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Lean Manufacturing, Agile Strategies, and Their Impact on Efficiency: A Critical Systematic Literature Review

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ABSTRACT

This research critically examines the application of lean manufacturing and agile strategies in improving operational efficiency across various industries. Using a systematic literature review methodology, a total of 23 articles published between 2017 and 2024 were analyzed. This research systematically investigates the role of lean manufacturing and agile strategies in improving operational efficiency and the adoption of agile strategies in the manufacturing sector. Key findings include the application of lean tools such as 5S, Kaizen, and Total Productive Maintenance (TPM) to reduce waste and increase workplace efficiency. Additionally, the emergence of digital supply chain tools and e-Lean systems is identified as a significant trend in integrating agile methodologies into manufacturing processes. This analysis highlights the transformative impact of lean practices on operational efficiency, as well as the explicit mention of agile strategies—such as Just-in-Time (JIT) and digital standardization—in addressing industry challenges. This review provides actionable insights into the development of lean and agile methods and offers a foundation for further research and practical application in manufacturing.

INTRODUCTION

Lean manufacturing has become a leading methodology in modern industrial operations, enabling organizations to improve efficiency while building agility in the face of dynamic market demands. Rooted in the principles of waste reduction and continuous improvement, lean practices empower companies to optimize resources, streamline workflows, and deliver superior value to customers. Studies by Santana et al. (2017) and Leksic et al. (2020) highlight the critical role of lean tools such as 5S, Kaizen, and Kanban in reducing operational inefficiencies and achieving sustainable production outcomes. These tools not only eliminate activities that do not add value but also lay the foundation for process stability and flexibility, enabling businesses to quickly adapt to market fluctuations.

The integration of lean manufacturing with advanced technologies such as Industry 4.0 and artificial intelligence (AI) further enhances its strategic significance. Research by Varela et al. (2019)

and Shahin et al. (2024) demonstrates how smart technologies enhance the predictive and adaptive capabilities of lean systems, enabling organizations to navigate market volatility through data-driven insights and automated solutions. Meanwhile, Iranmanesh et al. (2019) emphasize the importance of a lean culture in moderating the relationship between lean practices and organizational performance, thereby ensuring sustainable improvements across environmental, social, and economic dimensions.

In today's fast-paced global market, where customer expectations and competition are constantly evolving, the combination of lean manufacturing principles and agile strategies provides a robust framework for businesses to maintain their competitiveness. By driving operational excellence and embracing innovation, lean manufacturing enables companies to meet the demands for both efficiency and responsiveness simultaneously, positioning them for success in an increasingly complex industrial landscape.

RESEARCH METHODOLOGY

Lean manufacturing has become the cornerstone of operational efficiency strategies, with a focus on reducing waste, continuous improvement, and process simplification. In recent years, the integration of lean practices with emerging technologies and agile strategies has garnered increasing attention from both academia and industry. This development underscores the need for a systematic evaluation of existing research to understand the contribution of *lean manufacturing* to operational efficiency and to explore the explicit application of agile methodologies in the manufacturing sector.

To achieve this objective, a systematic literature review (SLR) methodology was employed, offering a rigorous and transparent approach to synthesizing research findings from 23 peer-reviewed journal articles published between 2017 and 2024. SLR is a recognized method in academic research for identifying, evaluating, and summarizing current knowledge on a specific topic. This methodology involves a structured process of article selection, data extraction, and thematic analysis, thereby ensuring the reliability and replicability of the findings synthesis.

This review was structured around two main research questions:

RQ1: Do journals related to *lean manufacturing* discuss its impact on operational efficiency between 2017 and 2024?

RQ2: Are there any agile strategies implemented during the period from 2017 to 2024 in the manufacturing sector to improve operational efficiency that are explicitly mentioned in the journals?

