in the district of Independencia, Peru, in 2023. The research employed an applied experimental design, integrating both qualitative and quantitative approaches to ensure a comprehensive evaluation.

Data collection involved the use of surveys, interviews, and geocoding to accurately identify and characterize the selected MSEs. The instruments included closed and open-ended questionnaires, methodological templates, and digital tools such as ArcMap 10.8 and Microsoft Excel for spatial and statistical analysis. The sample consisted of five intentionally selected MSEs from key economic sectors: automotive, furniture manufacturing, food services, and hospitality.

The outcome of the research was a tailored, easy-to-use circularity assessment tool specifically designed for the context of MSEs. The tool not only enabled the evaluation of circular practices across four strategic domains—product, supply chain, internal operations, and governance—but also guided the implementation of actionable circular economy strategies. Its application resulted in measurable improvements in operational efficiency, resource use, waste reduction, and sustainability engagement, contributing to enhanced competitiveness and innovation capacity within the participating MSEs.

Keywords Circular Economy Strategies · Micro and Small Enterprises · Circularity Assessment · Sustainability Tools · Small Business Sustainability

Introduction

This study aims to explore the challenges and opportunities faced by Micro and Small Enterprises (MSEs) in the district of Independencia, Peru, as they transition from a linear economic model to a Circular Economy (CE) approach. In the context of the MSEs in Independencia, business practices predominantly follow a linear economic model, characterized by the extraction, production, and disposal of waste without a systematic focus on sustainability. This model leads to inefficiencies in resource use, increased waste generation, and environmental degradation, which is particularly concerning in key sectors such as automotive, furniture manufacturing, and food and hospitality services.

Although the concept of Circular Economy (CE) has gained global relevance, its adoption among MSEs in Peru has been limited due to structural barriers such as the lack of technical knowledge, scarce resources, and

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the absence of measurement tools tailored to their specific needs. MSEs represent a significant portion of the Peruvian economy; however, despite their prevalence, they contribute a reduced share to total national sales, highlighting the challenges of accessing innovation and sustainable technology in these sectors.

This study focuses on the MSEs in the district of Independencia, with the aim of developing and validating a circularity assessment tool that allows these enterprises to measure and improve their level of integration of circular practices. What is novel about this approach is the creation of a methodology specifically designed for the local context of these businesses, which not only adapts to the reality of the studied sectors but also establishes a simple and practical evaluation system that facilitates the implementation of circular strategies in MSEs with limited resources. Unlike existing tools such as Circulytics or BS 8001, which are primarily aimed at large enterprises or industrial contexts, this tool is designed to be accessible and useful in the context of small Peruvian businesses, contributing to their transition towards more sustainable business models.

This approach provides an original contribution by addressing the lack of specific circularity indicators for MSEs in Peru and contributes to the development of a replicable methodological framework that can be used by other MSEs in similar contexts, promoting the inclusion of sustainability in local business strategies.

Theoretical Framework and State of the Art

The Circular Economy (CE) is an emerging concept that contrasts with the traditional linear economic model, characterized by the "take, make, dispose" pattern. The linear model leads to inefficient resource use, excessive waste generation, and environmental degradation (BSI Group, 2017). In contrast, CE proposes a sustainable framework that reduces waste, minimizes resource consumption, and addresses environmental externalities, aiming to create closed-loop systems where materials and resources are continuously reused (Kravchenko *et al.*, 2020). While CE has gained global recognition as a viable alternative to linear models, its adoption, particularly among Micro and Small Enterprises (MSEs), remains limited, especially in Latin America, where studies focusing on small businesses are still scarce (James *et al.*, 2023).

In Peru, MSEs represent a significant portion of the economy, constituting 96.4% of all businesses in the country, operating predominantly in services, commerce, and production sectors (INEI, 2022; COMEXPERU, 2023). Despite their prevalence, MSEs contribute only 5.6% of total sales, highlighting challenges related to resource access, innovation, and sustainable practices. These challenges, coupled with limited resources, simplified organizational structures, and a lack of expertise, hinder the adoption of CE practices, impacting the long-term sustainability and competitiveness of these enterprises (COMEXPERU, 2023). The adoption of CE in Peruvian MSEs is therefore crucial, and the development of localized tools and strategies is needed to assist these businesses in transitioning to circular models.

Recent literature on CE has predominantly focused on large enterprises in industrialized countries, leaving a gap in studies related to MSEs in developing countries. The research by Ortiz (2019) on the implementation of CE in small businesses in Cali, Colombia, found that the level of circularity in the studied enterprises was intermediate. This highlights that while CE adoption is advancing, there is still much work to be done to integrate it fully into business practices, especially for small enterprises in similar contexts. Ortiz's findings underscore the importance of evaluating and promoting CE in local contexts, where businesses face specific barriers related to resources and expertise.

In terms of measuring CE effectiveness, Rodríguez *et al*. (2022) proposed a Cost Minimum Consensus Model (CMCC) for large-scale group decision-making on circular economy measurement. Their research compared the CMCC with the traditional Delphi method, finding the CMCC to be more efficient and cost-effective for measuring CE practices in large groups. This model provides an alternative, efficient method for evaluating CE, contributing to the broader implementation of circular models across industries.

Additionally, Elba *et al*. (2021) developed the Ecopyme methodology, a step-by-step guide designed for industrial SMEs to adopt CE. This methodology, consisting of five iterative steps—identity, diagnosis, planning, implementation, and evaluation—emphasizes the importance of human commitment and value creation in successfully transitioning to CE. Their study revealed the need for practical methodologies that can

help guide SMEs through the adoption process. Similarly, Romero (2021) proposed a systemic planning methodology for implementing sustainable processes through CE in organizations in Mexico City, highlighting the importance of transforming business visions and production processes to align with circular practices.

The literature also identifies key strategies for implementing CE. Salvador *et al*. (2021) identified three influential strategies for business modeling in CE: i) the circularity strategy of companies, ii) engaging key actors throughout the value chain, and iii) utilizing digital technologies such as Industry 4.0. These strategies significantly influence business operations and relationships with clients and key alliances, demonstrating that a combination of business strategy and technological innovation is crucial for the successful adoption of CE.

At the national level, Peru has begun to incorporate CE principles into its policies. The National Competitiveness and Productivity Plan (2019) promotes sustainability and a transition toward circular models in various sectors, including industry, fishing, and agriculture (Soto Velásquez, 2022). However, challenges remain in fully implementing CE practices across all industries. Initiatives such as the "Tu Empresa" program launched by the Ministry of Production in 2017 aim to assist MSEs in adopting sustainable practices. Yet, the need for more robust policies and localized strategies remains a priority, ensuring the full integration of CE into the Peruvian business ecosystem.

The proposed analysis tool to measure the circularity of MSEs in Independencia stands out for its specific focus on these businesses, adapting to the local conditions of the Independencia district in Lima, Peru. Unlike methodologies such as Circulytics and BS 8001, which are primarily aimed at larger companies and do not fully address the local context, the new tool integrates four key dimensions: products/services, supply chain, business practices, and governance, with the latter being an aspect not included in other methodologies. Governance captures the influence of policies, regulations, and participation in collective initiatives, which are crucial for promoting circularity in the local context.

