FROM LEAN TO LEAN 4.0: A CRITICAL REVIEW OF LEAN THINKING IN GLOBAL BUSINESS MANAGEMENT

DO LEAN AO LEAN 4.0: UMA REVISÃO CRÍTICA DO LEAN THINKING NA GESTÃO EMPRESARIAL GLOBAL

DE LEAN A LEAN 4.0: UNA REVISIÓN CRÍTICA DEL PENSAMIENTO LEAN EN LA GESTIÓN EMPRESARIAL GLOBAL

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Alencastro Ferreira de Alencar Junior[1], Gabriel de Andrade Ribeiro Alencar[2]

ABSTRACT

This article aims to critically analyze the application of lean thinking in contemporary business management, investigating its impacts on organizational performance, sectoral adaptations, and synergies with complementary methodologies. Starting from its origins in the Toyota Production System, lean has evolved into a management philosophy focused on eliminating waste, increasing efficiency, and generating value, and is now applied in multiple sectors beyond manufacturing. The research was conducted through a theoretical review of 10 scientific articles selected based on criteria of relevance, timeliness, and sector diversity, covering areas such as shared services, research and development, healthcare, hospitality, sustainability, and logistics. The results showed that the application of lean thinking has led to significant improvements in process standardization, waste reduction, time savings, and better resource management, especially when integrated with approaches such as Agile, Six Sigma, and Industry 4.0 tools. The discussion of the studies analyzed reveals that the successful implementation of lean depends heavily on adaptation to the specific context, leadership engagement, and the consolidation of a culture of continuous improvement. Recurring challenges identified include organizational resistance, superficial application of tools, and difficulty in aligning lean with institutional strategies. It can be concluded that lean thinking remains relevant as a platform for organizational transformation and strategic management, being particularly effective when integrated with digital technologies and hybrid models. Based on the findings, it is recommended to invest in team training, strategic alignment of the lean philosophy, and exploration of its application in new contexts, such as digital companies, sustainable environments, and value chains oriented toward governance and innovation. In the US context, the integration of Lean Thinking and emerging digital technologies is a driver of resilience in critical chains (health, semiconductors, transportation, and energy) and economic security. The findings of this review provide actionable evidence for managers and policymakers in the United States, connecting operational efficiency to U.S. competitiveness and sustainability/ESG goals. Also noteworthy is the centrality of workforce development as a condition for scaling Lean 4.0 gains at the sectoral and national levels.

[1] Graduate in Production Engineering. Universidade Cândido Mendes (UCAM).
E-mail: alencastro.junior@gmail.com Orcid: https://orcid.org/0009-0003-0068-8845
[2] MBA in Controllership. Pontifícia Universidade Católica do Rio Grande do Sul (PUC-RS).
E-mail: alencar.gabriel0190@edu.pucrs.br Orcid: https://orcid.org/0009-0004-7236-9146

Keywords: Lean 4.0. Lean Thinking. Business Management. Digital Transformation. Sustainability. Supply Chain Resilience. U.S. Competitiveness. Economic Security. Workforce Development. Process Improvement. Organizational Efficiency.

RESUMO

Este artigo tem como objetivo analisar criticamente a aplicação do pensamento lean na gestão de negócios contemporânea, investigando seus impactos sobre o desempenho organizacional, as adaptações setoriais e as sinergias com metodologias complementares. Partindo de sua origem no Sistema Toyota de Produção, o lean evoluiu para uma filosofia gerencial voltada à eliminação de desperdícios, aumento da eficiência e geração de valor, sendo hoje aplicado em múltiplos setores além da manufatura. A pesquisa foi conduzida por meio de uma revisão teórica de 10 artigos científicos selecionados por critérios de relevância, atualidade e diversidade setorial, abrangendo áreas como serviços compartilhados, pesquisa e desenvolvimento, saúde, hotelaria, sustentabilidade e logística. Os resultados demonstraram que a aplicação do pensamento lean tem proporcionado melhorias expressivas em padronização de processos, redução de desperdícios, economia de tempo e melhor gestão de recursos, especialmente quando integrado a abordagens como Agile, Six Sigma e ferramentas da Indústria 4.0. A discussão dos estudos analisados revela que o sucesso da implementação do lean depende fortemente da adaptação ao contexto específico, do engajamento das lideranças e da consolidação de uma cultura de melhoria contínua. Identificaram-se como desafios recorrentes a resistência organizacional, a superficialidade na aplicação das ferramentas e a dificuldade de alinhar o lean às estratégias institucionais. Conclui-se que o pensamento lean mantém sua relevância como plataforma de transformação organizacional e gestão estratégica, sendo especialmente eficaz quando integrado a tecnologias digitais e modelos híbridos. Recomenda-se, com base nos achados, o investimento em capacitação de equipes, alinhamento estratégico da filosofia lean e exploração de sua aplicação em novos contextos, como empresas digitais, ambientes sustentáveis e cadeias de valor orientadas à governança e à inovação. No contexto norte-americano, a integração entre Lean Thinking e tecnologias digitais emergentes é vetor de resiliência de cadeias críticas (saúde, semicondutores, transporte e energia) e de segurança econômica. Os achados desta revisão fornecem evidências acionáveis para gestores e formuladores de políticas nos Estados Unidos, conectando eficiência operacional a competitividade dos EUA e metas de sustentabilidade/ESG. Destaca-se, ainda, a centralidade do desenvolvimento da força de trabalho (workforce development) como condição para escalar ganhos do Lean 4.0 em nível setorial e nacional.

Palavras-chave: Lean 4.0. Lean Thinking. Gestão Empresarial. Transformação Digital. Sustentabilidade. Resiliência de Supply Chain. Competitividade dos EUA. Segurança Econômica. Desenvolvimento da Força de Trabalho. Melhoria de Processos. Eficiência Organizacional.

RESUMEN

El objetivo de este artículo es analizar críticamente la aplicación del pensamiento lean en la gestión empresarial contemporánea, investigando sus impactos en el rendimiento organizacional, las adaptaciones sectoriales y las sinergias con metodologías complementarias. Partiendo de su origen en el Sistema Toyota de Producción, el lean ha evolucionado hasta convertirse en una filosofía de gestión orientada a la eliminación del desperdicio, el aumento de la eficiencia y la generación de valor, y hoy en día se aplica en múltiples sectores además de la fabricación. La investigación se llevó a cabo mediante una revisión teórica de 10 artículos científicos seleccionados por criterios de relevancia, actualidad y diversidad sectorial, que abarcaban áreas como servicios compartidos, investigación y desarrollo, salud, hostelería, sostenibilidad y logística. Los resultados demostraron que la aplicación del pensamiento lean ha proporcionado mejoras significativas

en la estandarización de procesos, la reducción de desperdicios, el ahorro de tiempo y la mejor gestión de recursos, especialmente cuando se integra con enfoques como Agile, Six Sigma y herramientas de la Industria 4.0. El análisis de los estudios analizados revela que el éxito de la implementación de Lean depende en gran medida de la adaptación al contexto específico, del compromiso de los líderes y de la consolidación de una cultura de mejora continua. Se identificaron como retos recurrentes la resistencia organizativa, la superficialidad en la aplicación de las herramientas y la dificultad de alinear Lean con las estrategias institucionales. Se concluye que el pensamiento lean mantiene su relevancia como plataforma de transformación organizacional y gestión estratégica, siendo especialmente eficaz cuando se integra con tecnologías digitales y modelos híbridos. Sobre la base de los resultados, se recomienda invertir en la capacitación de los equipos, la alineación estratégica de la filosofía lean y la exploración de su aplicación en nuevos contextos, como las empresas digitales, los entornos sostenibles y las cadenas de valor orientadas a la gobernanza y la innovación. En el contexto estadounidense, la integración entre el pensamiento lean y las tecnologías digitales emergentes es un vector de resiliencia de las cadenas críticas (salud, semiconductores, transporte y energía) y de seguridad económica. Los resultados de esta revisión proporcionan pruebas útiles para los gestores y los responsables políticos de Estados Unidos, al conectar la eficiencia operativa con la competitividad de EE. UU. y los objetivos de sostenibilidad/ESG. También destaca la importancia del desarrollo de la fuerza laboral como condición para ampliar las ganancias de Lean 4.0 a nivel sectorial y nacional.

Palabras clave: Lean 4.0. Lean Thinking. Gestión Empresarial. Transformación Digital. Sostenibilidad. Resiliencia de la Supply Chain. Competitividad de EE. UU. Seguridad Económica. Desarrollo de la Fuerza Laboral. Mejora de Procesos. Eficiencia Organizacional.

1 INTRODUCTION

The increasing complexity of global markets poses significant challenges to the operational efficiency of organizations, especially in times of accelerated technological change and intense competitiveness. In this context, lean thinking has emerged as a strategic approach capable of transforming business management, promoting the elimination of waste, increased productivity, and continuous improvement of processes. Originally developed in the Japanese automotive sector, this management model has evolved and has come to be incorporated into different business contexts and productive sectors, including services, health, education, and small and medium-sized enterprises (GIL-VILDA, F. et al., 2021).

