Sustainable Industrial Engineering: Integrating Innovation, Production Efficiency and Human Well-Being from an International Perspective

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ABSTRACT

Industrial engineering faces the challenge of improving the productivity of manufacturing organizations without neglecting its environmental and human effects. This article analyzes, from an international perspective, the relationship between continuous improvement, environmental sustainability, technological innovation and human well-being in manufacturing, with the purpose of proposing a framework that integrates these dimensions. A structured literature review was carried out of 25 documents published between 2017 and 2026, obtained from Google Scholar, SciELO, Redalyc and scientific publisher portals. The documents come from Europe, Latin America including Mexico, Asia and Africa, in addition to international reviews, and were organized into four thematic axes: continuous improvement and productivity; environmental sustainability and circular economy; technological innovation; and human-centered manufacturing. The dimensions that each one measures were identified. The results show that the evaluation of improvements focuses on productivity: the environmental dimension is mentioned in 17 of the 24 articles analyzed, but only 3 measure it with their own data; well-being and safety are measured in 2, and staff participation in none. Based on these findings, the People-Centered Sustainable Industrial Engineering Framework (MIISCP) is proposed, composed of five phases: process diagnosis, identification of opportunities, design of alternatives, implementation and monitoring, and standardization and continuous improvement that simultaneously evaluate production, environment, and people criteria. The framework constitutes a conceptual proposal that requires validation through case studies.

Keywords: Industrial Engineering; Sustainable Manufacturing; Continuous Improvement; Human-Centered Manufacturing; Literature Review.

INTRODUCTION

Industrial engineering studies and improves systems in which people, materials, information, equipment, energy, and working methods interact. Its contribution is not limited to increasing the volume of production: it also includes organizing processes, improving quality, reducing losses, and designing operating conditions that allow objectives to be achieved with a responsible use of resources. In a scenario of technological transformation and concern for environmental impacts, these functions must be analyzed from a perspective that considers both productive performance and the social consequences of technical decisions.

Continuous improvement and lean manufacturing provide tools to identify defects, lead times, unnecessary inventories, avoidable movements, and other activities that consume resources without generating value. However, reducing operational waste does not necessarily equate to an overall improvement in sustainability. An intervention can increase productivity while raising total energy consumption if the volume produced changes; similarly, automation can modify training requirements, task distribution, and workload. Therefore, results should be evaluated against indicators that reflect the relevant dimensions.

This need is recognized internationally. UNESCO (2021) points out that engineering is indispensable to achieve the Sustainable Development Goals, but that the profession must be transformed to be more innovative, inclusive and responsible.

Ferrazzi et al. (2025) reviewed 59 articles on the influence of lean manufacturing on environmental performance and identified promising effects on eco-efficiency, but also gaps in the factors and mechanisms that explain them. This supports the need to examine improvement tools beyond their operational benefits.

The Industry 5.0 perspective broadens the analysis by proposing that industrial transformation combines technological capabilities with human centrality, resilience, and sustainability. Díaz Martínez et al. (2026) synthesized research on these concepts and their technological enablers, while Castagnoli et al. (2024) identified that the people-centered approach still requires further development in the management literature and is usually approached from ergonomics in engineering studies.

The objective of this article is to analyze scientific literature published between 2017 and 2026 on the relationship between continuous improvement, waste reduction, technological innovation and sustainability, with the purpose of proposing a conceptual framework that integrates productive efficiency, responsible use of resources and human well-being from an international perspective. The analysis is not limited to a specific company or sector, but synthesizes approaches applicable to different production systems.

The contribution of the work is the Framework for Sustainable People-Centered Industrial Engineering (MIISCP), a conceptual proposal that organizes the diagnosis and evaluation of improvement initiatives in five phases and that is formulated based on the gaps identified in the literature.

Problem statement

Production systems must respond to objectives that can reinforce each other, but that can also come into tension: productivity, quality, costs, resource consumption, waste reduction and human well-being. Industrial engineering tools allow an important part of these challenges to be analyzed; however, the evaluation of an improvement can be incomplete if it is limited to a single indicator, such as cycle time, defect rate or unit cost.

The problem addressed in this article is not the lack of methods to improve processes, but the need to articulate their production objectives with environmental and human criteria. The literature on Lean and environmental performance identifies positive results in numerous cases, but also points out that the effects vary and that there are still questions about the conditions of implementation (Ferrazzi et al., 2025). In turn, human-centered manufacturing approaches propose expanding the evaluation to consider the human experience in the design and management of industrial systems (Castagnoli et al., 2024).

It is therefore pertinent to examine how these approaches can be integrated into a conceptual framework that helps to evaluate improvement alternatives without assuming that a productive gain alone guarantees environmental or social benefits.

Research Question

How can industrial engineering integrate strategies of continuous improvement, technological innovation and sustainability to reduce waste and improve the efficiency of production systems, while considering human well-being from an international perspective?

Objectives

General objective

To analyze the international scientific literature published between 2017 and 2026 on the relationship between continuous improvement, technological innovation, waste reduction and sustainability in industrial engineering, with the purpose of proposing a conceptual framework that integrates productive efficiency, responsible use of resources and human well-being.