In contrast, Circulytics 2.0 focuses on large companies and requires detailed data, making its implementation in MSEs more challenging. On the other hand, the BS 8001:2017 Standard provides general principles without offering a quantitative measurement tool for circularity levels. The proposed tool fills this gap, providing a quick qualitative assessment through a 15-question questionnaire, suitable for local MSEs, allowing the evaluation of circularity levels without the need for external assistance. In this way, it is better suited to the conditions of MSEs, integrating international practices in an accessible and effective manner.

Methodology

Study Design

The study employed an applied experimental design with a mixed-methods approach. This design was chosen to test and refine a circular economy (CE) assessment tool in real business contexts, focusing on practical implementation rather than theoretical simulations. Within the applied experimental framework, the assessment tool was introduced and used within each participating Micro and Small Enterprise (MSE) as an intervention to solve practical problems (e.g., improving resource efficiency). A combination of qualitative and quantitative methods was used to ensure a comprehensive evaluation of each MSE's performance in terms of circularity. The mixed-methods approach allowed for the capture of numerical indicators of circularity while contextualizing them with detailed qualitative insights, thereby strengthening the robustness of the findings.

Selection of MSEs and Inclusion Criteria

The research was conducted in the district of Independencia, Lima, Peru (Figure 01), focusing on five MSEs that met predefined inclusion criteria. These five enterprises were selected through convenience (intentional) sampling, a non-probabilistic approach suitable for this type of exploratory and applied study. The inclusion criteria for selecting the MSEs were as follows:

1. Prior commitment to sustainability: Each MSE had demonstrated involvement in sustainability or circular economy initiatives prior to the study. This criterion ensured that the companies had baseline knowledge and interest in circular practices, making them suitable candidates for implementing the CE assessment tool.
2. Availability of operational data: The MSEs maintained accessible operational data relevant to circular economy assessment (e.g., records of material use, waste generation or recycling, energy consumption). This ensured that the quantitative analysis was grounded in real data.
3. Representation of diverse sectors: The sample collectively represented a variety of industrial sectors to capture different operational contexts, including an automotive services provider, carpentry/furniture manufacturing workshops, a food service establishment (restaurant), and a hospitality business (lodging). Engaging multiple sectors helped assess the tool's applicability across different MSE activities.

All selected enterprises voluntarily participated. Table 01 details the main characteristics of these MSEs, including those engaged in material production and others providing services that involve material use. While the sample was small and not statistically representative, it was intentionally chosen to ensure rich, relevant data. Each enterprise provided informed consent to participate and provide information, in accordance with ethical research practices.

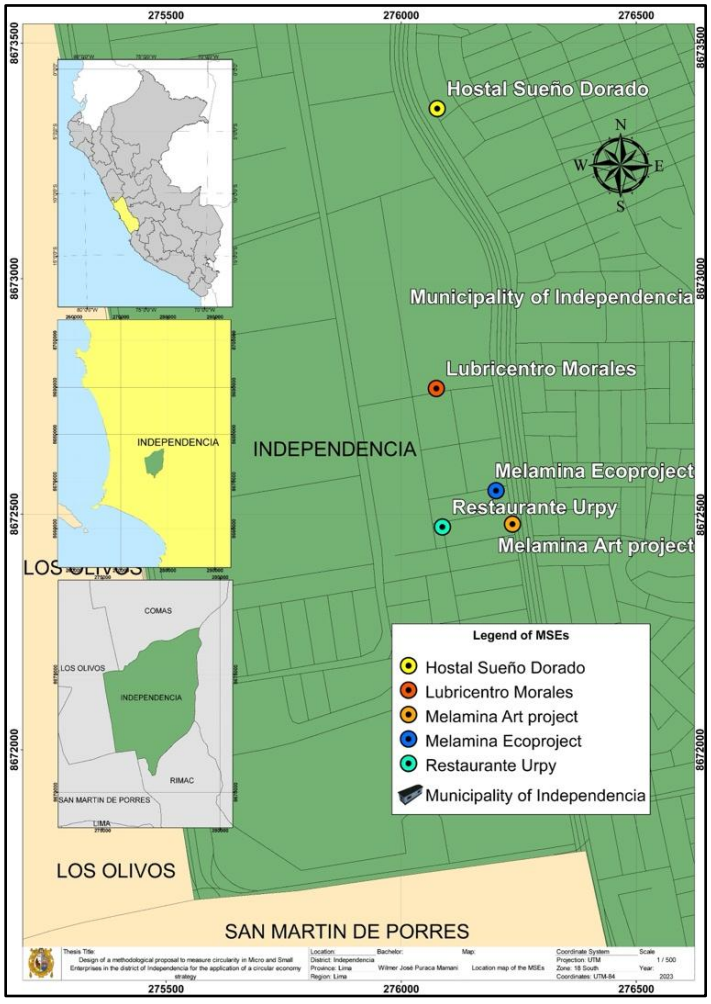

Figure 1 Spatial Location Map of the MSEs

Table 1 Characteristics of MSEs in the Study Area

Sector	Name	Production/Service	MSE Type	Number of MSEs
Automotive	Servicentro Morales	Auto services	Services with materials	1
Carpentry	Art. Perú	Production and sale of melamine furniture	Production of materials	2
	EcoProject	Production and sale of melamine furniture	Production of materials	
Food	Restaurante Urpy	Menus and delivery	Services with materials	1
Hospitality	Sueño Dorado	Accommodation services	Services with materials	1

Data Collection Procedures

Aligned with the mixed-methods design, data collection combined qualitative techniques—semi-structured interviews and document analysis—with quantitative measurement using a structured questionnaire.

Qualitative Data: Semi-structured interviews were conducted with key informants from each MSE, typically the owner or manager. The interviews, lasting 45 to 60 minutes, explored resource use, waste management, product lifecycle considerations, and attitudes toward sustainability. Additionally, internal documents such as waste logs, procurement records, and sustainability reports were reviewed to verify and complement the interviews. These materials enabled a contextual understanding of the sustainability practices of each enterprise.

Quantitative Data: A structured questionnaire of 15 Likert-scale items (1–5) was administered to each MSE to assess their circularity practices. The items were grouped into four dimensions: (1) Products/Services, (2) Supply Chain, (3) Internal Business Practices, and (4) Governance and Strategy. Each item captured specific circular practices, and participants were also encouraged to provide brief open-ended comments to clarify their responses. The use of standardized scoring enabled the quantification of circularity performance across all MSEs.

Analytical Tool Development

An analytical tool to assess circularity was developed, informed by international frameworks such as Circulytics, BS 8001, the CTI Tool, and MITECO guidelines. To this end, a comprehensive review of existing circular economy tools and guides was conducted (Table 02). Key principles and guidelines were extracted from this analysis, synthesized and categorized using a two-way table of conceptual similarity analysis (Table 03).

These principles were operationalized in closed-ended questionnaire questions (Table 04), each with a numerical score, and the resulting dimensions were weighted according to their relevance (e.g., distinguishing enabling factors from tangible outcomes). The weighting methodology was based on the Circulytics model by Ellen MacArthur Foundation (2020b), which evaluates both the "enablers" of change and tangible outcomes. Enablers assess the company's capacity to adapt to a circular economy model, while outcome indicators evaluate material and water flows, product and service design, asset and equipment management, and energy consumption.