To answer these questions, this study employed the following multi-stage research methodology:

1. Database Search and Inclusion Criteria: Academic databases were searched using keywords such as *lean manufacturing*, operational efficiency, agile strategies, and the manufacturing sector. Articles were selected based on their relevance to the research questions, the specified publication period (2017–2024), and their peer-reviewed status.
2. Screening and Selection: The initial search yielded a large number of articles, which were then screened based on the relevance of their titles, abstracts, and full texts. Articles that specifically focused on *lean manufacturing* and operational efficiency, with explicit mention of agile strategies (if any), were retained for further analysis.
3. Data Extraction and Synthesis: Key information, including research focus, methods/tools discussed, key findings, and implications, was extracted from each article. This data was then categorized to systematically address the research questions.
4. Thematic Analysis: The extracted data was analyzed to identify recurring themes, trends, and

knowledge gaps. This analysis highlights the role of lean tools such as 5S, Kaizen, JIT, and TPM in operational efficiency, and explores the application of agile methodologies—such as digital standardization and adaptive supply chains—to enhance lean practices.

Using a systematic and transparent methodology, this review presents a robust analysis of the role of *lean manufacturing* in operational efficiency and its integration with agile strategies. The findings of this study provide a deeper understanding of the evolving landscape of manufacturing practices and offer actionable insights for researchers and practitioners seeking to optimize efficiency in dynamic industrial environments.

Table 1. Inclusion and Exclusion Criteria

No	Inclusion	Exclusion
1	Studies focusing on *lean manufacturing* and *agile* operations to improve operational efficiency.	Studies that do not focus on *lean manufacturing* and *agile* operations to improve operational efficiency.
2	Literature published in English.	Literature not published in English.
3	Open-access literature sources.	Literature sources with restricted access
4	Fields of study include Business, Management, Accounting, Economics, Econometrics, and Finance.	Fields of study that do not include Business, Management, Accounting, Economics, Econometrics, and Finance.
5	Literature published from 2017 to 2024.	Literature published before 2017 and after 2024.

The identification stage aims to identify relevant literature sources from the specified databases. The initial search yielded 3,205 articles. In the first screening stage, articles were limited to publications from 2017 to 2024, reducing the number to 1,484 articles. Further screening was conducted to select open-access articles, resulting in 552 articles. Next, the articles were screened based on the English language and relevant subjects, including economics, business, social sciences, management, accounting, finance, and econometrics, leaving 215 articles. In the final stage, only articles discussing variables such as *lean manufacturing* and *agile* strategies related to improving operational efficiency were selected, resulting in 23 articles used for synthesis and reporting. These articles were then imported into Google Scholar and Mendeley for further organization and analysis.

The Quality Assessment phase is conducted to identify and evaluate data based on predetermined quality assessment criteria.

QA1: Do the journals on *lean manufacturing* discuss its impact on operational efficiency between 2017 and 2024?

QA2: Are there any *agile* strategies implemented during the 2017–2024 period across the manufacturing sector to improve operational efficiency that are explicitly mentioned in the journal?

For each journal, the response to QA1 and QA2 will be recorded as ‘Y’ for ‘Yes’ and ‘N’ for ‘No’.

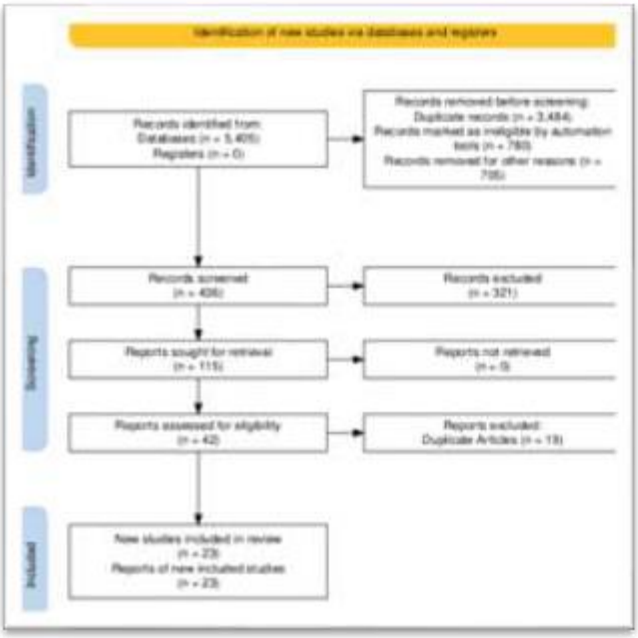

Figure 1. PRISMA Flowchart Diagram

RESEARCH RESULTS

Results of Inclusion and Exclusion Criteria Screening:

From the search process, journals were selected based on predetermined inclusion and exclusion criteria. At this stage, a total of 23 journals were identified. Next, data screening was conducted to ensure the relevance of these journals to the research objectives.