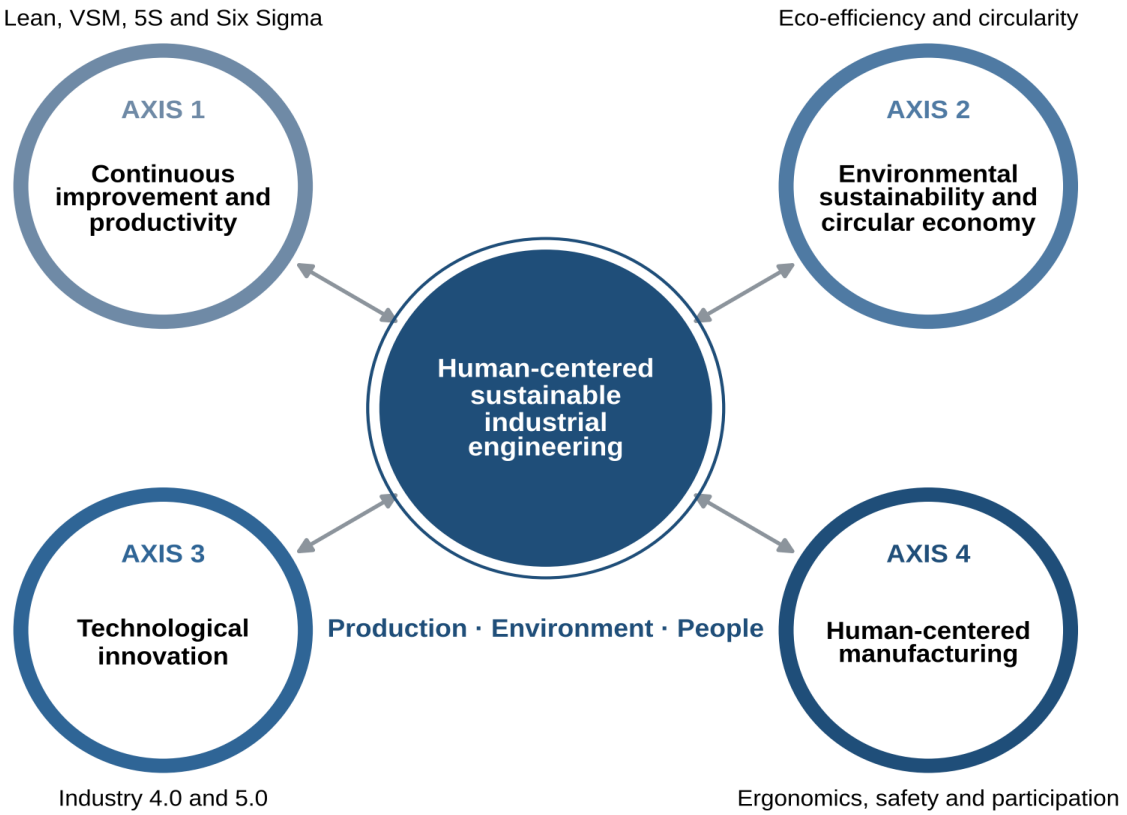
Specific objectives

1. Identify industrial engineering strategies used to reduce waste and improve the efficiency of production systems.
2. Examine the relationship between continuous improvement, technological innovation and environmental sustainability.
3. Analyze how human factors—such as ergonomics, safety, training, and participation—are incorporated into sustainable manufacturing approaches.
4. Recognize convergences, differences, and opportunities for integration in the selected literature.
5. Propose a conceptual framework to guide the evaluation of improvement initiatives using productive, environmental and human criteria.

THEORETICAL FRAMEWORK

The analysis is based on four thematic axes that, together, allow us to examine improvement initiatives from the productive, environmental and human dimensions (Figure 1). The following sections define the central concepts of each axis and the way in which they are used in this study.

Figure 1. Thematic axes of the study and its integration into sustainable industrial engineering



Note. Authors.

Continuous improvement and productivity

Continuous improvement is a management approach that seeks to identify problems, analyze their causes, implement changes, and verify their results in a cyclical manner; in industry, it is supported by tools such as the plan-do-check-act cycle, root cause analysis, and work standardization. Lean manufacturing shares this purpose and is aimed at eliminating activities that do not add value to the customer, such as defects, overproduction, waiting, unnecessary transportation, excess inventory, unnecessary movements, and reprocessing (Womack and Jones, 1996). In this study, both approaches form the basis of the productive dimension, which includes productivity, quality, and operating costs.

Environmental sustainability and circular economy

Waste reduction can generate environmental benefits when it decreases the consumption of materials and energy per unit produced; this relationship is studied under the Lean-Green approach (Chugani et al., 2017; Ferrazzi et al., 2025). However, higher efficiency per unit does not guarantee lower environmental pressure if the volume of production increases, so it is convenient to distinguish between relative and absolute indicators. The circular economy broadens this perspective by proposing that materials be kept in use through their reduction, reuse, recycling, and recovery, although the concept lacks a single definition (Kirchherr et al., 2017). For this study, the environmental dimension includes the consumption of materials and energy, as well as the generation of waste.

Technological innovation

Industry 4.0 incorporates technologies such as sensors, the Internet of Things, data analytics, simulation, and automation to improve visibility and control of processes. Industry 5.0 complements this paradigm by proposing that technological transformation be sustainable, people-centric, and resilient (Breque et al., 2021; Leng et al., 2022). From this perspective, technology is seen as an enabler of improvement and not an end in itself: its value depends on the problem it solves and its effects on resources and those who use it.

People-centric manufacturing

The people-centered approach considers workers as participants in the production system and not only as resources to achieve production goals. In addition to ergonomics and safety, it includes training, autonomy, and the participation of personnel in process improvement (Castagnoli et al., 2024; Reiman et al., 2021). In this study, the human dimension integrates these aspects and is evaluated through specific information, without assuming that a productive improvement generates better working conditions by itself.