The weighting values and the procedure for calculating the percentages corresponding to the categorized questions are illustrated in Figure 02. The final product was a closed-ended questionnaire with quantitative weightings to measure the level of circularity of MSEs.

Table 2 Circularity Tools

Tool	Author	Methodology Characteristics
CTI Tool V3.0	World Business Council for Sustainable Development (WBCSD)	Focuses on the product and material flow, helping companies prioritize circular strategies based on their circularity performance.
Circulytics 2.0	Ellen MarcArthur Foundation	Focuses on material flow performance and organizational aspects to guide the implementation of a circular economy strategy.
BS 8001	BS 8001: 2017 Standard	Applicable for the development of the implementation of a circular economy strategy in an organization.
Circular economy toolkit	Cambridge University	Applicable for organizations that are just starting, focusing largely on the product.
Good Practices in Circular Economy	Ministry for Ecological Transition and the Demographic Challenge - MITECO - Spain	It measures an organization based on the scope of action and the respective minimum circularity criteria, incorporating product, supply chain, company, and governance.
Morató *et al.* (2017)	Morató *et al.* (2017)	It proposes circular economy principles for building indicators that define progress in improving production and consumption efficiency in Europe.
Velenturf and Purnell (2021)	Velenturf and Purnell (2021)	It proposes circular economy principles that enable the implementation of a "sustainable" circular economy, while having harmful impacts on the environment and society when implemented.

Table 3 Filter of Circular Economy Principles and Guidelines

Ellen MarcArthur Foundation	World Business Council for Sustainable Development (WBCSD)	BS 8001: 2017 Standard	Circular economy toolkit (2013)	Morató et al. (2017)	Velenturf and Purnell (2021)	MITECO - Spain (2021)	Eligible Guidelines
Eliminate Waste and Pollution Through Design	Reduced Use of Materials		Material Reduction	Waste Prevention Design	Design for Circularity		Design for circularity (use of low environmental impact materials, longer lifespan)
	Durability		Extended Product Lifespan				
		Value optimization	Optimize Materials	Performance- Focused Approach	Reduce and Decouple Resource Use		Material optimization
				Building Resilience Through Diversity	Leverage Diversity to Develop a Plurality of Solutions		Building resilience through diversity
				Systems Thinking	Evaluation of the Entire System	Sistemic and Holistic Thinking	Evaluation of the entire production system
Keeping Products and Materials in Use	Optimal Reuse		Reuse / Redistribute	Cascade Thinking		Closing the Lifecycle (Reuse, Repair,	Minimize waste and close the life cycle (reuse, repair,

	Refurbishment / Replacement		Restore / Remanufacture			Remanufacture, Recycle)	remanufacture, recycle)
	Repair		Maintenance / Repair				
			Product Recycling	Waste is Food			
			Product as a Service		Transform Consumption		Product as a Service
		Collaboration	Industrial Symbiosis				Industrial Symbiosis
Regenerate Natural Systems					Beneficial reciprocal resource flows between nature and society	Rethink/Regenerate	Regenerating Natural Systems
				Use of Renewable Energy		Optimize	Energy Use Optimization
		Impact Management				Responsabilty for impacts	Responsibility for Impacts
	Update / Renewal	Innovation			Innovative Circular Business Models	Innovate and Virtualize	Innovate, Modernize, and Virtualize
		Transparency				Communication and Transparency	Communication and Transparency
					Citizen Participation in Sustainable Transitions		Citizen Participation in Sustainable Transitions
				Local Thinking	Coordinated, Participatory Change Among Multi-Level Actors	Share and Collaborate	Coordinated and Participatory Change Among Stakeholders Across Multiple Levels
					Political Economy for Multidimensional Prosperity		Political Economy for Multidimensional Prosperity

Table 4 Circularity evaluation questionnaire

Category	N°	Guideline Questions to Evaluate Circularity
Product	1	Are the (products) / (materials used to provide the service) made of ecological materials and designed to maximize their lifespan?
	2	Were the (products) / (materials used to provide the service) created using the minimum amount of materials and inputs?
	3	Can the (products) / (materials used to provide the service) perform multiple functions?
Supply Chain	4	Do you consider it important to know the origin and final destination of materials and equipment?
	5	Do you engage in practices to minimize waste generation and close the life cycle of products (reuse, repair, remanufacture, recycle)?
	6	Do you supply or source materials or waste from nearby companies?
Company	7	Do you rent your products instead of selling them?
	8	Do you carry out composting, tree planting, or similar practices?
	9	Do you optimize energy use?
	10	Do you have a strategic plan that integrates responsibility for impacts and business decisions?
	11	Have you implemented innovative, modern, or digital practices?
	12	Do you clearly, honestly, and comprehensively communicate your circular practices, challenges, and barriers to employees, customers, and suppliers?
	13	Do you involve customers and suppliers in the company's strategic decisions?
Governance	14	Do you participate in spaces that promote the circular economy, involving actors such as the government, society, businesses, and academia?
	15	Do you believe we have regulations that foster a circular economy to achieve environmental, social, and economic prosperity?

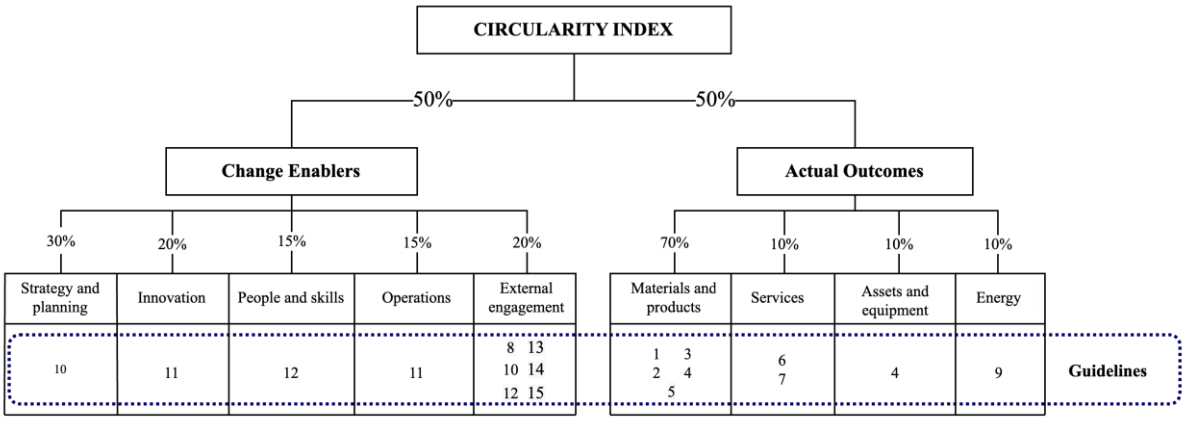

Figure 2 Weighting Values and Percentages by Questionnaire Item

Source: Ellen MacArthur Foundation (2020c)

Data Analysis

Qualitative Analysis: Interview transcripts and document review notes were analyzed using thematic content analysis. Open coding identified key circularity-related themes, which were grouped into broader categories such as waste minimization, supply chain barriers, and leadership engagement. These themes contextualized the quantitative findings, particularly where low scores revealed structural or operational barriers.

