

Analysis of Lean Manufacturing Strategies for Reducing Waste and Improving Production Efficiency in Medium and Large-Scale Industries

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Abstract

The increasing complexity of global manufacturing competition requires industries to continuously improve operational efficiency while minimizing production waste. Medium and large-scale industries frequently encounter inefficiencies such as overproduction, waiting time, excess inventory, and product defects that negatively affect productivity and operational performance. This study aims to analyze lean manufacturing strategies for reducing waste and improving production efficiency in medium and large-scale industries through a qualitative literature review approach. Data were collected from relevant academic publications indexed in major scientific databases and analyzed using comparative thematic synthesis. The findings indicate that the most dominant lean manufacturing strategies include 5S, Kaizen, Just in Time (JIT), Value Stream Mapping (VSM), and Total Productive Maintenance (TPM), all of which contribute significantly to reducing non-value-added activities and improving production flow efficiency. The study also reveals that lean implementation differs according to organizational scale. Medium-sized industries tend to emphasize flexibility and participative improvement systems, whereas large-scale industries rely more heavily on integrated management structures and technological support. In addition, common implementation barriers include weak management commitment, employee resistance, and insufficient organizational readiness. This study contributes academically by developing a comparative synthesis of lean manufacturing implementation based on industrial scale, highlighting that the effectiveness of lean strategies is context-dependent rather than universally standardized. The findings emphasize the importance of adaptive and organization-sensitive lean implementation to achieve sustainable operational performance and industrial competitiveness.

Keywords: Lean Manufacturing; Waste Reduction; Production Efficiency; Medium and Large Industries; Operational Performance

Abstrak

Kompleksitas persaingan industri manufaktur global menuntut perusahaan untuk terus meningkatkan efisiensi operasional sekaligus meminimalkan pemborosan produksi. Industri menengah dan besar masih menghadapi berbagai bentuk inefisiensi seperti overproduction, waiting time, excess inventory, dan product defects yang berdampak negatif terhadap produktivitas dan kinerja operasional. Penelitian ini bertujuan untuk menganalisis strategi lean manufacturing dalam mengurangi waste dan meningkatkan efisiensi produksi pada industri menengah dan besar melalui pendekatan kualitatif dengan metode studi literatur. Data diperoleh dari berbagai publikasi akademik yang terindeks pada basis data ilmiah utama dan dianalisis menggunakan comparative thematic synthesis. Hasil penelitian menunjukkan bahwa strategi lean manufacturing

yang paling dominan meliputi 5S, Kaizen, Just in Time (JIT), Value Stream Mapping (VSM), dan Total Productive Maintenance (TPM), yang secara signifikan berkontribusi dalam mengurangi aktivitas non-value-added dan meningkatkan efisiensi aliran produksi. Penelitian ini juga menemukan bahwa implementasi lean berbeda berdasarkan skala organisasi. Industri menengah cenderung menekankan fleksibilitas dan sistem perbaikan partisipatif, sedangkan industri besar lebih bergantung pada struktur manajemen terintegrasi dan dukungan teknologi. Selain itu, hambatan implementasi yang paling umum meliputi lemahnya komitmen manajemen, resistensi karyawan, dan rendahnya kesiapan organisasi. Penelitian ini memberikan kontribusi akademik melalui pengembangan sintesis komparatif implementasi lean manufacturing berdasarkan skala industri, yang menunjukkan bahwa efektivitas strategi lean bersifat kontekstual dan tidak dapat diterapkan secara seragam. Temuan penelitian menegaskan pentingnya penerapan lean yang adaptif dan sesuai dengan karakteristik organisasi untuk mencapai kinerja operasional dan daya saing industri yang berkelanjutan.

Kata Kunci: Lean Manufacturing; Pengurangan Waste; Efisiensi Produksi; Industri Menengah dan Besar; Kinerja Operasional

Introduction

The transformation of the global manufacturing sector over the past two decades has demonstrated that industrial competitiveness is increasingly determined by the ability of firms to achieve operational efficiency, minimize waste, and respond rapidly to dynamic market demands (Felsberger et al., 2022; Negrão et al., 2017). Medium and large-scale industries continue to face operational inefficiencies such as overproduction, waiting time, excess inventory, defects, and unnecessary process activities that increase operational costs and reduce productivity (Kumie, 2021; Sakib et al., 2025).

As manufacturing competition becomes more complex, industries require production management approaches capable of improving efficiency while maintaining quality and sustainability. Lean manufacturing has become one of the most widely adopted approaches for addressing these challenges because it focuses on eliminating non-value-added activities and maximizing customer value (Dara et al., 2024; Gupta, 2017). Originating from the Toyota Production System, lean manufacturing has evolved into a global framework for operational excellence and continuous improvement (Liker, 2020; Yamamoto et al., 2019). In practice, lean manufacturing is implemented through various managerial tools such as 5S, Kaizen, Just in Time (JIT), Value Stream Mapping (VSM), and Total Productive Maintenance (TPM), which are designed to improve workflow continuity, reduce waste, shorten lead time, and enhance operational performance (Pinto et al., 2018). Previous studies consistently report that lean implementation contributes positively to productivity, quality improvement, inventory reduction, and delivery reliability (Bevilacqua et al., 2017; Negrão et al., 2017).

Despite these benefits, the implementation of lean manufacturing differs substantially according to organizational scale. Medium-sized industries generally operate with limited financial resources, technological capability, and specialized expertise, making lean implementation more dependent on flexibility and employee involvement (Lin and Lai, 2021). In contrast, large-scale industries possess stronger technological and financial capacity but face higher bureaucratic complexity, coordination challenges, and organizational resistance to change (Marodin et al., 2016; Netland, 2016). These differences indicate that lean manufacturing cannot be applied uniformly across all industrial contexts because organizational scale significantly influences implementation strategy and operational outcomes.