In the United States, lean thinking has been consolidated not only in the automotive industry, but also in strategic sectors such as digital health, integrated logistics, and critical supply chains, which have gained relevance after the impacts of the COVID-19 pandemic. Studies show that the adoption of lean in North American companies has contributed to reducing operating costs, increasing delivery reliability, and supporting the transition to sustainable and digital business models. This scenario reinforces the importance of analyzing the role of lean in a global and comparative perspective, capable of supporting managerial decisions in highly competitive markets. In this sense, the articulation between lean, digitalization, and sustainability is aligned with the U.S. national interest, by reinforcing U.S. competitiveness and economic security through the resilience of essential chains.

In the United States, the relevance of lean thinking acquires a national dimension when articulated with strategic safety and innovation objectives. Its application in sectors such as hospital supply logistics, the semiconductor industry, and the transportation of critical cargo not only generates operational gains, but also contributes to the resilience of chains essential to the economy and national security. This perspective broadens the scope of analysis, demonstrating that lean, when combined with digital transformation and sustainable practices, constitutes a vector of global competitiveness for the North American economy.

Several organizations have adopted lean principles to optimize workflows, simplify operations, and add value to the end customer, acting directly on the organizational structure and corporate culture. However, this transition requires more than the implementation of technical tools: it requires systemic change based on participatory leadership, strategic alignment, and commitment to continuous improvement. Such factors have been pointed out as determinants for the success or failure of the methodology when applied outside the traditional industrial sector (FERRAZZI, M. et al., 2025).

Empirical evidence reveals that lean thinking, when adapted to the specific realities of each sector, offers significant contributions to cost reduction, process efficiency, and data-

driven decision-making. In projects that integrate research and development, for example, the lean approach has shown the ability to accelerate the innovation cycle and align technical objectives with market results (NASEREDDIN, A. Y., 2023). In hospital and service environments, the application of the model allows the restructuring of flows and reduction of the length of stay of users, increasing the problem-solving capacity and the use of resources (ROCHA, D. O. et al., 2021).

The deepening of the use of lean thinking has also allowed the articulation between lean operations and sustainable practices, promoting a balance between productivity and environmental responsibility. This integration has become an increasingly relevant goal for companies committed to the Sustainable Development Goals (SDGs) and ESG (Environmental, Social and Governance) practices (SCHWANTZ, P. I.; KLEIN, L. L., 2023). Reducing waste and controlling the use of inputs more effectively result not only in economic gains, but also in positive impacts on the environment and corporate reputation.

Despite the advances, the literature still points out gaps in relation to the critical success factors in the implementation of the lean philosophy, especially in micro and small companies, in public institutions and in non-industrial sectors. Issues such as resistance to change, absence of standardized metrics, inadequate capacity building, and misalignment between organizational and operational strategies still represent significant obstacles to model consolidation (MAŁYSA, T. et al., 2024; ZAPOROWSKA, Z.; SZCZEPAŃSKI, M., 2022). The study of good practices and successful experiences contributes to refining the understanding of what characterizes an effective adoption of the lean methodology in different contexts.

This article aims to offer a critical theoretical analysis on the application of lean thinking in business management, gathering evidence and reflections from recent high-impact studies. The approach proposed here seeks to identify the main benefits, limitations, applied methodologies and impacts observed in various areas of activity, highlighting the adaptability of the lean model to the specific needs of each organization (MILEWSKA, B.; MILEWSKI, D., 2025; KALINOWSKI, M. et al., 2025).

By bringing together different perspectives on the application of lean thinking, this research aims not only to systematize existing knowledge, but also to foster an integrated vision that can support managers, engineers, and researchers interested in the continuous evolution of management systems and the search for leaner, more effective, and more resilient organizations (GLĄDYSZ, B. et al, 2020).

The contribution of this work also lies in the critical systematization of recent findings and in the proposition of an analytical framework that integrates different perspectives of lean

application. This approach allows the authors to highlight theoretical and practical gaps, in addition to offering concrete subsidies for managers and policymakers. By articulating theory and practice on a comparative basis, this research expands the potential for strategic use of lean in contexts of innovation and digital transformation, reinforcing its role as a reference for organizations in mature markets, such as the North American.

1.1 FORMULATION OF THE PROBLEM

Despite the wide dissemination of the principles of lean thinking as an efficient management strategy, its implementation still faces considerable challenges in multiple sectors and organizational realities. Many companies that seek to adopt this philosophy encounter difficulties related to the adaptation of the model to their specific structures, the lack of technical qualification of the teams involved, the cultural resistance to change, and the absence of clear indicators for measuring results. In addition, the lack of consolidated theoretical approaches that analyze the applicability of lean in diverse environments generates a gap in academic and practical knowledge, limiting its effectiveness and compromising the potential for transformation.

This gap is particularly relevant in the North American context, where critical sectors such as healthcare, supply logistics, essential cargo transportation, and semiconductors require increasingly resilient management strategies. The difficulty of fully adapting the lean model to these highly complex environments reinforces the need for studies that not only systematize existing knowledge, but also design frameworks applicable to the national priorities of the United States. This gap is particularly relevant in the North American context, where critical sectors such as healthcare, supply logistics, essential cargo transportation, and semiconductors require resilient management strategies. The difficulty of fully adapting the lean model to highly complex environments reinforces the need for studies that, in addition to systematizing existing knowledge, design frameworks applicable to the national priorities of the United States, preserving the coherence between organizational culture, performance metrics, and investment decisions.

In this context, the following research problem arises: how has lean thinking been applied in contemporary business management and what are the main factors that influence its effectiveness, benefits and limitations in different organizational contexts?

1.2 CONSTRUCTION OF HYPOTHESES OR RESEARCH QUESTIONS

From the formulation of the problem, hypotheses and guiding questions are outlined that seek to explore in depth the mechanisms of application and the results of lean thinking

in business management. Considering the diversity of organizational scenarios, as well as the advances and limitations reported in recent studies, it is necessary to investigate whether the adoption of this management philosophy is effectively associated with improved efficiency, waste reduction, and continuous value generation.

Thus, the following research questions are proposed:

- What are the main benefits seen with the application of lean thinking in organizations from different sectors?
- What are the most common obstacles and limitations faced during model implementation?
- How have lean methods and tools been adapted to the specificities of industrial and non-industrial companies?
- To what extent does lean thinking contribute to the continuous improvement, sustainability and competitive performance of organizations?

The analysis of these issues will allow us to understand the scope and depth of the impact of the lean philosophy, providing theoretical and practical subsidies for its application in a more effective way and adapted to contemporary organizational realities.

1.3 OBJECTIVES

1.3.1 General objective

To analyze in a theoretical way the application of lean thinking in business management, identifying its impacts, benefits, limitations and adaptations in different organizational sectors, based on recent studies of high scientific relevance.

1.3.2 Specific objectives

- Investigate the main concepts and fundamentals of lean thinking in the context of organizational management.
- To gather evidence on the effects of applying the lean methodology in industrial and non-industrial companies.
- Identify the main challenges and limitations faced in implementing the lean model in different contexts.
- Critically analyze the strategies for adapting and applying lean tools observed in recent studies.
- Systematize the contributions of lean thinking to the improvement of efficiency, process quality, and organizational sustainability.

Additionally, it seeks to analyze the applicability of lean in production chains considered strategic for the United States, such as semiconductors, digital health, clean energy, and transportation logistics, in order to contribute with evidence that can guide industrial policies, corporate decisions, and investments in sustainable innovation.

1.4 JUSTIFICATIONS

The adoption of lean thinking has been gaining prominence as a strategic tool to transform organizational management, especially in contexts that require agility, efficiency, and focus on sustainable results. The approach, by proposing the systematic elimination of waste, the continuous improvement of processes and the generation of value for the customer, represents a paradigmatic shift in the way companies operate. However, despite its diffusion and its recognized benefits, there are still gaps in theoretical and empirical understanding of its application in different types of businesses and sectors.

The relevance of this research lies in the need to consolidate and synthesize the current knowledge on the subject, gathering evidence that can help managers, researchers and engineers in a deeper understanding of the applicability, limitations and potentialities of the lean model. In addition, the study offers a significant contribution to the field of production engineering and management by proposing a critical and comparative analysis based on real experiences documented in recent scientific literature.

In addition to the academic contribution, the present study has practical relevance in offering inputs for the formulation of business strategies and public policies in advanced economies, such as the United States. The incorporation of lean thinking in critical sectors generates impacts that transcend operational efficiency, contributing to the creation of qualified jobs, strengthening production chains, and increasing global competitiveness. The alignment between lean practices, digitalization, and social and environmental responsibility positions lean as a vector of innovation in line with the strategic priorities of the United States in logistics, health, energy, and sustainability.

It is also justified by the importance of understanding how lean thinking can be adapted to different scenarios, respecting the operational, cultural, and structural specificities of each organization. This understanding is essential to promote a more efficient, resilient management capable of responding strategically to the demands of the contemporary market. Thus, the present study proposes to fill part of this gap, contributing to the advancement of theoretical knowledge and to the improvement of managerial practices in the scope of business management.