Quantitative Analysis: Likert-scale responses were statistically analyzed to compute mean scores per item and per dimension. Dimensional scores were weighted based on local relevance and literature emphasis. A global circularity score per MSE was derived by summing the weighted dimension scores, normalized to a 1–5 scale. Triangulation between qualitative and quantitative data validated and enriched the findings, with convergence enhancing confidence and divergence prompting deeper review.

Additionally, the interpretation of the results was enhanced by applying SWOT and CAME analyses, which allowed for the identification of strengths, weaknesses, opportunities, and threats in terms of sustainability and the definition of corrective or improvement actions.

The CAME matrix complemented the SWOT analysis by translating its findings into actionable strategies—Correcting weaknesses, Addressing threats, Maintaining strengths, and Exploring opportunities. In this study, the matrix was applied after the SWOT analysis of each micro and small enterprise to formulate targeted circular economy initiatives. This enabled the design of measures to overcome internal limitations, respond to external risks, preserve existing capabilities, and leverage emerging market opportunities. The inclusion of the CAME matrix provided a clear framework for continuous improvement and helped align analytical insights with managerial decision-making, facilitating the systematic implementation of circular practices within the participating enterprises.

This integrative approach ensured rigor, clarity, and practical relevance in evaluating how each MSE embodies circular economy principles in their operations. The final output consisted of a detailed profile of circularity performance for each MSE and insights for improvement.

Circular Economy Implementation Strategy

To implement circular economy (CE) actions in micro and small enterprises (MSEs), a systematic strategy was followed, divided into key steps (Figure 03).

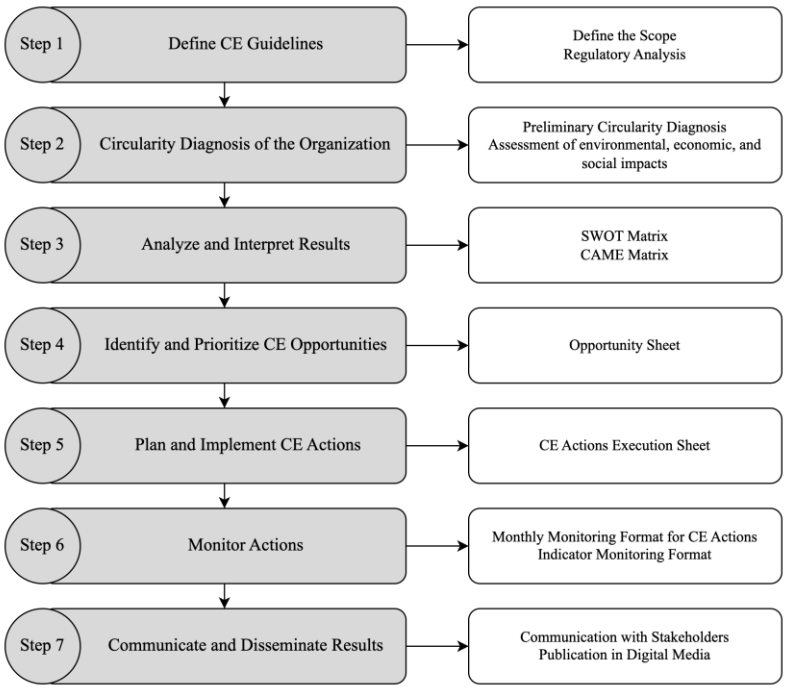

Figure 3 Seven- Step Circular Economy Strategy

The main steps are summarized below:

Definition of CE Guidelines: Relevant circular economy guidelines were established through a scope analysis (macro, meso, and micro levels) and regulatory review. This involved examining how regulations and sectoral dynamics affect circularity and prioritizing the guidelines with the highest potential impact within the organization.

Circularity Diagnosis: The current level of circularity of each organization was assessed. This included a preliminary diagnosis using the structured questionnaire developed (Table 04) and the calculation of basic indicators. In addition, a qualitative environmental impact assessment was conducted using the MET matrix, identifying flows of materials, energy, and waste at each stage of the product/service life cycle. This diagnosis integrated environmental, economic, and social aspects through a SWOT-CAME analysis.

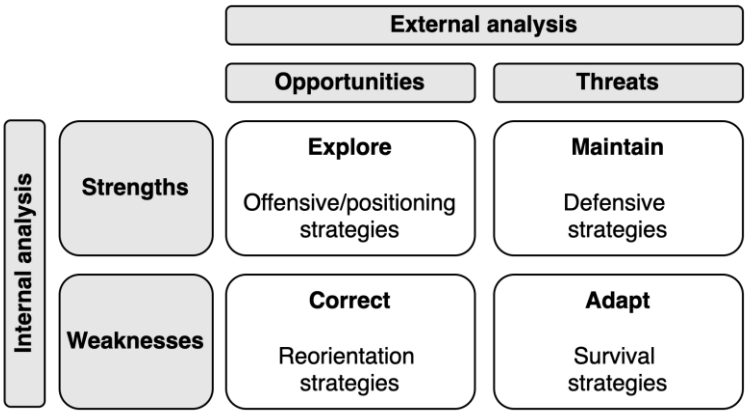

Figure 4 CAME Methodology

Source: Arnedo-Lasheras et al. (2020a)

Analysis and Interpretation of Results: The diagnosis findings were analyzed using a SWOT matrix to identify strengths, weaknesses, opportunities, and threats aligned with sustainability. Subsequently, the CAME method (Figure 04) was applied to define specific actions to correct weaknesses, mitigate threats, maintain strengths, and capitalize on opportunities, thereby supporting strategic decision-making.

Identification and Prioritization of Improvement Opportunities: Based on the diagnosis and analysis, an "opportunity sheet" was completed (Table 05), detailing for each company the recommended actions, necessary resources, expected impacts, and key stakeholders. These opportunities were formulated in accordance with circular economy guidelines and prioritized according to their feasibility and environmental, social, and economic impact.

Planning and Implementation of Circular Actions: Meetings were held with business owners to validate the environmental and economic feasibility of the proposed actions. Each approved action was recorded in a structured format During this phase; a detailed work plan was developed to implement circular measures in the MSEs' daily operations.

Monitoring of Implemented Actions: A monthly monitoring format was defined and customized indicators were established for each action. These indicators (social, environmental, and economic) enabled the evaluation of progress in the implemented actions, focusing on their positive contribution to triple-bottom-line impact. This stage ensures continuous monitoring and the adoption of corrective measures if necessary.

Communication and Dissemination: Finally, a communication plan was developed to share the results and insights with workers, customers, suppliers, and other stakeholders. This dissemination phase aims to foster transparency, feedback, and the broader adoption of circular practices, thus consolidating the efforts made.

Each of these steps was grounded in academic references and practical circular economy guidelines, ensuring a methodical and coherent process. Overall, the strategy enabled MSEs to systematize the implementation of circular economy, from goal definition to result monitoring, ensuring methodological rigor and applied relevance at each stage.