Quality Assessment Results:

Table 1 presents the quality assessment results, which indicate which data sources were deemed suitable for use in this study.

Table 1. Quality Assessment

No	Author	Article Title	Q1	Q2
1	Hernández Centeno & Sifuentes Huayanay (2022)	*Lean manufacturing: Literature review and implementation analysis.*	Y	Y
2	Medyński et al. (2023)	*Digital standardization of lean manufacturing tools according to the Industry 4.0 concept.*	Y	Y
3	Rahamneh et al. (2022)	*The effect of the digital supply chain on lean manufacturing: A structural equation modeling approach.*	Y	Y
4	Palange & Dhatrak (2021)	*Lean manufacturing: A vital tool for enhancing productivity in manufacturing.*	Y	Y

No	Author	Article Title	Q1	Q2
5	Vinodh (2023)	*Lean Manufacturing: Fundamentals, Tools, Approaches, and Industry 4.0 Integration.*	Y	Y
6	Shahin *et al.* (2024)	*Improving operations through a lean AI paradigm: A perspective on AI-aided lean manufacturing using a versatile convolutional neural network.*	Y	Y
7	Marinelli *et al.* (2021)	*Combined application of lean manufacturing and Industry 4.0: Practices and perceived benefits.*	Y	Y
8	Santos *et al.* (2021)	*Implementation of a standard work routine using Lean Manufacturing tools: A case study.*	Y	Y
9	Buer *et al.* (2021)	*The complementary effect of lean manufacturing and digitalization on operational performance.*	Y	Y
10	Jimenez *et al.* (2019)	*Improvement of Productivity and Quality in the Value Chain through Lean Manufacturing – A Case Study.*	Y	Y
11	Valamede & Akkari (2020)	*Evaluation of the relationship between lean manufacturing, Industry 4.0, and sustainability.*	Y	Y
12	Schmitt *et al.* (2021)	*Beyond "Leanear" production: A multi-level approach for achieving circularity in a Lean Manufacturing context.*	Y	Y
13	Santana, A., *et al.* (2017)	*Costing models for capacity optimization in Industry 4.0: Trade-off between utilized capacity and operational efficiency.*	Y	Y
14	Iranmanesh, M., *et al.* (2019)	*Impact of lean manufacturing practices on firms' sustainable performance: Lean culture as a moderator.*	Y	Y
15	Varela, L., *et al.* (2019)	*Lean 4.0: A new holistic approach for the integration of Lean Manufacturing tools and digital technologies.*	Y	Y
16	Leksic, I., *et al.* (2020)	*The impact of using different lean manufacturing tools on waste reduction.*	Y	Y
17	Shahin, M., *et al.* (2024)	*Improving Operations Through a Lean AI Paradigm: A Look at AI-Aided Lean Manufacturing Using a Versatile Convolutional Neural Network.*	Y	Y
18	Aureliano, *et al.* (2019)	*Application of lean manufacturing in construction management.*	Y	Y
19	Kumar *et al.* (2018)	*Real-time monitoring system for lean manufacturing.*	Y	Y
20	Romero *et al.* (2019)	*Rethinking Jidoka systems from the perspectives of automation and learning in the digital lean manufacturing world.*	Y	Y

No	Author	Article Title	Q1	Q2
21	Pinto Junior & Mendes (2017)	*Operational Practices of Lean Manufacturing: Enhancing Environmental Improvements.*	Y	Y
22	Wyrwicka & Mrugalska (2017)	*The Illusions of Lean Manufacturing in Practice.*	Y	Y
23	Alefari, Salonitis & Xu (2017)	*The role of leadership in implementing lean manufacturing.*	Y	Y

DISCUSSION

We will address and explain the results of the research questions, beginning with RQ1 and RQ2. The results are presented in Table 2 below:

Table 2. The Potential of Lean Manufacturing to Impact Operational Efficiency

No	Author	Article Title	Key Findings
1	Hernández Centeno & Sifuentes Huayanay (2022)	*Lean Manufacturing: A Literature Review and Implementation Analysis.*	- Lean manufacturing reduces waste and increases customer satisfaction. - 50% of the studies reviewed highlighted specific lean tools; the rest demonstrated improvements at the sector-wide level. - Benefits include reduced production time, improved quality, and lower costs.
2	Medyński et al. (2023)	*Digital standardization of lean manufacturing tools in accordance with the Industry 4.0 concept.*	- The “e-Lean” system increases TPM efficiency by 15%, streamlines machine maintenance and process monitoring. - Digital tools support predictive maintenance and enable faster decision-making. - Emphasizes the importance of integrating Industry 4.0 technologies into lean practices.