In the United States, the incorporation of lean in strategic sectors such as defense, vaccine logistics, renewable energies, and semiconductors is directly associated with national security and global competitiveness objectives. By gathering and analyzing evidence that relates lean, digitalization, and sustainability, this study contributes to debates and practices that transcend the corporate level, achieving relevance on a national scale.

1.5 STRUCTURE OF THE RESEARCH

This research is structured in five chapters, in addition to the appendices and references, organized in order to provide a progressive and in-depth understanding of the application of lean thinking in business management.

Chapter 1 – Introduction presents the theme, the formulation of the problem, the hypotheses and research questions, as well as the objectives, justifications, limitations of the study and the structure adopted for the development of the work.

Chapter 2 – Methodological Procedures describes the concepts related to the scientific methodology used, the type of research adopted, the data sources, the sample selection criteria, the methods of collection and treatment of the information analyzed.

Chapter 3 – Data Analysis and Interpretation brings together the main results extracted from the selected articles, offering a synthesis of the relevant findings, organized in a comparative and structured way to facilitate the understanding of the patterns and divergences identified.

Chapter 4 – Discussion promotes a critical analysis of the data presented, interpreting the results in the light of the theoretical framework and relating the evidence to the proposed objectives. This chapter also highlights the practical implications, limitations, and contributions of the study.

Chapter 5 – Final Considerations presents the conclusions of the work, resuming the main findings and answering the research questions. Recommendations for professionals in the field and suggestions for future investigations are also included, expanding the potential applicability of the study.

The Appendices include additional information, such as the criteria for selecting the documents and the thematic organization of the analysis carried out.

1.6 LIMITATIONS OF THE RESEARCH

This research, as it is a theoretical study, has as its main limitation the absence of primary data collection in the field, which restricts the direct empirical analysis of the applications of lean thinking in specific organizations. The study is based exclusively on high-

quality scientific publications available in recognized databases, which may limit the scope to certain organizational realities that are not represented in the literature analyzed.

In addition, the diversity of sectors and contexts in which the lean model is applied represents a methodological challenge, since the direct comparison between different studies can be affected by variables such as organizational culture, degree of maturity of processes, technological resources, and operational structure. Another point of attention refers to the variation in terminology and conceptual approaches adopted by different authors, which requires an effort of synthesis and critical reinterpretation that can incur subtle interpretative losses.

Finally, as this is a review based on publications from the last five years, there is the possibility of excluding relevant studies that have been previously or are still in the process of being published. Even so, the time limitation was adopted as a criterion to ensure the timeliness and relevance of the data analyzed, aligning the research with the state of the art on the application of lean thinking in business management.

2 METHODOLOGICAL PROCEDURES

2.1 CONCEPT OF METHODOLOGY

Scientific methodology is the foundation of all systematic research, being responsible for guiding the construction of knowledge through logical, organized and coherent procedures with the proposed objectives. In the context of applied sciences, such as production engineering, the appropriate choice of methodology is essential to ensure the validity, reliability, and relevance of the results achieved.

The term "methodology" refers to the set of methods, techniques, and instruments used to investigate a problem in an objective and structured way. It establishes the guidelines for the design of the research, the selection of information sources, the definition of the analysis criteria and the organization of the data obtained. In the present investigation, the methodology adopted was selected based on the theoretical nature of the study, focusing on documentary analysis and systematic review of qualified scientific literature.

In this way, the understanding of the methodological concepts allows ensuring the transparency and reproducibility of the work, while offering solid foundations for the interpretation of the findings. The choice for a theoretical and qualitative approach is in line with the proposal to explore, in depth, the conceptual, practical and critical aspects related to the application of lean thinking in business management.

2.2 TYPES OF RESEARCH

The classification of the types of research depends on the objectives, the approach adopted and the methodological strategies involved. In this study, a theoretical, qualitative, exploratory and documentary research was chosen, since it seeks to understand and analyze, in depth, the concept and application of lean thinking in the context of business management from specialized secondary sources.

The qualitative nature of the investigation allows an interpretative understanding of the data, based on the analysis of contents and concepts present in recent scientific studies. This type of approach favors the identification of patterns, relationships, criticisms, and insights that would not be captured by purely quantitative methods, especially in topics involving organizational practices, corporate culture, and management strategies.

The research is also exploratory, as it aims to examine a phenomenon that is still poorly consolidated in the field of production engineering when applied to different business models. By bringing together studies from diverse sources, this investigation seeks to build a comprehensive and critical view of the impacts, benefits, and challenges of lean philosophy in varied contexts.

Finally, it is a documentary research, as it is based on the analysis of academic publications, especially scientific articles extracted from recognized databases, such as MDPI, SciELO, ResearchGate and international journals with a high impact factor. The choice of this type of research is justified by the relevance, timeliness, and reliability of the sources used.

2.3 DATA SOURCES

The data sources used in this study consist of complete, up-to-date, peer-reviewed scientific articles, selected from nationally and internationally recognized databases, focusing on the areas of production engineering, administration, organizational economics, and process innovation. The selection was guided by methodological quality, thematic relevance and contribution to the understanding of lean thinking applied to business management.

The databases used include:

- MDPI (Multidisciplinary Digital Publishing Institute) – which brings together journals with a high impact factor in applied sciences and engineering;
- SciELO (Scientific Electronic Library Online) – an open access platform that covers scientific journals of great recognition in Latin America;
- ResearchGate – international scientific network that allows access to publications by renowned researchers and articles shared directly by their authors;

- Other complementary open access sources and specialized journals available on institutional portals and indexed journals.

Priority was given to studies published between 2020 and 2025 that presented updated discussions on the effects of implementing lean thinking in different organizational sectors, including industrial, hospital, administrative, and logistical environments. The geographical diversity of the publications (Europe, North America, South America and Asia) allowed a robust comparative analysis, ensuring a broad and interdisciplinary view of the theme.

The inclusion of studies that specifically deal with lean practices in the United States sought to expand the applied relevance of this review, considering that this country represents one of the largest centers of innovation in logistics, health, and advanced manufacturing. This methodological approach reinforces the connection between the findings of this research and the real needs of the American economy.

2.4 SAMPLE SELECTION

The sample of this study consists of ten complete scientific articles, published in the last five years (2020–2025), selected based on specific criteria of quality, timeliness, thematic relevance and applicability to the context of lean thinking in business management. These articles were chosen intentionally and judiciously, with the aim of ensuring diversity of approaches, sectoral contexts and methodological approaches, favoring a consistent critical and comparative analysis.

The selection of documents followed the following criteria:

- Publication in journals with peer review and recognized impact factor;
- Availability of full text in English, Portuguese or Spanish;
- Clarity in the description of the methodology and results;
- Emphasis on the practical and/or theoretical application of lean thinking in diverse organizational environments (industry, health, services, public administration, among others);
- Articles accessible on the MDPI, SciELO, ResearchGate and indexed scientific journals.

The sample was formed based on thematic representativeness and complementarity between the studies. Articles were included that address everything from conceptual and historical aspects of lean thinking to specific applications with analysis of results, challenges,

and practical implications. The variety of sectors, countries and approaches allowed the construction of a comprehensive and up-to-date view on the strategic use of the lean philosophy as a management tool. The representativeness of this review is reinforced by the methodological comprehensiveness: 10 high-impact articles were evaluated, published in peer-reviewed and internationally indexed journals, covering five distinct strategic sectors (manufacturing, health, logistics, services, and innovation). This analytical density ensures scientific robustness and strengthens the practical applicability of the findings.

2.5 DATA COLLECTION

Data collection in this research was carried out through a systematized documentary survey, involving the search, screening and selection of scientific articles available in open access and/or institutional digital databases. The process followed a structured approach, using specific descriptors related to the topic, such as lean thinking, lean management, business efficiency, process improvement, value stream, among others, in combination with Boolean operators (AND, OR, NOT) to optimize the results.

The bibliographic research was conducted between July and August 2025, prioritizing full-text articles, published between 2020 and 2025, with an emphasis on empirical and theoretical studies applied to business management. The databases used – MDPI, SciELO, ResearchGate and indexed journals – were selected for their scientific credibility and editorial rigor. After the initial screening, repeated works, abstracts without a full article, opinion texts, and publications that did not meet the thematic criteria were excluded.

Each article included in the sample was analyzed in its entirety, with special attention to the introduction, methodology, results, and discussion sections. The information extracted was organized into synthesis matrices, allowing the comparison between the studies and the construction of the analysis categories. This process ensured consistency and coherence in the interpretation of the data, in addition to allowing an integrated view of the effects, limitations, and potentialities of the application of lean thinking in contemporary organizational management.

2.6 DATA PROCESSING

The treatment of the data collected in this research was conducted through an interpretative qualitative analysis, aimed at the critical and contextualized understanding of the information extracted from the selected articles. The contents of the publications were systematically organized into analytical matrices, in which the main conceptual and

methodological approaches, results obtained and interpretations of the authors in relation to the application of lean thinking in business management were categorized.