Together, the four axes define the three dimensions with which the literature is analyzed and the MIISCP is structured: the productive, derived from continuous improvement; the environmental, linked to sustainability and the circular economy; and the human, associated with human-centered manufacturing. Technological innovation acts in a transversal way, as a means that can favor or compromise each of them depending on the way in which it is implemented.

METHODOLOGY

Study design

This study corresponds to a literature review aimed at the analysis of 25 documents published between 2017 and 2026 on the relationship between continuous improvement, environmental sustainability, technological innovation, and human well-being in manufacturing. The choice of this type of review is due to the fact that it allows the integration of research from various disciplines and developed with different methods (Snyder, 2019). The analysis included three components: first, the comparison of the studies through a matrix that systematizes their objective, methodology, results, and limitations; second, the identification of the dimensions evaluated in each study; and, finally, the formulation of the Framework for Sustainable People-Centered Industrial Engineering (MIISCP), based on the gaps identified in the literature.

Sources of information and search strategy

The search was carried out in October 2026 in Google Scholar, in the SciELO and Redalyc repositories and in the portals of the publishers Elsevier, Springer, MDPI, Taylor & Francis and Emerald. Preference was given to articles with DOI or with registration in institutional repositories, to ensure that their publication data could be verified. The search terms, in English and Spanish, were grouped into three categories: (a) continuous improvement and lean manufacturing, which included terms such as *lean manufacturing*, *continuous improvement*, *kaizen* and *value stream mapping*; (b) sustainability and circular economy, with terms such as *environmental performance*, *green manufacturing* and *circular economy*; and (c) technology and human factors,

with terms such as *Industry 5.0*, *human-centric manufacturing* and ergonomics. In addition, the references of the selected studies were examined in order to identify other relevant works.

Selection criteria

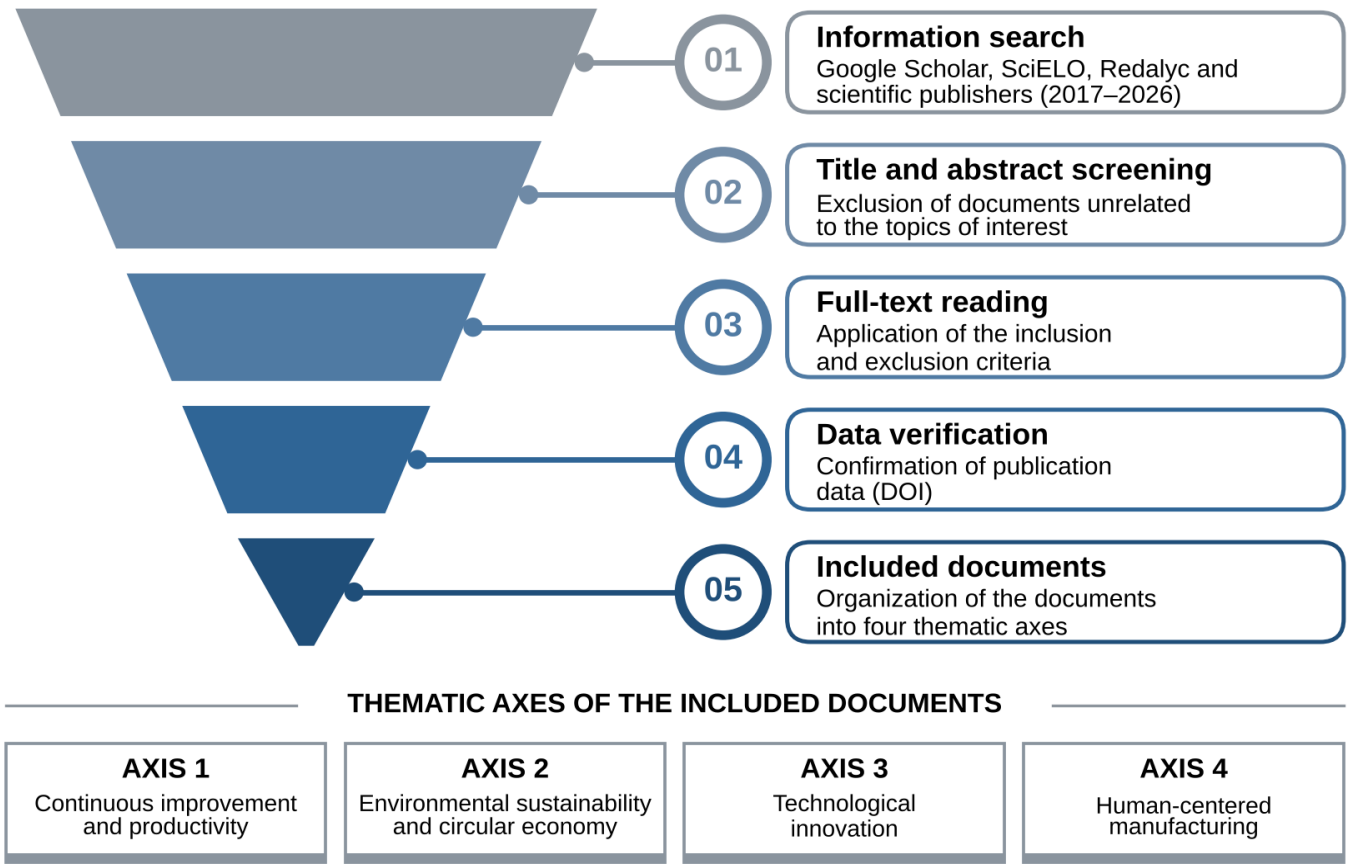
Research and review articles published between 2017 and 2026, in English or Spanish, in peer-reviewed journals, that addressed at least one of the dimensions of interest – productive, environmental or human – in the field of manufacturing or industrial engineering were included. Conference proceedings, book chapters, editorials, papers without access to the full text, and those whose publication data could not be verified were excluded. Likewise, studies that dealt with the topics of interest tangentially or that did not describe their methodology in sufficient detail were discarded. The UNESCO report (2021) was used exclusively as a context reference.