No	Author	Article Title	Key Findings
3	Rahamneh et al. (2022)	*The Effect of the Digital Supply Chain on Lean Manufacturing: A Structural Equation Modeling Approach.*	- Dimensions of the digital supply chain (e.g., performance management, IT) have a positive impact on *lean manufacturing*. - Identifies barriers such as high costs and challenges in integrating digital clients and suppliers. - Encouraging investment in the digital supply chain for long-term benefits.
4	Palange & Dhatrak (2021)	*Lean manufacturing: A vital tool for enhancing productivity in manufacturing.*	Improved workplace cleanliness, reduced cycle times, increased productivity, cost reductions, and improved employee morale.
5	Vinodh (2023)	*Lean manufacturing: Fundamentals, tools, approaches, and Industry 4.0 integration.*	Lean tools such as TPM and OEE improve efficiency; insights into training and project selection are crucial.
6	Shahin et al. (2024)	*Improving operations through a lean AI paradigm: A view toward AI-aided lean manufacturing via versatile convolutional neural networks.*	AI enhances lean tools such as VSM and predictive maintenance, improving real-time decision-making and efficiency.
7	Marinelli et al. (2021)	*Combined application of lean manufacturing and Industry 4.0: Practices and perceived benefits.*	Lean tools such as Kanban and continuous improvement have proven effective, while Industry 4.0 tools are perceived to have varying benefits.
8	Santos et al. (2021)	*Implementation of a standard work routine using Lean Manufacturing tools: A case study.*	Increasing productivity by balancing tasks and eliminating activities that do not add value.
9	Buer et al. (2021)	*The complementary effect of lean manufacturing and*	The integration of Lean and digital technology creates a synergistic effect, which improves cost

No	Author	Article Title	Key Findings
		digitalization on operational performance.	efficiency, quality, and delivery times.
10	Jimenez et al. (2019)	*Improvement of productivity and quality in the value chain through Lean Manufacturing – A case study.*	Improving productivity and quality; identifying critical areas for cost reduction and operational improvements.
11	Valamede & Akkari (2020)	*Evaluation of the relationship between Lean Manufacturing, Industry 4.0, and sustainability.*	The synergy between Lean tools and digital innovation leads to waste reduction, automation, and data-driven efficiency.
12	Schmitt et al. (2021)	*Beyond "Leanear" production: A multi-level approach for achieving circularity in a Lean Manufacturing context.*	Identifying challenges and potential in aligning Lean with circular economy practices for environmental and economic benefits.
13	Santana, A., Afonso, P., Zanin, A., & Wernke, R. (2017)	*Costing models for capacity optimization in Industry 4.0: Trade-off between utilized capacity and operational efficiency.*	Lean management supports capacity optimization but can mask inefficiencies; ABC and TDABC models are effective for cost management in an Industry 4.0 environment.
14	Iranmanesh, M., Zailani, S., Hyun, S. S., Ali, M. H., & Kim, K. (2019)	*Impact of lean manufacturing practices on firms' sustainable performance: Lean culture as a moderator.*	Lean practices significantly enhance environmental, social, and economic sustainability. A Lean culture reinforces these impacts.
15	Varela, L., Araújo, A., Ávila, P., Castro, H., & Putnik, G. (2019)	*Lean 4.0: A new holistic approach for the integration of Lean Manufacturing tools and digital technologies.*	Lean manufacturing impacts sustainability, but its impact is less pronounced without the integration of Industry 4.0, which has a strong correlation with the economic, environmental, and social pillars.
16	Leksic, I., Stefanic, N., & Veza, I. (2020)	*The impact of using different lean manufacturing tools on waste reduction.*	Tools such as 5S, Kaizen, Kanban, and TPM are most effective for waste reduction; selecting the right tools and the correct