Table 5 Opportunity Sheet Format

Category	Question to Evaluate Circularity	Yes / No	Main Actions to Execute	Resources Used	Expected Impacts	Key Stakeholders
Product	Are the materials used for the service made from eco-friendly materials and designed to maximize their lifespan?					
	Were the materials used for the service produced with the least amount of materials and inputs?					
	Can the materials use for the service perform more than one function?					
Supply Chain	Do you consider it important to know the origin and final destination of materials and equipment?					
	Do you implement practices to minimize waste generation and close the product life cycle (reuse, repair, remanufacture, recycle)?					
	Do you supply or source material or waste from nearby companies?					
	Do you rent your products instead of selling them?					
	Do you implement composting, tree planting, or similar practices?					
	Do you optimize energy use?					
	Do you have a strategic plan that integrates the responsibility of business impacts and decisions?					
	Have you implemented innovative, modern, or digital practices?					
	Do you communicate your circular best practices, challenges, and barriers to employees, customers, and suppliers clearly, honestly and completely?					
	Do you involve customers and suppliers in the company´s strategic decisions?					
Governance	Do you participate in spaces that promote the circular economy where actors such as government, society, businesses and academia are involved?					
	Do you consider that there are regulations that promote the circular economy to achieve environmental, social and economic prosperity?					

Results

Regulatory Context and Circularity Guidelines

The study focused on the application of CE in micro and small enterprises (MSEs), prioritizing process optimization, waste reduction, and resource efficiency. A regulatory analysis was conducted to identify relevant regulations and anticipate future modifications impacting businesses. The importance of adapting to new regulations was highlighted to strengthen the competitiveness and sustainability of MSEs. In Table 06, the main regulations that indicate legislative trends aligned with the circular economy (CE) in the Peruvian context were identified.

Table 6 Peruvian Regulatory Analysis on Circular Economy

Approval Date	Regulation
23/12/2016	Legislative Decree No. 1278, which approves the Integral Solid Waste Management Law and its amendment, Legislative Decree No. 1501.
19/12/2018	Law No. 30884, Law regulating single-use plastics and disposable containers or packaging, and its Regulation, Supreme Decree No. 006-2019-MINAM.
31/12/2018	Supreme Decree No. 345-2018-EF, National Competitiveness and Productivity Policy.
28/07/2019	Supreme Decree No. 237-2019-EF, National Competitiveness and Productivity Plan.
19/02/2020	Supreme Decree No. 003-2020-PRODUCE, Roadmap towards a Circular Economy in the Industrial Sector.
05/03/2020	Supreme Decree No. 005-2020-PRODUCE, which approves the National Strategy for the Development of Industrial Parks.
02/06/2023	Supreme Decree No. 006-2023-PRODUCE, which approves the Priority Lines of the Production Sector "Peru Produce".
21/06/2023	Supreme Decree No. 007-2023-PRODUCE, which approves the Green Finance Roadmap for Peru.
16/12/2023	Supreme Decree No. 011-2023-PRODUCE, which approves the Roadmap towards a Circular Economy in the Fisheries and Aquaculture Subsectors
16/07/2021	Ordinance No. 2367-2021, Ordinance that incorporates circular economy principles into local management (applicable only to the Metropolitan Municipality of Lima).

Baseline Circularity Assessment and Impact Analysis

The degree of implementation of circular practices was assessed through questionnaires and analyses of environmental, economic, and social impacts. The initial diagnosis revealed heterogeneous levels of circularity among the five MSEs (Figure 05).

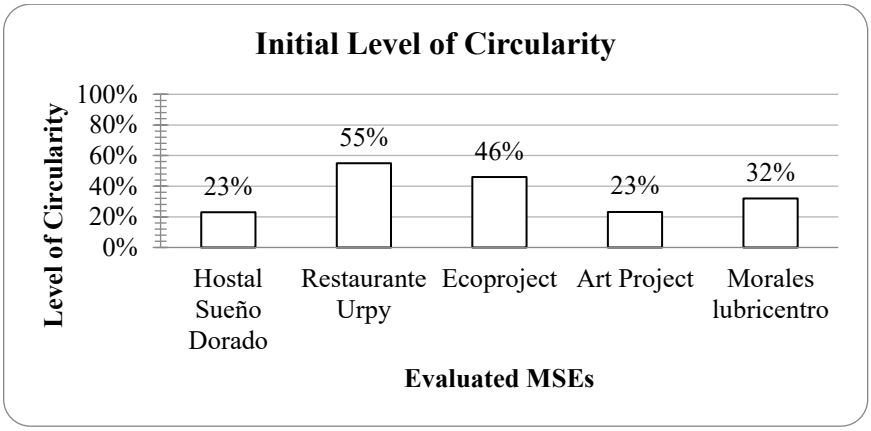

Figure 5 Initial Level of Circularity of MSEs

Ecoproject and Restaurante Urpy displayed the highest circularity scores, attributed to their prior experience in sustainability projects and proactive management. Conversely, Art Project and Morales Lubricentro presented lower levels, largely due to limited resource availability, fragmented governance structures, and low awareness of CE principles.

It was identified that materials with the highest environmental impact (Figure 06) come from petroleum derivatives and synthetic chemicals, whereas those with the lowest impact originate from natural resources or have an extended lifespan.

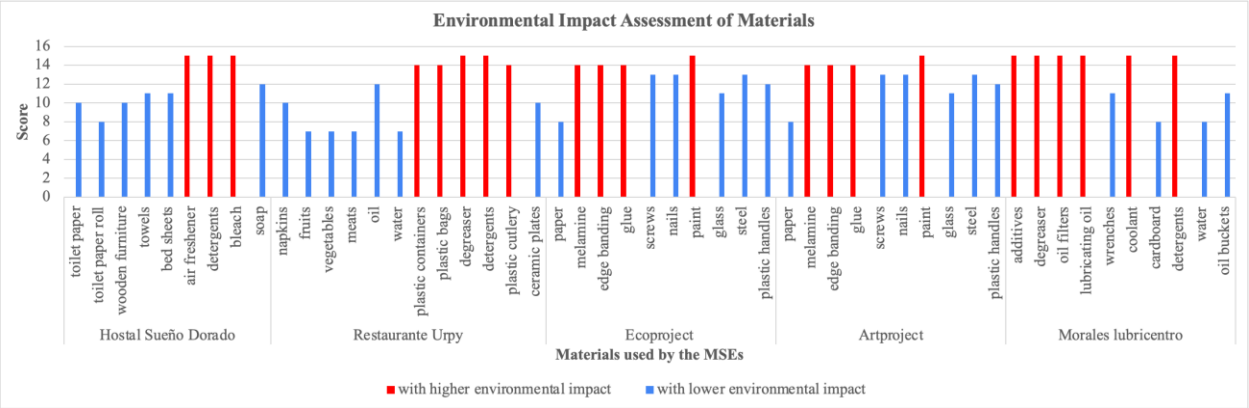

Figure 6 Environmental Impact Assessment of Materials

In economic terms (Figure 07), the highest concentration of costs is found in the manufacturing stage, which clearly suggests opportunities for circular optimization through strategies such as product redesign, improvements in energy efficiency, the use of recycled materials, and the implementation of clean technologies. These actions could not only reduce operational costs but also increase the competitiveness of MSEs.