Selection process

Theselection of the documents was carried out in three stages. In the first, the titles and abstracts of the records obtained were reviewed; in the second, the relevant documents were read in full and the selection criteria were applied; in the third, their publication data were verified.

As a result of this process, 25 documents were selected: 24 peer-reviewed articles and an institutional report. For their analysis, the publications were organized into four thematic axes: (1) continuous improvement and productivity, with 12 documents; (2) environmental sustainability and circular economy, with 4; (3) technological innovation, with 4; and (4) human-centered manufacturing, with 4. The institutional report was considered as a context reference. Regarding the type of study, the set is made up of 12 case studies, 8 literature reviews, 2 surveys, and 3 other documents.

Figure 2. **Selection process and organization of the documents analyzed**



Note. Own elaboration.

Recording and analysis of information

The title, objective, methodology, results, limitations, and contribution to the present research were recorded; this information is presented in the Results section (Table 1).

In order to identify the aspects addressed by the literature, each document was reviewed with respect to six dimensions: productivity, quality and waste, resources and environment, well-being and safety, participation and economic viability. In each one, it was distinguished whether the study measured the dimension with its own data, if it only mentioned it or if it did not address it. From this review, the number of those that measure and those that address each dimension was counted from a total of 24 peer-reviewed articles; the institutional report was excluded from this calculation, since it was used only as a context reference.

Methodological limitations

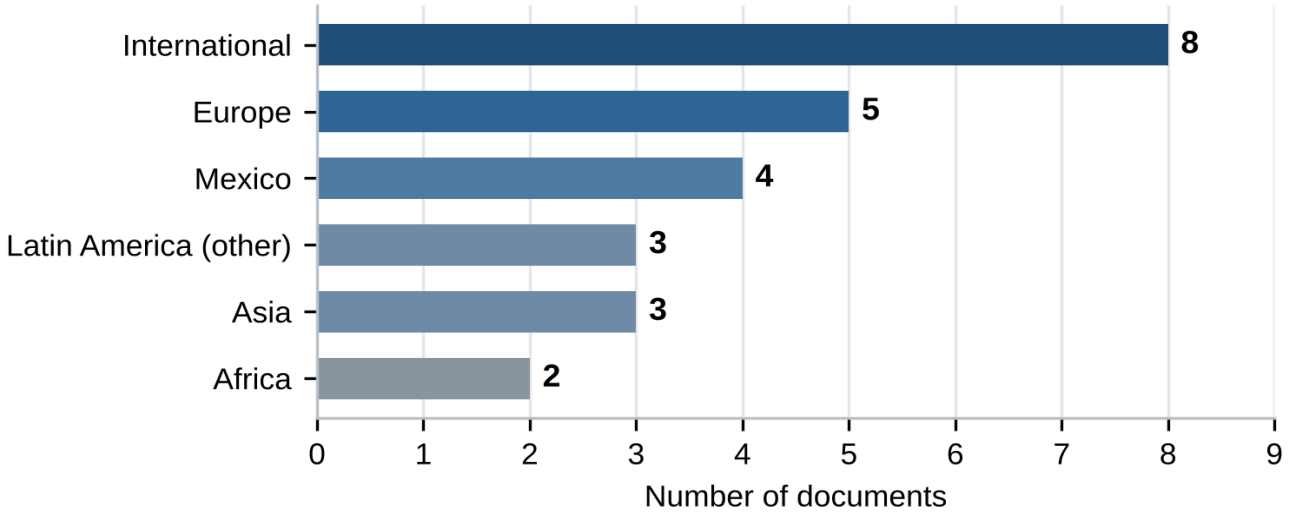
The search was limited to the sources described and to publications in English and Spanish, so there could be relevant studies not included; to mitigate this effect, the references of the selected documents were reviewed. Likewise, the classification of the studies was based only on the information that each one reports, and the analysis is based on 24 articles; therefore, the results describe the literature analyzed and should not be generalized to all research in the area.

RESULTS AND DISCUSSION

Origin of the documents analyzed

The documents analyzed come from five regions (Figure 3). International reviews and studies carried out in Europe and Mexico predominate, which supports the international perspective of the analysis and incorporates, at the same time, evidence from the Mexican context.

Figure 3. Distribution of the documents analyzed by region



Note. Prepared by the authors. n = 25 documents. The "International" category groups reviews and studies without a specific country of application.

Comparison of studies

In order to systematize the evidence and facilitate its comparison, a matrix was developed that brings together, for each of the 25 documents, its title, objective, limitations, methodology, results and contribution to the present research (Table 1). The documents are grouped by thematic axis and, within each axis, they are ordered by year of publication, which allows contrasting studies with different purposes and methods under the same criteria.