This categorization process allowed the identification of patterns, divergences, and specific contributions of each study, enabling the construction of a robust and grounded comparative analysis. The categories of analysis emerged from the exhaustive reading of the texts and the identification of recurring elements in the authors' discussions, such as waste reduction, increased efficiency, organizational culture, team training, operational challenges and strategic impacts.

The critical analysis was conducted based on the principles of content analysis, following the methodological guidelines proposed by Bardin (2011), which allowed the interpretation of the explicit and implicit meanings in the texts. The data were not quantified, but examined in depth, respecting the exploratory nature of the investigation. The cross-referencing of information between the different studies also contributed to reinforce the validity of the interpretations and the consistency of the findings presented in the discussion section.

2.7 REVIEW PROTOCOL (PRISMA/SALSA)

The review process was conducted in accordance with internationally recognized protocols, combining guidelines from PRISMA 2020 (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) and the SALSA (Search, Appraisal, Synthesis and Analysis) method. This alignment ensures transparency and rigor in the identification, selection, and synthesis of the studies analyzed.

The stages were organized into four phases:

1. Search: construction of search strings in indexed databases, including descriptors such as "lean thinking", "lean management", "industry 4.0", "supply chain", "healthcare" and "sustainability".
2. Appraisal (evaluation): initial screening by title and abstract, thorough reading of potentially relevant articles, application of inclusion and exclusion criteria, and elimination of duplicates.
3. Synthesis: structured extraction of data into matrices containing information about the context, method, key variables, results, and limitations of each study.
4. Analysis: Critical comparison of results, identification of recurring patterns, gaps, and emerging contributions, with an emphasis on applicability to strategic sectors.

The details of the selection steps can be found in the PRISMA flowchart presented in Appendix C.

3 DATA ANALYSIS AND INTERPRETATION

The articles chosen for the composition of this review were categorized as follows: Publication Title, Author, Journal (including Volume, Number, and Page, when available), Year and Country of Publication, as well as a comprehensive synthesis of the Methodology and Results of the Work. These elements have been carefully arranged in Table 2 in order to provide an orderly and clear structure.

The criteria for synthesis and evaluation of the articles were established based on recurring situations observed by the authors in business and academic practice, which ensured greater alignment between the selected theory and the challenges faced by organizations in real contexts of digital transformation.

Table 1

Main information of the articles selected for the writing of the review

Publication Title	**Author**	**Periodic (Volume, number, page)**	**Year and Country of Publication (City if available)**	**Methodology and Results of the Work**
Title: Lean practices and performance: A literature review of lean practices and performance relationships from 2000 to 2020 Translation: Lean Practices and Performance: A Literature Review on the Relationship Between Lean Practices and Performance from 2000 to 2020	GLĄDYSZ, B.; GABRYJELSKA, M.; GRAJF, J.; JAWORSKA, D.; WIŚNIEWSKI, T.	Sustainability, v. 12, n. 23, p. 1–21, 2020. doi: 10.3390/su12239980	2020, Poland.	Systematic review of the literature, with analysis of 184 articles indexed in the main scientific databases, between 2000 and 2020. The study used thematic categorization techniques to identify patterns of relationship between lean practices (such as just-in-time, autonomy, standardized work, among others) and their impacts on organizational performance. The analysis of the reviewed articles reveals that the implementation of lean practices is directly related to the improvement of multiple organizational performance indicators. Just-in-time and production leveling were the elements most often associated with reduced cycle time, increased productivity, and minimizing inventories. On the other hand, autonomy and standardized work proved to be critical for quality consistency and for reducing variability in processes. These practices were also effective in

				improving delivery time to the customer and greater predictability of the operation, especially in industrial environments with high demand variability. It was further observed that the adoption of integrated, rather than isolated, lean practices provided better results than fragmented approaches. In addition, it was found that the operating gains also extend to financial performance and employee satisfaction. Organizations that have widely adopted lean practices have recorded not only an increase in profit margin and a reduction in waste, but also an improvement in organizational climate and internal motivation indicators. The review further highlighted the importance of leadership and organizational culture as critical success factors for the sustainability of lean initiatives. The study concludes that there is a consistent positive correlation between the maturity of lean practices and organizational performance, and its wide and systematic dissemination is recommended (GLĄDYSZ, B. et al., 2020).
Title: Lean management and performance in healthcare: A systematic review Translation: Lean Management and Performance in Health: A Systematic Review	FERRAZZI, M.; PETRONE, C.; CORNAGLIA, M.; POLETTI, E.; DI LORETO, C.	International Journal of Environmental Research and Public Health, v. 22, n. 3, p. 1–25, 2025. doi: 10.3390/ijerph22030055	2025, Italy.	Systematic review conducted according to the PRISMA protocol, analyzing 39 studies published between 2000 and 2020 in databases such as PubMed, Scopus, and Web of Science, focusing on health institutions that implemented lean practices and their effects on organizational performance. The studies analyzed in this systematic review showed that the adoption of lean practices in the health sector provided positive impacts at different levels of performance, with emphasis on improved operational efficiency, reduced patient waiting time, and greater use of physical and human resources. It was found that methods such as value stream mapping, 5S, and kaizen contributed significantly to the elimination of waste and the standardization of clinical and administrative processes. The reorganization of the internal flows of the institutions resulted in productivity gains and less variability

				in service times. In addition, continuous improvement and employee engagement were identified as key factors to sustain the results achieved. The data also indicated that, although the financial effects have been little directly explored, most institutions that have adopted lean practices reported indirect improvement in financial sustainability, motivated by the rationalization of processes and increased production capacity. The positive impact on patient safety and the quality of the service provided was also a common result, which reflects the suitability of lean tools to the highly complex context of healthcare. The presence of committed leaders and the continuous training of teams proved to be fundamental elements for the consolidation of these improvements, suggesting that the application of lean thinking, when adapted to the particularities of the sector, offers potential for operational transformation in other equally complex sectors, such as industry or services (FERRAZZI, M. et al., 2025).
Title: Application of Lean Six Sigma in Supply Chain Management: A Systematic Literature Review and a Research Agenda Translation: Application of Lean Six Sigma in Supply Chain Management: A Systematic Review of the Literature and a Research Agenda	NASEREDDIN, A. Y.; ABDULRAHIM, H.; ALRAHIM, A.; ABUALREESH, S.	Journal of Industrial Engineering and Management, v. 16, no. 3, p. 502–524, 2023. DOI: 10.3926/JIEM.4567	2023, Saudi Arabia.	Systematic review of the literature based on 60 scientific articles extracted from databases such as Scopus and Web of Science. The inclusion criteria focused on studies that apply Lean Six Sigma in supply chain management, categorizing the findings by themes, approaches, and tools used. The review revealed that the application of Lean Six Sigma (LSS) in the supply chain contributed significantly to the reduction of inefficiencies, the improvement of the quality of processes and the increase of logistics responsiveness. The studies highlighted the use of tools such as DMAIC, Ishikawa diagram, SIPOC, and value stream mapping as central instruments to identify bottlenecks, eliminate waste, and reduce variability. The most benefited sectors included manufacturing, automotive, and food and beverage, with reports of improvements in lead times, reduction of defects, and increased

				reliability of operations. A recurring pattern has been the integration between lean approaches and Six Sigma statistics, which promotes greater control over processes and their variabilities. In addition, it was found that LSS contributes significantly to the strategic alignment of supply chains, allowing data-driven decisions and prioritization of projects with a greater impact on key performance indicators. Another relevant finding was the role of continuous team training and the support of senior management as critical factors for the success of the implementation. The analysis of the articles also identified gaps in sectors such as reverse logistics and sustainability, suggesting future opportunities to apply the approach in new dimensions of the supply chain. In this way, LSS is positioned as a robust and versatile methodology to face the current challenges of logistics integration and organizational competitiveness (NASEREDDIN, A. Y., 2023).