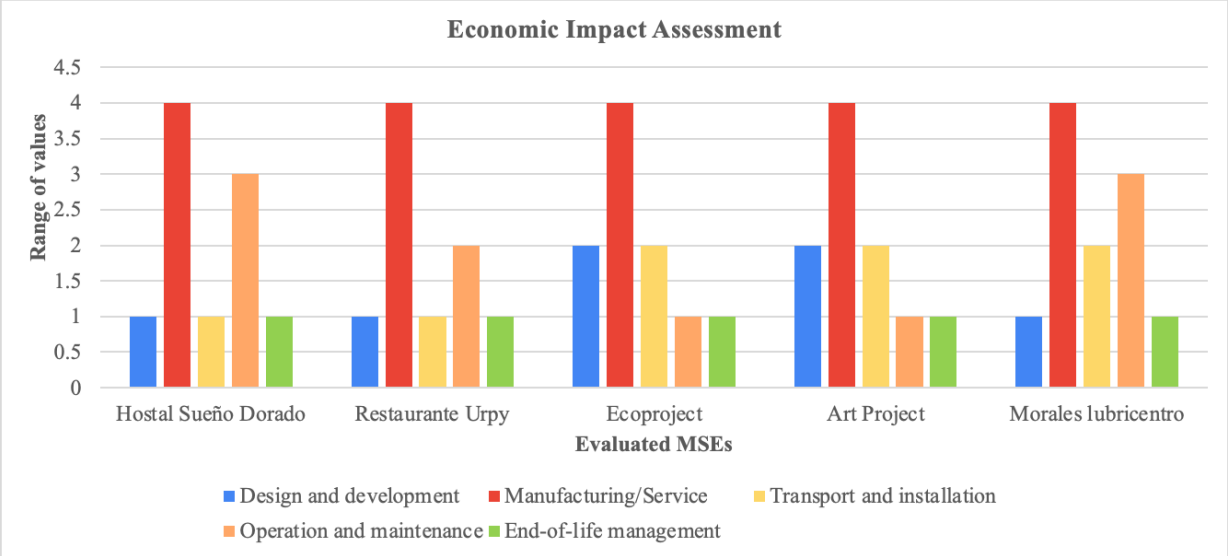

Figure 7 Economic Impact Assessment

Regarding social aspects (Figure 08), the main concerns are related to working conditions and occupational risks in production and maintenance stages. This highlights the need to strengthen occupational health and safety measures, as well as to promote fairer and safer work environments. The circular economy, by encouraging cleaner and more efficient processes, can indirectly contribute to reducing these risks and improving employee well-being, aligning environmental sustainability with corporate social responsibility.

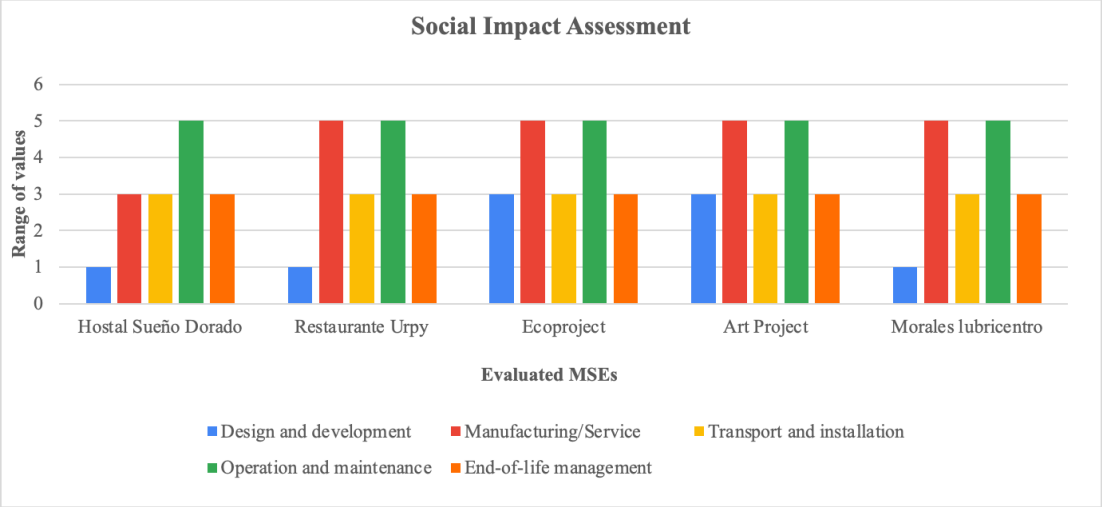

Figure 8 Social Impact Assessment

SWOT analysis and Strategic Interpretation

The CAME Matrix and the Opportunity Sheet were used to analyze internal strengths and weaknesses, as well as external threats and opportunities. This allowed for the identification of strategic actions to improve circularity in MSEs.

To deepen the interpretation of findings, a SWOT matrix was constructed (Table 07), synthesizing internal and external factors affecting CE adoption.

Table 7 SWOT Matrix of MSEs in Circular Economy Implementation

Strengths	**Weaknesses**
Prior participation in sustainability programs	Lack of technical expertise on CE
Entrepreneurial openness to innovation	Limited financial resources
Basic environmental compliance already in place	Weak internal planning and data management
Opportunities	**Threats**
Existence of CE-friendly public policies	Regulatory complexity and low clarity of incentives
Access to CE support networks and pilot initiatives	Market pressure favoring short-term profits
Growing consumer interest in sustainable products	Supplier inertia and resistance to change

From this matrix, the CAME analysis was applied to define improvement strategies: correcting internal weaknesses (e.g., through training and technical assistance), confronting external threats (e.g., regulatory barriers) via improved advocacy, maintaining strengths (e.g., participatory culture), and exploiting opportunities (e.g., joining CE platforms). These strategic directions were then operationalized through tailored circular actions for each MSE (Table 08).

Table 8 Validated Practices for Their Execution

N°	**MSE**	**Number of CE Actions Implemented**	**Circular Economy Actions Implemented**
1	Hostal Sueño Dorado	8	Use of eco-friendly detergents Replacement of plastic bags for storing towels with PVC baskets Reuse of soaps Installation of water-saving faucets and dual-flush toilets Commercialization of inorganic waste Use of LED bulbs with motion sensors

			Participation in local CE projects Training in strategic planning
2	Restaurante Urpy	10	Use of natural detergents Replacement of single-use plastic bags with bioform containers Change of extractor hood filter Maintenance of the natural gas kitchen Standardization of ingredient quantities in meal preparation Replacement of a pot that generated waste Installation of motion-sensor LED bulbs and solar panels Installation of water-saving faucets and dual-flush toilets Participation in local CE projects Training in strategic planning
3	Ecoproject	10	Production of modular products Training in eco-design Minimization of plastic packaging and wrapping Reuse of melamine waste from own production and other SMEs in the same sector Installation of water-saving faucets Installation of solar panel reflectors Maintenance of cutting and edge-banding machines Promotion of products at CE fairs Participation in local CE projects Training in strategic planning
4	Art Project	6	Production of modular products Reuse of melamine waste Installation of water-saving faucets Installation of solar panel reflectors Maintenance of cutting and edge-banding machines Training in strategic planning
5	Morales Lubricentro	7	Implementation of waste storage and recovery Maintenance of washing equipment Installation of solar panel reflectors Roof replacement for better natural lighting Installation of water-saving faucets Participation in local CE projects Training in strategic planning

Implementation and Monitoring of Circular Actions

During the monitoring of five micro and small enterprises (MSEs), varying levels of staff engagement in circular economy (CE) actions were observed, with participation rates ranging from 40% to 100%. On average, 74% of workers were actively involved, and companies with higher participation levels implemented a greater number of CE actions. This highlights the crucial role of workforce commitment in the effective implementation of sustainable practices.