Table 1. Comparative matrix of the studies analyzed

Author (Year)	Title	Objective	Limiting	Methodology	Results	Analysis
Axis 1. Continuous improvement and productivity						
Chugani et al. (2017)	Investigating the green impact of Lean, Six Sigma and Lean Six Sigma: A systematic literature review	Examine the environmental impact of Lean, Six Sigma, and Lean Six Sigma.	The sample is limited to 16 journals and a small set of keywords; few articles directly link these methods to the environment.	Systematic review of 70 articles published in 16 operations and quality management journals.	Lean is the most studied approach (53 articles), compared to Six Sigma (14) and Lean Six Sigma (3); both contribute to conserving resources and saving energy, although the evidence on Six Sigma is less.	It expands the analysis from Lean to Six Sigma and Lean Six Sigma; it constitutes a precedent of Ferrazzi et al. (2025).
Minh et al. (2019)	Applying Lean Tools and Principles to Reduce Cost of Waste Management: An Empirical Research in Vietnam	Evaluate how Lean tools applied to industrial waste collection reduce costs and benefit the environment.	Only one case (Toyota Motor Vietnam); authors participated in the project; there is no life cycle data or quantified monetary savings.	Case study: waste stream mapping based on VSM, pull system, visual control and Andon.	Waste management personnel from 40 to 31 operators (−23%); delivery routes from 28 to 16.	It extends the VSM to the waste stream, exemplifying the application of Lean to environmental goals.
Vasconcelos et al. (2019)	Lean and green: the contribution of lean production and environmental management to the waste reduction	Investigate how the combination of lean production and environmental management contributes to reducing waste.	Three companies from one state, intentional sampling, 12 respondents, data from 2012 and missing evaluation indicators.	Multiple qualitative case study in three companies with ISO 14001 (electric power, automotive and steel); questionnaires, reports and triangulation.	About 75% of respondents perceive that Lean contributes to reducing environmental impacts; about 60% say that environmental principles are applied in Lean activities; the steel company reuses almost 80% of its process waste.	Its main limitation, the lack of indicators, reinforces the need to define metrics in the MIISCP.
Huerta Estévez (2021)	Reducing In-Line Material Handling in an Auto Assembly Plant by Applying Lean Manufacturing	Reduce line stoppages and long material handling runs in an automotive assembly plant.	A single case; no statistical proof; assumptions of the cost of the company; some benefits still under evaluation.	Applied research: diagnosis, sequencing of parts with internal supplier, skills matrix and electronic kanban (pull).	Cost per stoppage from 47,175 to 22,950 USD; distance per cycle from 1,600 to 800 m; delivery cycles from 110 to 20.	Mexican case with values before and after; it incorporates cross-training of personnel.
Logesh y Balaji (2021)	Experimental investigations to deploy green manufacturing through	Examine how Lean tools contribute to green manufacturing	Only one case; the abstract does not report quantitative values.	Experimental research in an electrical components plant by	Reducing Lean waste reduces environmental effects of the process, such as	It provides evidence of the link between Lean and green manufacturing

	reduction of waste using lean tools in electrical components manufacturing company	in an electrical components company.		applying Lean tools at all stages of production.	wastewater and pollution.	in an emerging economy.
Schoeman et al. (2021)	Value Stream Mapping as a Supporting Management Tool to Identify the Flow of Industrial Waste: A Case Study	Demonstrate the VSM as a tool to identify and evaluate the waste stream in a steel mill.	A single case; the model excludes some flows and the layout; inconsistent cost data; results only for the first year.	Case study with six years of waste data, audits, sampling and laboratory analysis; material efficiency by segment; current and future VSM.	In the first year, waste fell by 28% and the cost of its removal by 45%; 2.15 t of waste per t of crude steel were generated (world average 0.3 t).	It shows that the VSM can be adapted to environmental indicators, such as waste generation.
Elemure et al. (2023)	Integration of Lean Green and Sustainability in Manufacturing: A Review on Current State and Future Perspectives	Review the application of lean-green practices in manufacturing in sub-Saharan Africa.	Only five bases; evidence concentrated in the automotive sector.	Literature review of 118 articles (1990–2022) from five databases.	In developed economies, the studies cited report cost savings of 5% to 30% with lean-green practices; limited evidence on how Lean translates into green outcomes.	It provides the perspective of developing economies and a range of savings associated with lean-green practices.
Ortiz Porras et al. (2023)	Green Lean Six Sigma model for waste reduction of raw material in a nectar manufacturing company of Lima, Peru	Reduce raw material waste in a nectar factory.	Only one case; the article does not present the absolute base values.	Experimental research with Green Lean Six Sigma model: E-VSM, DMAIC, Poka-Yoke and design of experiments; Anderson-Darling and Student's t tests.	Raw material waste −2.23% (about 120 kg), environmental impact −2.2%, waste costs −5.5% and overall productivity +2.4%.	Latin American example of Lean-green integration backed by statistical evidence.
Salwin et al. (2023)	Value-Stream Mapping as a Tool to Improve Production and Energy Consumption: A Case Study of a Manufacturer of Industrial Hand Tools	Apply VSM to reduce waste and evaluate its effects on energy, reliability, and OEE.	A single case; several subsequent figures are projections, not measurements; data for one month.	Case Study: Interviews, observation, standard times, energy readings; current and future VSM, OEE, and financial analysis.	Operator productivity +9.4%; machine availability 70.3% to 85.2%; OEE +18%; claimed products −90.3%; projected savings of about 295,000 kWh per year.	Integrate productivity, quality, and energy consumption indicators into a single analysis.
Alva Rocha et al. (2024)	Implementation of continuous improvement applied to the production process of the sustainable recycling company in Reynosa, Tamaulipas	Implement a continuous improvement process to standardize and organize the production process of a recycling company.	Only one case, without a control group or statistical tests; some improvements are reported without an initial value.	Action research in four phases; 5S-based checklist of 29 items applied to 62 operators; Ishikawa and flowcharts.	Compliance in the organization increased from 71% to 98%, in the order of 85% to 98%, in cleanliness from 60% to 100%, and in standardization from 83% to 100%.	A Mexican case that links continuous improvement with standardization and involves operational personnel in the process.