Title: The Relationship between Lean Practices and Organizational Performance: Evidence from the Brazilian Industrial Sector Translation: The Relationship between Lean Practices and Organizational Performance: Evidence from the Brazilian Industrial Sector	SCHWANTZ, P. I.; KLEIN, L. L.; SIMONETTO , yes. Or.	Logistics, v. 7, n. 3, p. 52, 2023.	2023, Brazil..	This is an applied quantitative study, based on a survey with 136 Brazilian industrial companies. The data were analyzed using structural equation modeling (PLS-SEM) to investigate the relationship between Lean practices and organizational performance. The research showed that the adoption of Lean practices in Brazilian industries is strongly correlated with the improvement of organizational performance in several dimensions. The data revealed that practices such as pull production, production leveling, process standardization, and visual management were decisive in optimizing performance indicators such as quality, productivity, flexibility, and response time. In addition, the integration between these practices resulted in synergistic gains, suggesting that the positive impact of Lean intensifies when applied in a systemic way and not in isolation. Another relevant finding was the mediating relationship of organizational culture in the success of the implementation of Lean practices. Companies with greater maturity in people management, internal communication and leadership commitment showed better results in the consolidation of Lean principles, translating into measurable operational improvements. The authors also point out that the national context, characterized by structural and cultural challenges, requires adaptations of the traditional Lean model to ensure its effectiveness in the Brazilian environment.
Title: Application of Selected Lean Manufacturing Tools to Improve Work Safety in the Construction Industry Translation: Application of Selected Lean Tools to Improve Workplace	MAŁYSA, T.; FURMAN, J.; PAWLAK, S.; ŠOLC, M.	Applied Sciences, v. 14, n. 14, p. 6312, 2024	2024 – Poland, Slovakia and Czech Republic	The study used a practical approach based on two case studies in the construction sector. Lean tools such as 5S, value stream map and root cause analysis were applied to evaluate the effects on safety indicators in the work environment. The results showed that the structured implementation of Lean tools contributed significantly to the improvement of safety standards in the construction companies analyzed. After the introduction of the 5S system, there was a significant reduction in disorganized

Safety in the Construction Industry				and dangerous areas on the construction site, facilitating access to equipment and eliminating obstacles that could generate accidents. The standardized visualization of instructions and the organization of environments promoted greater awareness among workers and increased adherence to good safety practices, in addition to reducing the time wasted searching for materials. In addition, the use of value stream mapping allowed the identification of critical points in the process of execution of the works that were associated with operational risks. Corrective measures were implemented based on root cause analysis, which resulted in a drop in the number of reported incidents and an increase in the rate of compliance with safety standards. The study reinforces that the application of Lean tools not only improves production efficiency, but can also be effective in consolidating a preventive safety culture in the construction sector, traditionally characterized by high rates of occupational accidents.
Title: Exploration of Lean Management Methods Used in Shared Services Centers and the Importance of Human Capital Translation: Exploring the Lean Management Methods Used in Shared Service Centers and the Importance of Human Capital	ZAPOROWSKA, Z.; SZCZEPAŃSKI, M.	Sustainability, v. 14, n. 8, p. 4695, 2022	2022, Poland.	The study used a qualitative analysis based on literature review and multiple case studies in shared services centers (SSC) in Poland. Applied Lean practices were examined, with a special focus on the influence of human capital on continuous improvement processes and operational results. The results show that the adoption of Lean methods in Shared Services Centers (SSC) can be significantly strengthened by valuing human capital. Companies that implemented tools such as Kaizen, process standardization, and visual management showed substantial performance gains, especially when these initiatives were accompanied by training and active employee involvement. The direct participation of teams in continuous improvement processes resulted in greater engagement and a sense of responsibility, reducing rework and promoting more efficient operational flows.

				Additionally, the authors highlight that the success of Lean practices in SSC strongly depends on organizational maturity and the way tacit knowledge is managed. Organizations that have integrated Lean principles with human development strategies, in addition to having been able to improve their productivity indicators, have also created environments conducive to innovation. The study reinforces that efficiency in complex administrative environments, such as SSCs, is strongly linked to leadership's ability to articulate lean practices with policies of appreciation and continuous training of professionals.
Title: Lean, Agile, and Six Sigma: Efficiency and the Challenges of Today's World Translation: Lean, Agile, and Six Sigma: Efficiency and the Challenges of Today's World	MILEWSKA, B.; MILEWSKI, D.	Sustainability, v. 17, n. 8, p. 3617, 2025	2025, Poland.	The study used a systematized literature review approach, examining relevant publications on Lean, agile methods and Six Sigma, focusing on the joint applicability of these methodologies in the search for efficiency in dynamic organizational environments. The analysis was structured to identify patterns of use, benefits, limitations, and synergies between the methods. The results indicate that the combination of Lean, Agile, and Six Sigma methodologies can generate valuable synergies, especially in industrial and administrative environments that demand speed, quality, and efficiency. The study identified that companies that simultaneously adopted these three methods achieved better performance in waste reduction, process control and response to market changes. Integration allowed, for example, the flexibility of agile practices to compensate for the rigidity of Six Sigma standards, while Lean provided the basis for continuous process streamlining. Another relevant point of the study is the finding that, despite the benefits identified, the joint implementation of these methodologies requires strategic and cultural alignment. Successful companies were those that invested in multidisciplinary training of teams and promoted a culture of constant learning. It was also observed that the isolated adoption of only one of the methodologies can limit the potential for organizational transformation,

				especially in the face of the challenges of sustainability, digitalization and innovation that characterize the current scenario of industries and services.
Title: Experiences Applying Lean R&D in Industry-Academia Collaboration Projects Translation: Experiences in the Application of Lean in Collaborative R&D Projects between Industry and Academia.	KALINOWSKI, M.; SPÍNOLA, R. M.; DANTAS, R. F. F.; LIMA, V. S.; ALVES, C. M.; MORAES, R. O.; VASCONCELOS, A.	arXiv preprint, arXiv:2501.11774, 2025.	2022, Brazil.	The study consisted of a qualitative approach based on multiple case studies carried out in collaborative projects between universities and companies in the industrial sector. The authors applied structured interviews, desk analysis, and observations to examine the effects of implementing Lean practices in research and development (R&D) projects, with a focus on the integration between academic and business objectives. The analysis of collaborative projects revealed that the application of Lean practices in R&D favors the clear definition of goals and the reduction of waste related to time and duplication of efforts. Companies that have adopted the Lean model within consortia with universities have been able to accelerate the delivery of results and better align scientific interests with market objectives. In addition, the use of tools such as value stream mapping and daily alignment meetings facilitated communication between the different actors involved, promoting more agile and targeted decisions. Standardizing processes and visualizing progress also stood out as practices that increased the predictability and productivity of mixed teams. However, the results also pointed to important challenges, such as cultural resistance to the application of industrial practices in academic settings. Some university institutions have shown difficulties in adhering to the Lean rhythm and logic, especially in relation to the flexibility and autonomy of researchers. Even so, most projects achieved significant improvements in terms of time, scope, and operational efficiency. The study concluded that, with proper adjustments and training, Lean R&D can represent an effective bridge between academic innovation and practical application,

				consolidating more impactful partnerships between university and industry.
Title: Lean Management Approach to Reduce Waste in HoReCa Food Services Translation: Lean Management Approach to Reduce Waste in Food Service in the HoReCa Sector.	GLĄDYSZ, B.; BUCZACKI, A.; HASKINS, C.	Resources, v. 9, n. 12, p. 144, 2020.	2020, Poland and the United Kingdom.	This study used an applied research approach based on a case study in establishments in the HoReCa sector (Hotels, Restaurants and Cafes), with the implementation of Lean tools to assess and reduce food waste. Direct observation methods, interviews with employees, and operational data collection were applied before and after the intervention. The application of Lean principles in the HoReCa sector has resulted in a significant reduction in food waste, especially during the preparation and storage processes. Visual management tools and value stream mapping made it possible to identify bottlenecks and inefficient practices that, once corrected, reduced the loss of inputs by up to 30%. The standardization of processes and the implementation of portion control and inventory procedures have also contributed to the more rational use of resources and increased operational efficiency. Participating establishments reported improvements in both productivity and customer satisfaction, evidencing the positive impact of the Lean methodology. The study also showed that employee training was crucial to the success of the initiative. The team involved started to adopt a mindset of continuous improvement, identifying opportunities for savings and waste reduction on a daily basis. There were also advances in internal communication and accountability for tasks, which increased employee engagement. The research concluded that even in traditionally less technological sectors, such as food service, the Lean philosophy can be effective in the pursuit of operational sustainability and in promoting more responsible practices in the use of resources.
Impact of the lean methodology	ROCHA, D. O.; MARASCHIN	Cogitare Nursing, v.	2021, Brazil.	The study conducted a quantitative research, with a quasi-experimental design, evaluating data on the length

on the stay of patients in an emergency room	, M.; TONINI, N. S.; BORGES, F.; CUNHA, M. A.	26, e71970, 2021		of stay of patients in an emergency room before and after the implementation of the Lean methodology. Administrative data were collected from electronic medical records and statistical analyses were applied to identify significant differences. The implementation of the Lean methodology in a Brazilian emergency room resulted in substantial improvements in the management of patient length of stay. After the adoption of Lean principles, there was a significant drop in the average length of stay of users in the emergency unit, with an approximate reduction of 30%. This result was attributed to the reorganization of care flows, the elimination of redundant steps in care, and the restructuring of the processes of screening, referral, and release of patients. The introduction of standardized protocols and the strategic repositioning of the teams allowed for greater fluidity in care, optimizing the unit's operational capacity. A notable improvement was also observed in the use of beds and in hospital efficiency indicators. The agility in hospital discharge and in the redirection of less severe cases to appropriate areas contributed to a better allocation of available resources. There was also a positive impact on the satisfaction of the health team, which began to perceive greater control over the processes and better use of time. The study reinforces that the use of the Lean approach can be a viable and effective alternative to address the challenges of overcrowding and slow care, promoting a more efficient environment centered on patient safety and well-being.

Source: Authors.