No	Author	Article Title	Key Findings
			sequence is crucial for Lean success.
17	Shahin, M., Maghanaki, M., Hosseinzadeh, A., & Chen, F. F. (2024)	*Improving operations through a lean AI paradigm: A view toward AI-aided lean manufacturing via versatile convolutional neural networks.*	AI enhances lean practices by providing predictive analytics, real-time optimization, and adaptive learning for continuous improvement.
18	Aureliano, Costa, Júnior, & Rodrigues (2019)	*Application of lean manufacturing in construction management.*	The application of lean principles in construction resulted in cost savings of 9%, 5%, and 7% across three companies by reducing waste, increasing transparency, and streamlining processes.
19	Kumar, Vaishya, & Parag (2018)	*Real-time monitoring system for lean manufacturing.*	The integration of IoT and cloud manufacturing boosts productivity in SMEs by automating production monitoring, reducing human error, and addressing inefficiencies in workflows.
20	Romero, Gaiardelli, Powell, Wuest, & Thürer (2019)	*Rethinking Jidoka systems from the perspectives of automation and learning in the digital lean manufacturing world.*	Advocates for "Jidoka" (automation with a human touch) as a principle for SMEs, emphasizing balanced automation, worker adaptability, and cyber-physical interaction.
21	Pinto Junior & Mendes (2017)	*Operational practices of lean manufacturing: Enhancing environmental improvements.*	The implementation of lean practices reduced energy consumption (21%) and water usage (17%). Achieved annual cost savings of $17,900.
22	Wyrwicka & Mrugalska (2017)	*The illusions of lean manufacturing in practice.*	A high level of implementation of tools such as 5S and SMED does not result in the complete elimination of waste due to a lack of alignment with organizational

No	Author	Article Title	Key Findings
			culture and the absence of a holistic strategy.
23	Alefari, Salonitis & Xu (2017)	*The Role of Leadership in Implementing Lean Manufacturing.*	Leadership commitment, employee engagement, and continuous leadership development are essential for overcoming barriers such as a lack of understanding and habits that hinder the adoption of lean.

The first three studies share a common focus on improving *lean manufacturing* through systematic methodologies and digital advancements. All of these studies emphasize the importance of waste reduction, process optimization, and increased production efficiency as the primary goals of *lean manufacturing*. Hernández Centeno & Sifuentes Huayanay (2022) explore traditional lean tools such as 5S and Kaizen, highlighting their benefits in minimizing production time and costs, while Medyński et al. (2023) integrate Industry 4.0 technologies to digitize tools such as Total Productive Maintenance (TPM), demonstrating a 15% increase in efficiency. Similarly, Rahamneh et al. (2022) examined the impact of digital supply chains, finding that tools such as Just-in-Time (JIT) and Value Stream Mapping (VSM) benefit from digital integration despite challenges such as costs and adoption barriers. All these studies emphasize the critical role of leadership, training, and technological investment in achieving continuous improvement in *lean manufacturing* practices.

The fundamental goal of *lean manufacturing* is to increase productivity and efficiency by minimizing waste and optimizing processes. Palange and Dhatrak (2021) highlight traditional lean tools such as 5S, Kaizen, and Value Stream Mapping (VSM), demonstrating their effectiveness in boosting productivity, reducing costs, and fostering employee engagement across various sectors. Vinodh (2023) builds on this foundation by integrating lean tools with Industry 4.0 technologies, such as Total Productive Maintenance (TPM) and Overall Equipment Effectiveness (OEE), to address modern challenges like digitalization and sustainability. Similarly, Shahin et al. (2024) explore the integration of *lean manufacturing* with artificial intelligence (AI), demonstrating how AI-enhanced tools such as predictive maintenance and real-time VSM can further improve efficiency and decision-making. These three studies emphasize the adaptability and ethos of continuous improvement inherent in lean methodologies, making them relevant in both traditional manufacturing environments and digital.