Veseli et al. (2024)	The Implementation of Lean Manufacturing on Zero Waste Technologies in the Food Processing Industry: Insights from Food Processing Companies in Kosovo and North Macedonia	Examine how Lean practices affect operational performance and their integration with zero-waste technologies.	Nine companies from two countries; qualitative approach not generalizable.	Multiple qualitative case study in nine companies; semi-structured interviews and thematic analysis.	JIT, TPM, statistical control and staff participation improve efficiency, quality and response; the barriers are resistance to change and lack of resources.	Identifies staff participation as an enabler of Lean, in line with the human dimension of the MIISCP.
Ferrazzi et al. (2025)	Investigating the influence of lean manufacturing approach on environmental performance: A systematic literature review	Analyze how Lean practices influence the environmental performance of manufacturing.	It does not explain what factors condition the magnitude and direction of environmental effects.	Systematic review of 59 articles.	Promising effects on eco-efficiency (energy, carbon footprint, raw materials, waste); VSM, TPM, Kaizen, JIT and 5S do not affect all indicators in the same way.	It shows that the environmental benefit of Lean is not automatic; it justifies the MIISCP incorporating explicit environmental indicators.
Axis 2. Environmental sustainability and circular economy						
Kirchherr et al. (2017)	Conceptualizing the circular economy: An analysis of 114 definitions	To analyze how the circular economy is defined in the academic and professional literature.	Analysis of definitions, not of empirical practices or results.	Content analysis of 114 definitions of circular economy.	Definitions of circular economy are heterogeneous; those that associate it with reduce, reuse and recycle predominate, and few explicitly link it to sustainable development.	It provides the conceptual basis for defining the circular economy and explains the difficulty of comparing studies.
Dey et al. (2022)	Adoption of circular economy practices in small and medium-sized enterprises: Evidence from Europe and the UK	Examine the adoption of circular economy practices in SMEs and their effect on sustainable performance.	Only four European countries; data reported by the companies themselves.	Mixed methods (survey, interviews and cases) with about 100 SMEs per country.	The adoption of the circular economy improves environmental performance more than economic and social performance; design is the function that contributes the most and recovery the least.	He agrees with Loza-Hernández and Arroyo (2023) that recovery is the least developed circular stage.
Loza-Hernández and Arroyo (2023)	Actions to Foster the Circular Economy: A Case Study of Multinational Manufacturers in	Identify circular economy actions in multinational manufacturing	Six subsidiaries, two sectors and a single country.	Qualitative analysis of six subsidiaries (automotive and fast-moving	Resource reduction, the water cycle, packaging, and renewables predominate;	It shows the distance between reducing the use of resources and closing the

	the Automotive and Fast Moving Consumer Goods Sectors in Mexico	companies operating in Mexico.		consumer goods).	extending the shelf life and closing the supply chain are less developed.	material cycles in the industry operating in Mexico.
Singh y Khaira (2026)	Minimizing carbon emissions, energy consumption, and waste in manufacturing: a green manufacturing approach	Propose a green manufacturing framework for auto parts SMEs that integrates carbon, energy, waste and Industry 4.0.	It does not report the number of cases or base values; results expressed in ranges.	Systematic review (2016–2025), validation with experts and case-based performance evaluation.	Estimated emission reductions of 15% to 35%, energy consumption of 10% to 25% and material waste of up to 40%.	It proposes a framework comparable to MIISCP, focusing on environmental and technological objectives.
Axis 3. Technological innovation						
Tortorella and Fettermann (2018)	Implementation of Industry 4.0 and lean production in Brazilian manufacturing companies	Examine the relationship between lean production practices and adoption of Industry 4.0 technologies.	Sample from a single country and data based on respondents' perception.	Survey of 110 Brazilian manufacturing companies; multivariate analysis.	Lean practices are positively associated with Industry 4.0; implementing them together is linked to greater performance improvements; context moderates the relationship.	It shows that Lean and digitalization are complementary, which supports its integration into the MIISCP.
González-Hernández and Granillo-Macías (2020)	Competencies of the industrial engineer in Industry 4.0	To analyse the competencies required by industrial engineers in the face of Industry 4.0.	Mexican university context; it addresses training, not production systems.	Qualitative documentary research and curricular analysis of the industrial engineering program of a Mexican university.	It highlights capabilities in information technology, big data, IoT, and simulation.	It supports training as a component of the human dimension in the face of technological change.
Leng et al. (2022)	Industry 5.0: Prospect and retrospect	Review the evolution of Industry 5.0, define it and propose an architecture to implement it.	No formal search protocol; research in Industry 5.0 is still incipient.	Narrative review with architectural proposal in three dimensions (technique, reality and application).	It identifies human centrality, sustainability, and resilience as core traits; it sets out enablers, implementation routes, and challenges.	It conceptually bases the integration of the productive, environmental and human dimensions.
Díaz Martínez et al. (2026)	A systematic review of Industry 5.0 and sustainability in manufacturing: Clustering of concepts, characteristics, and technological enablers	Identify, classify, and group concepts, characteristics, and enabling technologies of Industry 5.0 and sustainability in manufacturing.	Only three bases (Scopus, ScienceDirect, MDPI); the grouping by co-occurrence and the 30% threshold are subjective decisions.	Systematic review with PRISMA 2020: 240 records, 32 duplicates, 140 articles included (2007–2025); content analysis and heat maps.	20 key concepts, 10 pillars present in at least 30% of the publications and 5 clusters (environmental sustainability, humanization, intelligent enablers, resilience, business models). Most cited technologies: AI, IoT, digital	It supports considering technology as an enabler and not as an end in itself.