4 DISCUSSION OF THE RESULTS

The transition from the traditional lean production model to Lean 4.0 proves to be challenging, as it requires a reinterpretation of the lean philosophy in a context of digital transformation. Evidence shows that the incorporation of Industry 4.0 technologies, such as IoT and big data, does not replace lean principles, but enhances them, offering greater

visibility and control of processes. Even so, the survey reveals that many organizations still see Lean 4.0 as a sum of technological tools, ignoring its philosophical basis centered on waste elimination and continuous improvement (GIL-VILDA, F. et al., 2021).

Another relevant point is the difficulty of companies in correctly mapping their evolutionary stages towards Lean 4.0, often starting with the acquisition of technologies without first consolidating a lean culture. Lean maturity, in this context, becomes a prerequisite for successful digitalization, as it ensures that investments in technology are guided by real needs and not just market trends. The proposed historical analysis shows that the cycles of evolution of lean thinking are not linear, being strongly influenced by industrial pressures and global socioeconomic changes (GIL-VILDA, F. et al., 2021).

In addition, the historical view also allows us to understand that Lean 4.0 is not a disruption, but rather a continuation of the lean journey adapted to the new digital context. The systematic review points out that organizations that managed to align technology and lean culture had better performance in productivity, quality, and sustainability. This demonstrates that the successful integration between the pillars of Industry 4.0 and the fundamentals of lean thinking depends more on cultural change than on investment in infrastructure (GIL-VILDA, F. et al., 2021).

In the United States, this integration acquires a strategic dimension by supporting the resilience of critical supply chains, the transition to renewable energies, and the digitalization of industrial processes. By aligning lean practices with emerging technologies such as IoT and artificial intelligence, not only greater operational efficiency, but also a strengthening of national economic security, a central aspect of the American political and industrial agenda.

The analysis of people-oriented lean practices revealed that human capital remains one of the biggest competitive differentiators of organizations. The adoption of "soft lean" practices, such as training, empowerment and involvement of employees in operational decisions, has shown a direct impact not only on production performance, but also on environmental sustainability indicators. This connection between human engagement and environmental results shows that the rationalization of processes cannot be detached from inclusive and ethical management policies (FERRAZZI, M. et al., 2025).

Another important finding concerns the synergy between participatory leadership and lean practices. Organizations that encourage servant and horizontal leadership get greater adherence to lean practices and are able to implement change with less resistance. The emphasis on continuous employee development, combined with transparency in organizational objectives, strengthens the resilience of teams in the face of external

pressures. This reinforces the importance of treating lean as an organizational philosophy and not just as a set of tools (FERRAZZI, M. et al., 2025).

The discussion also shows that, although the traditional focus of lean has been on operational efficiency, the human and environmental impact of the practices adopted has been gaining prominence. Companies that integrate sustainability into their lean strategy demonstrate better long-term results in productivity, as well as institutional reputation and customer loyalty. Thus, "soft" practices should be understood as vectors of innovation and sustainability, and not as peripheral elements (FERRAZZI, M. et al., 2025).

In the industrial context of Jordan, lean thinking has shown significant effects on the strategic planning of companies, especially in improving flexibility and adaptability. The research points out that the application of lean principles contributes to reducing the rigidity of strategic plans, which allows for more agile adjustments in the face of market changes. Such a capacity is crucial in emerging economies, where political and economic instabilities require quick and efficient responses (NASEREDDIN, A. Y., 2023).

When seen from the perspective of the North American market, the integration between lean and digital transformation has been decisive for strengthening critical supply chains, such as semiconductors, healthcare, and transportation. Continuous investment in emerging technologies — IoT, artificial intelligence, and big data — leverages lean principles, enabling greater predictability and resilience in highly complex environments. This reality demonstrates that the application of lean in the United States is not limited to operational gains, but is intrinsically linked to strategic objectives of national security, sustainability, and innovation, positioning the country as a global leader in the evolution of lean thinking.

In addition, the incorporation of lean into strategic planning allowed the identification of operational deficits and waste that, until then, were not considered in management decisions. This integration strengthens the connection between the tactical and operational levels, bringing the strategic discourse closer to the realities of the production line. However, the effectiveness of this alignment depends on organizational maturity and clarity in the performance indicators used (NASEREDDIN, A. Y., 2023).

Another critical point observed was the need to customize lean tools for local contexts. Companies that tried to apply ready-made models, without adapting them to their institutional environment, showed less effectiveness. This suggests that the success of lean depends on its flexibility and cultural adaptation, rather than on a mechanical replication of foreign models. Lean thinking needs to be sensitive to cultural and structural specificities to produce concrete effects (NASEREDDIN, A. Y., 2023).

In the study that relates lean practices to organizational performance, it was observed that success strongly depends on the coherence between practices adopted and institutional objectives. The simple adoption of tools, without a clear strategic direction, can lead to conflicting results or even operational setbacks. The research showed that the alignment between lean and corporate goals is a predictor of positive performance, which reinforces the need for integrated planning (SCHWANTZ, P. I.; KLEIN, L. L., 2023).

One of the most relevant findings was the finding that lean practices do not affect all dimensions of performance equally. While aspects such as quality and efficiency showed significant improvements, variables such as innovation and market growth showed more modest results. This indicates that lean, by itself, does not replace expansion or differentiation strategies, being more effective as a basis for support for other approaches (SCHWANTZ, P. I.; KLEIN, L. L., 2023).

Finally, the study reinforces that the commitment of top leadership is fundamental to the success of lean. In companies where executives acted as facilitators of the transformation process, the results were more robust and long-lasting. The active presence of leadership not only legitimizes actions, but also motivates employees to engage with the lean philosophy. Visionary leadership is, therefore, an essential catalyst of organizational performance (SCHWANTZ, P. I.; KLEIN, L. L., 2023).

The use of specific lean manufacturing tools in industrial environments has demonstrated important results in improving safety at work. The analysis reveals that the standardization of processes, combined with the organization of physical space through 5S and visual management, contributes not only to operational efficiency, but also to the mitigation of occupational risks. A cleaner, more organized and predictable environment reduces human errors, accidents and occupational diseases, configuring a direct impact of the lean approach on workers' health and safety indicators (MAŁYSA, T. et al., 2024).

Another point addressed was the role of the active participation of workers in the construction of a safer environment. By being involved in improvement decisions and risk mapping, employees start to act as prevention agents, promoting a culture of collective responsibility. This cultural transformation aligns with the principle of respect for people, one of the pillars of lean thinking, and reinforces that lean practices should not be implemented in an imposing way, but collaboratively and inclusively (MAŁYSA, T. et al., 2024).

This study reinforces that the application of lean with a focus on safety requires a redesign of inspection, training and internal communication routines. The simple implementation of techniques does not guarantee change if there is no clarity about the objectives and benefits for everyone involved. The lean safety-oriented culture is built on

transparency, continuous learning, and valuing safe work as an intrinsic part of operational excellence (MAŁYSA, T. et al., 2024).

The analysis of lean practices in Shared Service Centers revealed a particular scenario in which lean management needs to be adapted to the intangible nature of administrative processes. Unlike manufacturing, where physical flows are evident, shared services involve information, documents, and digital flows that require new control metrics and tools such as flowcharts, digital value stream mapping, and interactive dashboards. The introduction of lean in this environment has brought agility gains, reduced rework, and improved perception of value by end users (ZAPOROWSKA, Z.; SZCZEPAŃSKI, M., 2022).

The study also highlighted the importance of a robust governance system to underpin lean initiatives in shared services. Without systematic monitoring and well-defined indicators, the improvements obtained tend to be diluted over time. Therefore, the creation of lean committees, continuous training, and short feedback loops proved essential to ensure the continuity of transformations. These mechanisms consolidate the idea that lean, even in non-industrial environments, needs to be institutionalized (ZAPOROWSKA, Z.; SZCZEPAŃSKI, M., 2022).

Another relevant finding is the perception that, in services, the focus on the end-user experience becomes a central factor. The application of lean is not limited to reducing internal waste, but to delivering more effective, faster and more value-added solutions to internal and external customers. The measurement of "time to value" and the reduction of bureaucratic steps were fundamental for increasing efficiency in the centers analyzed, proving the versatility and adaptability of lean thinking to sectors of high administrative complexity (ZAPOROWSKA, Z.; SZCZEPAŃSKI, M., 2022).

The comparison between lean, agile, and six sigma revealed that, although they share similar goals of continuous improvement and elimination of waste, each approach has specific approaches and applications. Lean stands out for its comprehensive philosophy and cultural base, centered on creating value and respecting people, while six sigma focuses on statistical variability and agile on team adaptability. The research demonstrated that the integration of the three methodologies can expand the reach and robustness of organizational transformations when well contextualized (MILEWSKA, B.; MILEWSKI, D., 2025).

However, the attempt to combine these methodologies indiscriminately can generate confusion and methodological conflicts. The study showed that the lack of clarity regarding the objectives of each approach leads to overlapping efforts, loss of focus and resistance on the part of the teams. Thus, it is essential to define precisely where each methodology will be

applied, respecting its limits and potential. Conceptual clarity and transparent communication are critical success factors in this integration (MILEWSKA, B.; MILEWSKI, D., 2025).