Regarding environmental indicators, companies proposed between 10 and 13 CE actions and successfully implemented between 6 and 10 (Table 08), achieving an average implementation rate of 67%. The most common actions focused on waste reduction and valorization, resource efficiency, and improvements in internal management. The results suggest that the successful adoption of environmental measures is closely linked to internal cohesion and organizational capacity. Economically, four out of five MSEs achieved some level of monthly cost savings, and two of them reported significant increases in profitability, demonstrating that sustainable practices can also generate tangible short-term economic benefits.

Communication and Final Evaluation

The findings were presented at an in-person event and further disseminated through social media platforms. A clear increase in the circularity levels of the MSEs was observed, as evidenced by improvements in resource efficiency, waste reduction, and the adoption of more sustainable practices. As illustrated in Figure 09, the final circularity assessment demonstrates a significant progression from the initial baseline. This improvement

highlights the effectiveness of the implemented strategy, resulting in enhanced operational efficiency, a marked decrease in waste generation, and the integration of circular practices into the daily operations of the MSEs.

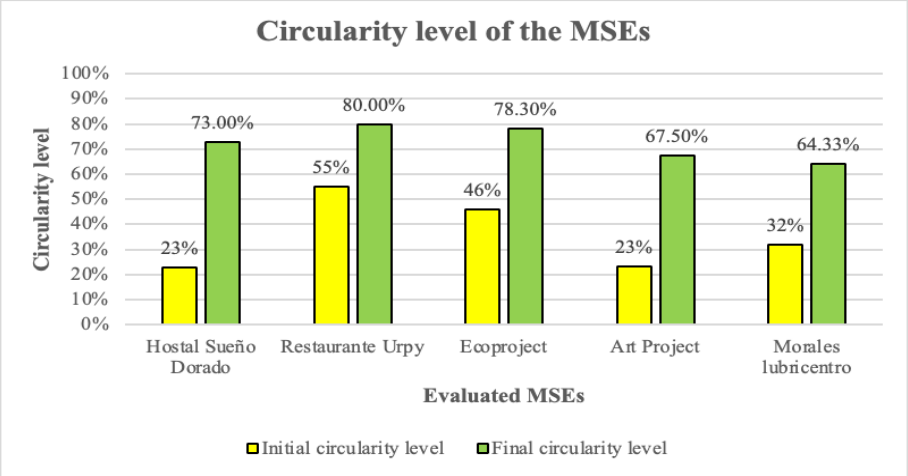

Figure 9 Final Circularity Assessment

Discussion

The implementation of the proposed circularity assessment tool across five micro and small enterprises (MSEs) in Independencia—Hostal Sueño Dorado, Restaurante Urpy, Ecoproject, Art Project, and Morales Lubricentro—revealed diverse levels of circular economy (CE) integration, shaped by both internal capacities and external enabling factors. As a diagnostic and planning instrument, the tool facilitated the identification of environmental, economic, and social impacts, and informed the prioritization of improvement actions. Notably, MSEs with higher initial circularity scores, such as Ecoproject and Restaurante Urpy, tended to demonstrate greater organizational structure, stronger leadership commitment, and previous engagement in sustainability initiatives. These enterprises also showed better capacity to implement the recommended CE actions, reinforcing the relevance of internal governance and strategic direction.

The tool's structure—centered around four dimensions: products/services, supply chain, internal practices, and governance—proved particularly effective in capturing the multifaceted nature of CE at the MSE level. Unlike other established methodologies such as the CTI Tool, Circulytics, or the BS 8001 standard, the proposed tool specifically targets the needs and limitations of MSEs in resource-constrained environments. While previous frameworks (e.g., Ortiz, 2019) focused on only three domains, this tool includes governance as a core dimension, acknowledging its critical role in regulatory compliance, leadership engagement, and integration of circularity into decision-making processes.

From an implementation perspective, the tool demonstrated clear positive outcomes across multiple impact dimensions. Manufacturing-oriented enterprises like Ecoproject and Art Project achieved measurable reductions in material waste, improved energy and water efficiency, and reported cost savings and enhanced profitability. Service-sector businesses, such as Hostal Sueño Dorado and Restaurante Urpy, while realizing fewer tangible economic benefits, reported improvements in brand image, customer engagement, and alignment with local sustainability goals. Morales Lubricentro, operating in automotive services, focused its actions on waste storage, energy optimization, and natural lighting. These differentiated outcomes reflect the varied nature of MSE operations and confirm that CE strategies need to be tailored by sector to maximize impact. This is consistent with findings by Salvador *et al.* (2021), who emphasized the importance of aligning CE strategies with business models and stakeholder engagement.

Given the applied nature of this research, it is essential to highlight its practical implications at both managerial and social levels. From a managerial perspective, the findings offer strategic guidance for owners and managers of micro and small enterprises transitioning toward circular models. The proposed tool enables the diagnosis of inefficiencies and supports process improvements, resulting in operational benefits such as cost savings, increased efficiency, and waste reduction. The study also highlights the critical role of committed leadership and openness to innovation, which facilitated the successful adoption of circular actions and strengthened business management in terms of sustainability. At the social level, the adoption of circular practices generates positive impacts by improving energy efficiency, reducing pollution, and promoting responsible resource use, thus contributing to cleaner and healthier communities. It also reinforces corporate social responsibility, enhances reputation among customers, and encourages conscious consumption. Over time, these transformations support the creation of shared value by fostering green jobs and local partnerships. Overall, the study demonstrates how circular transitions in MSEs can contribute to a more sustainable, inclusive, and resilient local economy.

However, the study also identified persistent challenges. In particular, MSEs with lower circularity scores often faced constraints such as limited technical knowledge, weak managerial capacity, or resistance to operational change. These barriers hindered the implementation of CE practices, despite the availability of proposed interventions. Resistance to change remains a key obstacle, often fueled by limited awareness of the benefits of circular models, as echoed by Delgado Neyra (2020). These findings underscore the need for more robust policy frameworks and regulatory incentives that actively support CE adoption in small businesses. While the European Union has developed comprehensive CE action plans (e.g., MITECO, 2021a), Latin America—including Peru—requires a more coherent institutional framework to promote innovation, producer responsibility, and sustainability transitions (C. de Miguel *et al*., 2021).