					twins, cobots, additive manufacturing.	
Axis 4. People-centered manufacturing						
Brito et al. (2018)	Integration of lean manufacturing and ergonomics in a metallurgical industry	Show how an integrated approach improves productivity and ergonomic conditions at the same time.	A single case in a metallurgical company, which limits the generalization of its results.	Case study: RULA, Strain Index and REBA for ergonomics; VSM and 7 wastes for Lean.	It is possible and desirable to attend to ergonomics and productivity together; ergonomic improvements contribute to productivity.	It demonstrates that Lean tools and ergonomic assessment can be applied together.
Gualtieri et al. (2020)	Design of human-centered collaborative assembly workstations for the improvement of operators' physical ergonomics and production efficiency: A case study	Design a collaborative station that improves physical ergonomics without losing productivity.	A single case in a harness assembly operation; results that cannot be generalized to other processes.	Case study: Transformation of a manual harness assembly station into a human-robot collaborative station.	Biomechanical overload −12% (right) and −28% (left); risk postures −57% and −50%; cycle time −12.3%.	It provides quantitative evidence that ergonomic and productive improvement can be achieved simultaneously.
Reiman et al. (2021)	Human factors and ergonomics in manufacturing in the Industry 4.0 context – A scoping review	Describe the state of research on human factors and ergonomics related to Industry 4.0 in manufacturing.	Scoping review: describes the literature, but does not evaluate empirical results of interventions.	Scope review: 336 articles identified, 37 analyzed with a human-centered work system framework.	It proposes characteristics of an organizational maturity model to optimize the sociotechnical system in the face of technological change.	It supports that well-being is evaluated at the level of the work system and not only of the position.
Castagnoli et al. (2024)	A new research agenda for human-centric manufacturing: A systematic literature review	Review the literature on human-centered manufacturing and propose a research agenda.	Management literature on the subject is scarce; period 2011–2023.	Systematic review of 69 studies (2011–Dec. 2023).	The approach is little researched in management and in engineering it is mainly from ergonomics; transdisciplinary approaches are requested.	It supports that the human dimension includes participation and training, in addition to ergonomics.
Background						
UNESCO (2021)	Engineering for sustainable development: Delivering on the Sustainable Development Goals	Analyze the role of engineering in meeting the SDGs.	Institutional document, not peer-reviewed.	Report of an international organization.	Engineering capacity is insufficient to achieve the SDGs; engineering contributes to all 17 goals and needs to become more innovative, inclusive and accountable.	It places engineering as a key actor in the fulfilment of the Sustainable Development Goals.

Note. Prepared by the author based on the documents analyzed.

Thematic findings

Axis 1. Continuous improvement and productivity

This axis brings together 12 documents and concentrates most of the empirical evidence. Value stream mapping (VSM) is the most frequent tool and, in several cases, extends to waste and energy analysis (Minh et al., 2019; Salwin et al., 2023; Schoeman et al., 2021). All case studies that measured productivity report improvements (Alva Rocha et al., 2024; Huerta Estévez, 2021); in contrast, only two cases measured an environmental indicator before and after the intervention (Ortiz Porras et al., 2023; Schoeman et al., 2021), and reviews warn that the mechanisms of these environmental effects are not sufficiently explained (Chugani et al., 2017; Ferrazzi et al., 2025). ***Implication for the MIISCP:*** productive improvements must be accompanied by an explicit baseline and environmental measurement, without entailing environmental benefit.

Axis 2. Environmental sustainability and circular economy

Circular practices focus on reducing resource use, while material recovery and supply chain closure remain less developed, both in multinationals operating in Mexico and in European SMEs (Dey et al., 2022; Loza-Hernández and Arroyo, 2023). Added to this is the absence of a unified concept of circular economy, which makes it difficult to compare studies (Kirchherr et al., 2017). For their part, Singh and Khaira (2026) propose a green manufacturing framework for SMEs, although its benefits are expressed as estimates and not as post-implementation measurements. ***Implication for MIISCP:*** the design of alternatives must consider, in addition to reduction, options for reuse and recovery of materials.

Axis 3. Technological innovation

This axis does not include case studies; the evidence comes from literature reviews, a curriculum analysis, and a survey. Tortorella and Fettermann (2018) found, in 110 Brazilian companies, a positive association between Lean practices and the adoption of Industry 4.0 technologies, and the reviews on Industry 5.0 coincide in three traits: human centrality, sustainability, and resilience (Díaz Martínez et al., 2026; Leng et al., 2022). ***Implication for the MIISCP:*** technology is incorporated as an enabler, and its selection is evaluated with productive, environmental, and human criteria, including staff training (González-Hernández & Granillo-Macías, 2020).

Axis 4. People-centered manufacturing

Human dimensions are the least measured in the literature analyzed: well-being and safety are measured in only 2 of the 24 articles, and staff participation in none; when they are addressed, they are mainly studied from the perspective of ergonomics (Castagnoli et al., 2024; Reiman et al., 2021). The available cases show that ergonomic and productive improvement are compatible: Gualtieri et al. (2020) reduced risk postures by up to 57% and cycle time by 12.3%, and Brito et al. (2018) integrated Lean tools with ergonomic assessments in a metallurgical company. ***Implication for the MIISCP:*** the human dimension must be assessed beyond ergonomics, and incorporate safety, training, and staff participation.

Overall, the findings indicate that the evaluation of industrial improvements focuses on productive outcomes, while environmental and, above all, human effects remain insufficiently measured. From this gap, the following proposal is formulated.