In addition to this data, the synergy between lean, agile, and six sigma depends on organizational maturity and leadership preparation. Companies that invested in training leaders with transversal knowledge of the methodologies were able to conduct more efficient and integrated projects. The training of "hybrid leaders", capable of moving between different management logics, proved to be a competitive advantage in environments of high volatility and operational complexity (MILEWSKA, B.; MILEWSKI, D., 2025).

The application of lean thinking in collaborative projects between industry and academia has revealed relevant opportunities, but also considerable challenges. The survey showed that successful projects were those that prioritized continuous communication, the alignment of expectations, and the clear definition of responsibilities among partners. The absence of these factors generated delays, rework, and frustrations, compromising the expected results. Lean, in this context, served as a common language to integrate actors with different organizational cultures (KALINOWSKI, M. et al., 2025).

Another important aspect was the use of lean tools for knowledge management within collaborative projects. The mapping of processes, PDCA cycles and performance indicators facilitated the systematization of learning and the replicability of good practices. This demonstrates that lean not only optimizes workflows, but also strengthens the capacity for innovation and organizational learning, especially in multidisciplinary contexts (KALINOWSKI, M. et al., 2025).

The experience in academic-industrial environments has shown that the success of lean initiatives is directly linked to institutional commitment. Projects in which there was formal support from academic and business leaders showed better governance, resource allocation, and responsiveness. Thus, the institutionalization of lean within the scope of partnerships proves to be a decisive factor for the sustainability of projects and for the generation of concrete impact on production processes (KALINOWSKI, M. et al., 2025).

The adoption of lean in the hospitality and food sector (HoReCa) has shown a strong potential for reducing waste and increasing operational efficiency. The study showed that in restaurants and hotels, lean can be applied in the supply chain, food preparation, and customer service, resulting in significant improvements in time management, service quality, and loss reduction. This demonstrates that lean thinking is applicable even in sectors traditionally considered poorly structured (GLĄDYSZ, B. et al., 2020).

The implementation of lean practices in the HoReCa sector also required changes in the work culture and behavior of employees. The involvement of the team, through training

and encouragement to solve problems in the workplace, proved to be essential to sustain the gains obtained. The initial resistance was overcome when employees began to realize the direct benefits of lean in their routine and customer satisfaction, highlighting the transformative role of the approach (GLĄDYSZ, B. et al., 2020).

Finally, the analysis highlights that the application of lean in this sector favors not only efficiency, but also environmental sustainability. Reducing food, energy, and input waste strengthens the institutional image and responds to the growing demand for responsible practices by consumers. With this, lean is no longer just a management tool to become a positioning strategy in the hospitality and food market (GLĄDYSZ, B. et al., 2020).

The introduction of the lean methodology in hospital environments has proven to be effective in reducing the length of stay of patients, especially in short and medium complexity hospitalization sectors. The study highlighted that, by applying principles such as the elimination of waste, standardization of care flows, and reorganization of tasks, there was a significant improvement in bed turnover indicators. The adoption of optimized flowcharts for admission, discharge, and internal displacements allowed for greater predictability of the stages and facilitated integration between multidisciplinary teams, promoting agility in care and avoiding bottlenecks in care processes (ROCHA, D. O. et al., 2021).

In addition, the implementation of lean has favored a new patient-centered organizational culture, in which the delivery of value is not limited to clinical care, but also encompasses waiting time, comfort, and the reduction of unnecessary steps. The direct involvement of health professionals in the identification of failures and the construction of solutions was decisive for the success of the interventions, since it provided autonomy, recognition and improvement of communication between sectors. The methodology proved to be especially effective when accompanied by short feedback loops and daily meetings for alignment, known as "daily huddles" (ROCHA, D. O. et al., 2021).

However, the article also pointed out important limitations. Institutional resistance to change, a shortage of trained human resources, and staff overload were factors that partially compromised the continued application of lean practices in some sectors. There were variations in the results according to the engagement of the leaders and the support of strategic management, which highlights the need for planning, political-institutional support and systematic training. Even so, the data showed that, when well executed, the lean approach contributes significantly to the improvement of hospital efficiency and patient safety, reinforcing its potential as a structuring tool for quality management in health (ROCHA, D. O. et al., 2021).

4.1 AUTHORS' CONTRIBUTIONS – ANALYTICAL PROPOSITION

Although this research was structured as a critical review of the literature, the analysis carried out allowed us to identify gaps and propose authorial contributions that go beyond the mere systematization of previous results. Such contributions emerge from the integrated interpretation of the findings and are organized into four main analytical axes.

First, a Lean 4.0 Maturity Framework is proposed, structured in four evolutionary stages:

1. Foundational, marked by the initial adoption of lean principles in productive environments;
2. Integrated, in which digital tools such as IoT and big data are associated with lean management;
3. Predictive, characterized by the use of advanced analytics, artificial intelligence, and automation to anticipate failures and optimize flows;
4. Orchestrated, a stage in which the lean philosophy and digital resources are aligned with corporate strategies and public policies, amplifying systemic impact.

This model seeks to offer organizations a conceptual map of progression, overcoming fragmented readings of Lean-Industry 4.0 integration.

The second axis consists of a bridge between policy and operations, highlighting that the evolution to Lean 4.0 is not restricted to the productive sphere, but is directly connected to international competitiveness and economic security. The integration between lean practices, digitalization, and sustainability is a vector of resilience in critical supply chains, especially in the United States, where semiconductors, health, and logistics are strategic priorities of the State. Such a perspective contributes to repositioning lean as a tool of relevance not only corporate, but also national and geopolitical.

The third axis highlights the integration between "soft lean" and workforce development, understanding that digital transformation is only consolidated when anchored in human skills. The emphasis on capacity building, participatory leadership, and team empowerment underpins the continuity of lean practices in high-complexity environments. Thus, Lean 4.0 should be understood not only as synonymous with automation and digitalization, but also as a social process that depends on valuing human capital and institutionalizing an organizational culture oriented to continuous improvement.

Finally, an action research agenda applied to strategic sectors — health, energy, semiconductors, and logistics — is outlined, focusing on impact indicators related to productivity, process variability, environmental sustainability, and the generation of qualified

jobs. This agenda seeks to bring academia and the productive sector closer together, transforming Lean 4.0 into a fertile field of practical innovation and aligned with global sustainability and competitiveness priorities.

These propositions reinforce that the evolution to Lean 4.0 is not limited to the conceptual expansion of the literature, but constitutes an applied transformation agenda. By combining technology, organizational philosophy, and development policies, Lean 4.0 emerges as a managerial infrastructure of global interest, especially for the United States, by aligning business gains with economic resilience, technological innovation, and long-term sustainability.

In addition to critical systematization, the main author played a central role in the design of the Lean Maturity 4.0 framework and in the explicit articulation between the analyzed literature and the strategic priorities of the United States. This contribution shows intellectual leadership in the definition of practical guidelines for the integration of Lean Thinking with industrial and workforce development policies, reinforcing the authorial and applied character of this research.

5 FINAL CONSIDERATIONS

The analysis of the ten studies revealed that the application of lean thinking in business management transcends the traditional industrial environment, proving to be adaptable to sectors such as shared services, healthcare, research and development, environmental sustainability and hospitality. In each context, the logic of eliminating waste, standardizing processes, valuing people, and focusing on the customer allowed significant advances in productivity, quality, and stakeholder satisfaction. The diversity of approaches highlights the flexibility of the lean philosophy, but it also requires sensitivity to adapt its tools to the organizational culture and operational specificities of each sector.

However, challenges remain. Many studies point to cultural barriers, resistance to change, the need for engaged leadership, and failures to measure results as factors that limit the success of lean initiatives. The lack of integration between "hard" tools and "soft" practices also compromises the sustainability of the improvements implemented. The intersection with Industry 4.0 concepts, sustainability, and innovation in R&D demands a continuous reinterpretation of lean principles, which reinforces the importance of promoting an organizational culture focused on learning, flexibility, and constant experimentation.

Based on the results analyzed, it is concluded that lean thinking remains highly relevant, as long as it is contextualized with the new business dynamics. Its potential for transformation is amplified when combined with digitalization strategies, employee

participation, and clarity of institutional purpose. It is suggested, therefore, that future applications prioritize systemic approaches, continuous leadership training and integrated evaluation metrics, promoting a lean, responsive and value-centered management generated to society.

These results are in direct dialogue with recent U.S. initiatives, such as the **CHIPS and Science Act** (aimed at the semiconductor chain), the **Energy Transition Policy** (related to renewable energy and industrial sustainability), and the **Workforce Innovation and Opportunity Act (WIOA),** which prioritizes the development of technical skills in critical sectors. The analysis conducted in this study offers conceptual and practical inputs that can serve as a reference for such policies, aligning operational efficiency with goals of economic security and global competitiveness.

From a public policy perspective, the results are in line with **the U.S. national interest** by strengthening **international competitiveness**, **economic security,** and workforce development in critical sectors. Lean 4.0–ESG integration provides a pragmatically viable path to increasing productivity with social and environmental responsibility.