These studies converge on the theme of improving operational efficiency through *lean manufacturing* by integrating modern tools and methodologies. Marinelli et al. (2021) and Buer et al. (2021) both explore the complementary roles of *lean manufacturing* and digital technologies such as the IoT, big data analytics, and cyber-physical systems, highlighting their potential to enhance operational performance. Similarly, Santos et al. (2021) emphasize the effectiveness of lean tools such as Takt Time and Value Stream Mapping in optimizing workflows and eliminating waste. These three studies demonstrate that *lean manufacturing* serves as the foundational framework for waste reduction and continuous improvement, with the integration of digital tools providing synergistic effects that enable better resource utilization, leaner processes, and higher productivity. The consistent emphasis on lean principles and the adoption of technology underscores the evolving role of *lean manufacturing* in modern industrial practices.

Improving operational efficiency and sustainability through the application of *Lean Manufacturing* principles. Jimenez et al. (2019) focused on waste reduction and process optimization in the food processing industry, while Valamede and Akkari (2020) explored the integration of lean tools with Industry 4.0 technologies to achieve automation and minimize waste. Similarly, Schmitt et al. (2021) examine the relationship between lean principles and the circular economy concept to maximize resource use and reduce environmental impact. Collectively, these studies highlight the adaptability *of lean manufacturing* across various contexts and its evolving role in enhancing productivity, minimizing waste, and achieving sustainability goals.

The reviewed literature consistently highlights *Lean Manufacturing* as a powerful methodology for improving operational efficiency and sustainability. Santana et al. (2017) emphasize the role of lean in capacity management, while Iranmanesh et al. (2019) link lean practices to sustainable performance, moderated by lean culture. Varela et al. (2019) explore the synergy between *lean manufacturing* and Industry 4.0, highlighting its sustainability potential. Leksic et al. (2020) highlight the importance of adopting lean tools such as 5S and Kaizen to reduce waste. Shahin et al. (2024) propose integrating AI with lean practices to enhance efficiency and predictive insights. Overall, these studies reveal the diverse impacts of *lean manufacturing*, shaped by contextual applications and complementary technologies.

Pinto Junior and Mendes (2017) highlight the environmental and cost benefits of lean tools such as Kaizen and PDCA, while Wyrwicka and Mrugalska (2017) reveal challenges in achieving the expected waste reduction due to fragmented implementation and cultural mismatches. Similarly, Alefari, Salonitis, and Xu (2017) emphasize the critical role of leadership and employee engagement in overcoming barriers and sustaining lean practices. Overall, these studies confirm that while *lean manufacturing* offers great potential, its success depends on a holistic approach, cultural integration, and strong leadership to align organizational processes with lean principles.

CONCLUSION

This systematic literature review demonstrates that lean manufacturing remains one of the most effective operational management approaches for improving efficiency across manufacturing industries. Based on the analysis of 23 peer-reviewed articles published between 2017 and 2024, the findings consistently show that lean practices—including 5S, Kaizen, Just-in-Time (JIT), Total Productive Maintenance (TPM), Value Stream Mapping (VSM), and Kanban—contribute significantly to waste reduction, process optimization, shorter production cycle times, improved product quality, and lower operational costs. Moreover, the review reveals that the effectiveness of lean manufacturing is increasingly enhanced through the integration of digital technologies associated with Industry 4.0, such as artificial intelligence (AI), Internet of Things (IoT), digital supply chains, predictive maintenance, and real-time monitoring systems. These technological developments enable organizations to move beyond traditional waste elimination by creating more responsive, data-driven, and adaptive manufacturing systems capable of sustaining competitive advantage in dynamic business environments.

Furthermore, this review indicates that although agile strategies have not yet been extensively integrated into lean manufacturing practices, existing evidence suggests that their combination offers considerable potential for enhancing operational flexibility and organizational resilience.

Agile approaches, including digital standardization, adaptive supply chains, flexible production systems, and hybrid lean–agile frameworks, complement lean principles by enabling manufacturers to respond more rapidly to changing customer demands and market uncertainties. Nevertheless, the literature also identifies several challenges, including organizational culture, leadership commitment, technological readiness, and employee capability, which influence the successful implementation of lean-agile initiatives. Therefore, future research should focus on developing comprehensive hybrid frameworks that integrate lean manufacturing, agile strategies, and emerging digital technologies to support sustainable operational excellence. Such efforts will provide stronger theoretical contributions while offering practical guidance for organizations seeking to improve efficiency, adaptability, and long-term competitiveness in the era of digital manufacturing.

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