Proposal: Sustainable People-Centered Industrial Engineering Framework (MIISCP)

The MIISCP is proposed as a conceptual guide to organize the evaluation of improvement initiatives in different production systems. Its five phases are: process diagnosis; identification of opportunities; design of alternatives; implementation and monitoring; and standardization and continuous improvement. The sequence is iterative: the results of the monitoring can lead to a revision of the diagnosis and reformulation of the alternatives. Table 2 describes the actions and evaluation criteria of each phase, as well as the finding of the review that supports it; in this way, each component of the framework responds to the evidence analyzed.

Table 2. MIISCP phases, evaluation criteria, and review findings supporting them

Phase	Proposed actions	Evaluation criteria	Finding of the review that supports it
1. Process diagnosis	Define the process and record a baseline before intervening.	**Production:** productivity, quality and costs. **Environment:** consumption of materials and energy, and waste. **Human:** working conditions and risks.	Environmental benefit affirmed, but little measured.
2. Identifying opportunities	Analyze waste, reprocesses, waits and risks; collect proposals from staff.	**Production:** defects and lead times. **Environment:** material and energy losses. **Human:** ergonomic and safety risks; staff proposals.	Well-being assessed only from physical ergonomics; staff participation not measured.
3. Design of alternatives	Compare improvement solutions and possible technologies.	**Production:** expected profit and cost. **Environment:** reduction, reuse and recovery of materials. **Human:** effects on the tasks and training required.	Technology without evidence of applied cases; circularity focused on resource reduction.
4. Implementation and monitoring	Apply the selected alternative and measure its results.	The same indicators as the baseline, with comparable units and periods in all three dimensions.	Results of isolated cases, with heterogeneous and difficult to compare indicators.
5. Standardization and continuous improvement	Document improvements, correct deviations, and review indicators periodically.	**Production:** permanence in results. **Environment:** monitoring of consumption and waste. **Human:** Staff participation in reviews.	Staff participation not measured.

Note. Prepared by the author based on the results of the review.

Illustrative indicators

The evaluation criteria described in Table 2 need to be translated into concrete indicators in order to be measured. To this end, Table 3 proposes, for each of the six dimensions, a set of baseline indicators and the precautions to be considered when interpreting them. Their final selection will depend on the process and context in which the framework is applied.

Table 3. Illustrative indicators for future implementation of the MIISCP

Dimension	Possible indicators	Interpretation Caution
Productivity	Hourly conforming units; cycle time; program compliance.	Define period, unit and comparable conditions.
Quality and waste	Defect rate; rework; discarded material; first-pass performance.	Distinguish absolute reduction and rate per unit produced.
Resources and environment	Material and energy per unit; total consumption; waste; water where applicable.	Consider changes in production volume and system limits.
Well-being and safety	Ergonomic assessments; identified risks; incidents; corrective actions.	Do not infer well-being only from productivity.
Participation	Proposals received, evaluated and implemented; participation in reviews.	The amount alone does not prove that the participation is significant.
Economic viability	Implementation cost; operational cost; maintenance; payback period if applicable.	Explain assumptions, time horizon and costs not included.

Note. Prepared by the author based on the results of the review.

Contribution compared to other improvement approaches

The MIISCP does not replace existing improvement tools, but rather expands its evaluation criteria. The PDCA cycle and the DMAIC methodology structure improvement in stages, but are mainly oriented towards productive performance and quality; Lean-Green approaches incorporate the environmental dimension, although, as the

results of this review show, the human dimension is rarely measured. The MIISCP's contribution consists of integrating the three dimensions in all phases and explicitly measuring staff participation, an aspect that none of the articles analyzed evaluated.

Implications for industrial engineering

The proposal implies that an improvement initiative should be evaluated using a set of criteria and not on the basis of a single performance indicator; for example, a reduction in cycle time should be examined alongside quality, safety, and resource consumption. The framework also suggests integrating people who know the operations during the diagnosis and evaluation, and documenting how their input was considered. For technology, its incorporation should be justified by the problem it solves and include training, maintenance, and evaluation of its impact on tasks.

Limits and future agenda

The MIISCP is a conceptual proposal derived from the review and has not yet been applied or validated in an organization. To examine its usefulness, future research could: (1) apply it in case studies in manufacturing firms, particularly in the Mexican context; (2) validate the relevance of its phases and indicators by consulting specialists; and (3) compare its results with those of evaluations focused solely on productivity, in order to determine whether the framework allows for the identification of effects that these omit.

CONCLUSION

Industrial engineering plays a central role in the transition towards sustainable production systems on an international scale, since its decisions determine how resources are used, how work is organized and what effects production generates on the environment and people. The review of 25 documents from Europe, Latin America including Mexico, Asia and Africa shows that this discipline has effective tools to improve productivity, but that it still partially evaluates them.

The main finding is that the gap between what the literature states and what it measures is repeated in different contexts: the environmental dimension is mentioned in 17 of the 24 articles, but only 3 measure it with their own data; well-being and safety are measured in 2, and staff participation in none. The fact that this pattern appears in different countries and sectors indicates that it is a common challenge of industrial engineering and not a local problem.

People are the least evaluated component and, at the same time, the most decisive, since they are the ones who know the operations and sustain the improvements. For this reason, the MIISCP is proposed, a five-phase framework that simultaneously evaluates production, environment and people criteria, and that explicitly measures the participation of personnel. As it does not depend on a specific sector or country, it can be adapted to different production contexts.

The framework is a conceptual proposal that requires validation; as a future work, it is proposed to apply it in Mexican manufacturing companies and contrast its results with those of other international contexts.

In short, the contribution of industrial engineering to sustainable development will depend not only on its ability to increase production, but also on its ability to measure and address, anywhere in the world, its effects on resources and on the people who make improvement possible.

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