In particular, this review highlights that the application of Lean 4.0 has direct implications for the United States, where the resilience of critical supply chains, industrial digitalization, and sustainability goals are state priorities. The results analyzed demonstrate that the consolidation of a lean culture integrated with Industry 4.0 can strengthen North American competitiveness in strategic sectors, reduce logistical vulnerabilities and accelerate the transition to sustainable business models with high social impact. Thus, the present study contributes not only to the academic literature, but also to the formulation of public policies and corporate strategies aligned with US national priorities.

From a socioeconomic point of view, the adoption of Lean 4.0 produces indirect and direct effects on qualified employment, continuous training and investment attraction. By reducing variability and cycle time, organizations increase production capacity and predictability, which favors plant expansions, onshoring/nearshoring, and new technical vacancies with better pay. In parallel, workforce development programs focused on data literacy, maintenance 4.0, and continuous improvement increase employability and reduce skills asymmetries, reinforcing long-term competitiveness and territorial resilience in industrial and logistics ecosystems in the United States.

In particular, the results indicate that the next frontier of lean application should consider its integration into public policies and private initiatives aimed at strengthening critical chains in the United States and other central economies. By connecting operational efficiency to sustainability goals and technological innovation, lean consolidates itself as an

essential tool to face the global challenges of competitiveness, social inclusion, and energy transition. This perspective expands not only the academic relevance of the topic, but also its practical applicability in decisive contexts for economic and social development.

Looking ahead to the next decade, the convergence of Lean 4.0, industrial digitalization, and ESG positions the United States to lead cycles in sustainable advanced manufacturing, smart logistics, and digital health. The lean data-driven discipline, added to innovation ecosystems and accelerated technical training, tends to reduce external dependencies, shorten chains, mitigate risks, and expand structural competitive advantages. In this trajectory, lean ceases to be a set of tools to constitute a managerial infrastructure of national interest. In summary, this study provides actionable evidence for business managers and policymakers in the United States, positioning Lean 4.0 as a strategic management infrastructure. Its integrated adoption can strengthen critical chains, accelerate the energy transition, increase logistical resilience, and consolidate workforce development programs, transforming business gains into long-term national benefits.

5.1 RECOMMENDATIONS

1. Sector Adaptation: Organizations must adapt lean tools to the specificities of their sector, avoiding the standardized and uncritical application of industrial production methods in service or innovation contexts.
2. Integration with Soft Skills: It is recommended to promote training in leadership, communication and organizational culture, ensuring that "soft" practices are integrated with lean "hard" tools to ensure lasting behavioral changes.
3. Adoption of Combined Indicators: It is essential to develop metric systems that combine operational indicators (time, cost, rework) with qualitative indicators (satisfaction, engagement, well-being), enabling a holistic view of performance.
4. Support for Digital Transformation: The insertion of lean in digital transformation environments should be planned with an emphasis on interoperability between lean processes and Industry 4.0 technologies, such as IoT, Big Data, and intelligent automation.
5. Valuing Local Knowledge: It is recommended to strengthen active listening and employee participation in the construction of lean solutions, especially in sectors with a strong human component, such as health, services, and research.

The contribution of this study should also be read in the light of the strategic demands of the United States, where global competitiveness depends on more agile,

resilient and sustainable production chains. The alignment between Lean Thinking, Industry 4.0 and ESG practices can serve as a catalyst for industrial policies aimed at reducing external dependence, generating qualified jobs and strengthening the US position in critical sectors of the world economy.

5.2 SUGGESTIONS FOR FUTURE RESEARCH

1. Lean in Digital Ecosystems: Investigate how lean philosophy can articulate with agile frameworks and digital collaboration platforms, especially in interconnected supply chains and networked business environments.
2. Longitudinal Impact Assessment: Develop longitudinal studies that evaluate the sustained impact of lean programs over the years, mapping the factors that favor or compromise the maintenance of initial gains.
3. Lean and Social Sustainability: Explore how lean practices can go beyond operational efficiency and contribute directly to social sustainability goals such as inclusion, diversity, and well-being at work.
4. Lean Diagnostic Instruments: Create and validate more sophisticated lean diagnostic and maturity instruments, specifically aimed at non-industrial sectors and small and medium-sized organizations.
5. Development of Hybrid Models: Propose theoretical frameworks that combine lean, design thinking, knowledge management and digital transformation, in order to respond to the current complexities of business with interdisciplinary approaches.

5.3 FORWARD-LOOKING AGENDA 2026–2030 (US)

To catalyze systemic gains, it is recommended to:

1. Lean 4.0 sector programs in semiconductors, health and critical cargo logistics, with standardized metrics (lead time, OTIF, variability, emissions).
2. Centers of excellence for workforce development (data upskilling, maintenance 4.0, quality) integrated into industrial communities.
3. Full-chain pilots (supplier-factory-distribution) to validate resilience and emissions reduction.
4. ESG-lean governance to internalize environmental goals without loss of productivity.
5. Action research in academia-industry partnership to accelerate technology transfer and disseminate high-impact practices.

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APPENDIX

APPENDIX A – CRITERIA FOR SELECTION OF DOCUMENTS

Strict criteria were established for the selection of the articles that make up this theoretical review, in order to ensure scientific relevance, thematic timeliness and diversity of application of lean thinking in different organizational contexts. The criteria defined were:

- Time frame: Articles published between the years 2020 and 2025.
- Databases: Selection carried out from the MDPI, arXiv, SciELO and Cogitare Enfermagem platforms, with full access to the content of the articles.
- Language: Articles written in English or Portuguese.
- Type of study: Case studies, empirical investigations with qualitative and quantitative methods, and robust theoretical analyses that presented a section of results and discussion were included.
- Relationship with the theme: The selected articles directly addressed the application of lean thinking in organizational environments, either in isolation or in integration with other methodologies (such as Agile, Six Sigma or Industry 4.0), highlighting impacts, challenges and innovations.
- Scientific quality: All studies were published in peer-reviewed journals, recognized in the areas of management, production engineering, logistics, administration or innovation.
- Exclusions: Articles with duplicate content, without a results section, without methodological clarity, or that dealt only with historical or conceptual aspects of lean without contemporary practical application were excluded.

APPENDIX B – THEMATIC ORGANIZATION OF THE ANALYSIS

The 10 selected articles were organized into thematic axes based on the empirical and theoretical contributions observed, aiming to facilitate a critical analysis of the application of lean thinking in multiple sectors. The defined axes were:

1. Application of lean in contemporary manufacturing Studies that demonstrate how lean remains relevant in the industrial sector, promoting efficiency, safety, and sustainability even in environments already familiar with the philosophy.
2. Lean in services and administrative centers Work that explores the implementation of lean in shared services, back office, call centers and administrative functions, with an emphasis on standardization and process improvement.

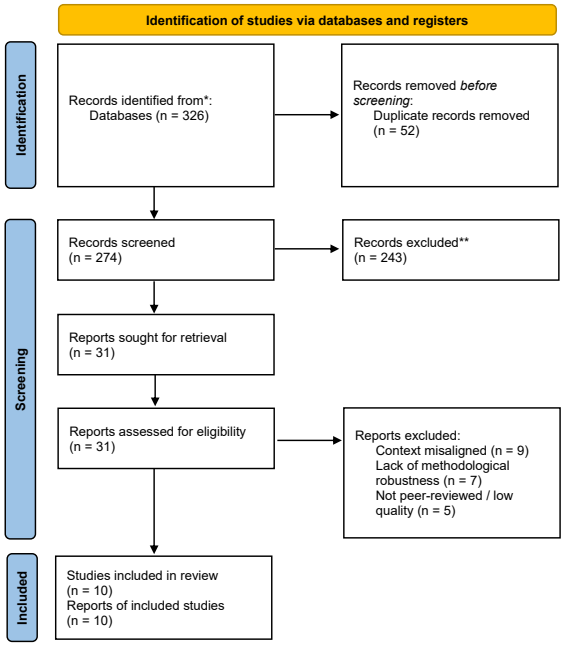
3. Integrating lean with Industry 4.0 Articles that address the combination of lean thinking with emerging technologies such as digitalization, artificial intelligence, big data, and automation.
4. Lean in health and hospitality Research that investigates the effects of the application of lean in hospitals, wards, health units and the hotel sector, with a focus on length of stay, quality of service and optimization of flows.
5. Lean in R&D, innovation, and sustainability Studies that discuss how lean thinking has been adapted to research and development environments, collaborative projects, and initiatives aimed at corporate sustainability.
6. Challenges, limitations, and critical success factors Work that identifies cultural, technical, and structural barriers to lean implementation, as well as strategies for overcoming it, the importance of leadership engagement, and strategic alignment.

APPENDIX C – PRISMA FLOWCHART 2020

The following flowchart presents the process of identification, screening, eligibility assessment, and inclusion of studies in the review, according to the PRISMA 2020 protocol. This procedure ensures transparency and methodological rigor in the conduct of the research.

Figure 1

PRISMA 2020 Flowchart



Source: The authors