In this context, the SWOT analysis conducted for each MSE provided a strategic lens to understand the internal and external factors influencing CE implementation. Strengths included managerial openness, initial sustainability practices, and alignment with local policy goals. Opportunities were identified in areas such as access to green financing, participation in local CE initiatives, and growing consumer interest in sustainable products. Weaknesses involved operational informality, limited technical capacity, and insufficient monitoring systems. Threats included supply chain rigidity, lack of incentives, and market volatility. Based on this analysis, CAME strategies were formulated to enhance circularity performance. These included leveraging strengths to exploit opportunities (e.g., promoting CE-oriented branding), addressing weaknesses through partnerships and training, and minimizing threats by adopting resource-efficient technologies and improving compliance with environmental standards.

The findings of this study align consistently with the existing literature on circular economy (CE) implementation in small enterprises. In general, the results reinforce previously identified trends. For instance, Ortiz (2019) reported that the level of circularity among small businesses in Cali, Colombia, was moderate, suggesting that the full adoption of CE practices remains a work in progress. This observation mirrors the initial conditions found among the MSEs in Independencia, where baseline circularity levels were generally modest prior to the intervention. Furthermore, the evidence supports the conclusions of Salvador *et al.* (2021), who emphasized the importance of tailoring CE strategies to the specific business model and sector. In the present study, the most significant improvements varied across sectors, confirming that sector-specific approaches are essential to maximizing circular impact.

In addition, the barriers encountered during implementation—particularly resistance to change and limited technical knowledge—reflect challenges previously documented in the literature. As noted by Delgado Neyra (2020), low awareness of circular economy principles among Peruvian enterprises often hinders the transition toward sustainable models. These findings underscore the importance of targeted support and awareness-raising efforts as part of any CE strategy.

A notable contribution of this study lies in the incorporation of governance as a core analytical dimension—an element absent in several earlier frameworks. For example, Ortiz (2019) considered only three dimensions, omitting governance. By integrating this fourth dimension, the proposed tool adopts a more holistic approach that recognizes the role of public policy, institutional frameworks, and internal leadership in enabling circular

transitions. This expanded analytical scope enhances the tool's relevance in practice and provides a more comprehensive understanding of the conditions that facilitate or constrain CE adoption.

In summary, the comparative analysis confirms that the results are consistent with prior research, while also contributing novel insights—particularly the emphasis on governance—that enrich the body of knowledge on circular economy implementation in micro and small enterprises.

It is also important to mention that the study presents some limitations that should be taken into account. The small sample size limits the generalizability of the results, and the use of questionnaires and interviews may introduce response bias from participants. Moreover, the study did not include medium- or long-term follow-up, which restricts the analysis of the sustainability of the implemented actions. These limitations open opportunities for broader and more in-depth future research, which could incorporate representative samples, evaluation of specific quantitative indicators, and longitudinal analyses.

Even so, the scalability and adaptability of the tool are notable strengths. Although originally designed for the Independencia district, the methodology can be applied more broadly across similar urban-industrial contexts in Peru and other Latin American countries. Its ease of use, qualitative-quantitative hybrid structure, and alignment with existing policy instruments position it as a practical and context-sensitive solution for accelerating CE transitions in MSEs. To maximize its impact, however, further institutional support is needed—particularly in the form of public-private collaboration, sector-specific technical assistance, and the development of knowledge-sharing platforms. These actions will be essential in overcoming current barriers and fostering systemic change towards a circular and inclusive economy.

Lastly, the study's findings highlight the need to strengthen regulatory frameworks and public policies to facilitate the adoption of the circular economy (CE) in micro and small enterprises (MSEs) in Peru. Despite the growing interest in CE, regulatory gaps, limited incentives, and weak interinstitutional coordination hinder effective implementation. It is recommended to establish economic support instruments—such as green loans or tax benefits—along with the simplification of regulations to reduce bureaucratic barriers. Additionally, it is essential to promote technical assistance and training programs coordinated among the government, local authorities, academia, and business associations. These measures would enable the provision of specialized support, encourage the use of tools tailored to the MSE context, and generate systematic evidence to monitor progress. Altogether, these actions would help build an enabling ecosystem for a circular transition, with tangible and lasting impacts on the competitiveness and sustainability of MSEs.

Conclusions

This study developed and implemented a specific analytical tool to assess the level of circularity in micro and small enterprises (MSEs) in the district of Independencia, Lima, as part of a comprehensive circular economy (CE) strategy. The tool, designed with a qualitative-quantitative approach and structured around four key dimensions—products/services, supply chain, internal practices, and governance—enabled the identification of gaps, opportunities, and priority actions tailored to the local context of MSEs in Peru.

The results showed that enterprises with previous experience in sustainability, stronger organizational cohesion, and committed leadership displayed higher initial levels of circularity, as well as a greater capacity to implement circular actions. In contrast, businesses with more informal structures or technical limitations faced greater difficulties in adopting sustainable practices, despite the existence of concrete proposals. This reinforces the importance of internal governance and technical support as key enabling factors in transition processes toward circular models.

The strategy proved effective not only as a diagnostic tool but also as a practical roadmap for planning, executing, and monitoring circular actions adapted to different sectors. Participating enterprises achieved significant progress in resource efficiency, waste reduction, and strengthening of environmental, economic, and social performance. Tangible benefits were observed, such as cost savings, increased profitability, sustainable brand positioning, and greater engagement with the local community.

Furthermore, the SWOT-CAME analysis made it possible to identify critical factors influencing CE adoption and to guide strategic decision-making based on the capacities and environment of each enterprise. Although structural challenges persist—such as the lack of clear incentives, resistance to change, and regulatory complexity—the study's experience demonstrates that progress toward more circular business models is achievable through context-specific, methodologically robust, and participatory interventions.

Finally, the proposed tool shows high potential for scalability and adaptability, making it replicable in other urban-industrial districts in Peru and Latin America. Its accessibility, operational simplicity, and alignment with existing regulatory frameworks position it as a viable solution for accelerating transitions toward an inclusive circular economy in the MSE sector. To maximize its impact, it will be essential to coordinate efforts among public, private, and academic sectors, and to promote knowledge-sharing platforms that strengthen local capacities and drive systemic change toward sustainability.

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Author Contributions Giuliana Patricia Becerra Celis was responsible for the conceptualization of the article, the complete drafting of the manuscript, the critical review of the results, as well as the editorial management and communications with the journal. In addition, Author 1 assumed the overall coordination of the project, methodological supervision, validation of the findings, and the institutional arrangements required for publication. Wilmer José Puraca Mamani conducted the research as part of their undergraduate thesis, being responsible for the problem statement, methodological design, fieldwork, and data processing. Their contributions to the generation of original information and technical analysis constitute the foundation of the results presented.

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Data Availability The data supporting the findings of this study are openly available in the institutional repository of the Universidad Nacional Mayor de San Marcos (Cybertesis UNMSM) at the following link: https://cybertesis.unmsm.edu.pe/item/2e61ae7e-1e5a-4a8c-ae62-a67718133365.There are no restrictions or conditions for access. The dataset is publicly accessible and may be used freely for academic and research purposes.

Declarations

Competing interests The authors declare no competing interests.

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