Previous studies have extensively examined the relationship between lean manufacturing and operational performance; however, most studies focus on single-company cases, specific industrial sectors, or general discussions of lean practices without explicitly comparing implementation across industrial scales. Comparative literature syntheses that analyze how lean manufacturing strategies differ between medium and large-scale industries remain limited. In particular, insufficient attention has been given to how organizational scale influences the selection of lean tools, waste reduction priorities, implementation barriers, and production efficiency outcomes.

Therefore, the novelty of this article lies not only in conducting a literature review on lean manufacturing, but also in developing a comparative synthesis framework based on industrial scale. This study positions lean manufacturing as an adaptive managerial system whose effectiveness depends on organizational characteristics rather than as a universally standardized operational method. By emphasizing scale-based analysis, this article contributes a broader conceptual understanding of how lean strategies should be adjusted to different industrial environments.

From a practical perspective, lean manufacturing is increasingly important for industries seeking sustainable competitiveness and operational resilience. Many manufacturing firms continue to experience high inventory levels, machine downtime, inefficient layouts, and fragmented process coordination that weaken competitiveness in domestic and international markets. Lean principles support industrial transformation by encouraging resource efficiency, process simplification, and continuous improvement. Consequently, insights from this study may provide valuable implications for managers, policymakers, and researchers in developing more effective operational improvement strategies. This study aims to analyze lean manufacturing strategies in reducing waste and improving production efficiency in medium and large-scale industries based on findings from the academic literature. Specifically, the study seeks to identify dominant lean tools, major types of production waste, operational efficiency improvements, implementation barriers, and differences in lean application according to industrial scale. Through this approach, the article intends to provide a more systematic and context-sensitive understanding of lean manufacturing implementation.

Method

This study employed a qualitative literature review approach to analyze lean manufacturing strategies for reducing waste and improving production efficiency in medium and large-scale industries. The study used a descriptive-analytical design by synthesizing findings from previous academic research related to lean manufacturing implementation, operational efficiency, and waste reduction. The literature search was conducted through major academic databases, including Google Scholar, Scopus, ScienceDirect, SpringerLink, and Emerald Insight. The keywords used in the search process included “lean manufacturing,” “lean production,” “waste reduction,” “production efficiency,” “operational efficiency,” “medium industry,” “large industry,” and “continuous improvement”. The literature review process consisted of four stages: identification, screening, eligibility, and inclusion. During the identification stage, relevant publications were collected from academic databases using predefined keywords. The screening stage involved removing duplicate and irrelevant articles based on titles and abstracts. In the eligibility stage, full-text articles were evaluated according to publication quality, topical relevance, accessibility, recency of publication, and direct discussion of lean manufacturing implementation in manufacturing industries. Finally, articles meeting all criteria were included in the analysis. A total of 35 academic sources consisting of journal articles, books, conference proceedings, and institutional reports were selected for final review. Data analysis was conducted using content analysis and

comparative thematic synthesis. Each source was examined to identify dominant lean strategies, major types of production waste, operational efficiency outcomes, implementation barriers, and differences in lean application between medium and large-scale industries. Similar findings were grouped into thematic categories, while contrasting findings were comparatively analyzed to identify contextual differences across industrial scales. This method was selected because it enables a comprehensive and evidence-based understanding of lean manufacturing implementation without relying on a single empirical case study, thereby providing broader conceptual insights relevant to both academic research and industrial practice.

Result and Discussion

Based on the literature review conducted from various academic sources, the findings indicate that lean manufacturing strategies consistently contribute to waste reduction and production efficiency improvement in medium and large-scale industries. The reviewed studies reveal that lean implementation is commonly associated with improvements in workflow continuity, inventory reduction, machine reliability, labor productivity, and delivery performance. The most frequently applied lean tools include 5S, Kaizen, Just in Time (JIT), Value Stream Mapping (VSM), Total Productive Maintenance (TPM), and standardized work systems.

These tools function as integrated managerial mechanisms aimed at eliminating non-value-added activities and improving operational responsiveness. The reviewed literature also identifies several dominant forms of production waste, including overproduction, waiting time, excess inventory, unnecessary transportation, defects, and inefficient motion. These waste categories remain highly relevant within contemporary manufacturing environments because they directly increase operational costs, reduce flexibility, and weaken organizational competitiveness.

Overproduction frequently occurs due to inaccurate demand forecasting and inefficient production scheduling, while waiting time is commonly associated with machine downtime, delayed material supply, and coordination inefficiencies. Excess inventory remains particularly problematic in firms relying on conventional planning systems because it increases holding costs and limits cash flow flexibility. Product defects also contribute significantly to rework costs and customer dissatisfaction.

Table 1. Major Types of Waste Reported in Reviewed Literature

Waste Type	Description	Operational Impact
Overproduction	Producing more than customer demand	High storage cost
Waiting Time	Idle time of workers/machines	Lower productivity
Excess Inventory	Unused raw materials/finished goods	Increased holding cost
Defects	Product quality failure	Rework and waste cost
Transportation	Unnecessary movement of materials	Longer lead time
Motion	Unnecessary worker movement	Low efficiency

Source: Synthesized by Researcher From Reviewed Literature

The persistence of these waste categories confirms the continuing relevance of the classical lean manufacturing framework introduced by (Ohno, 2019). However, the findings also suggest that the operational impact of waste differs according to organizational scale and production complexity. In medium-sized industries, inventory waste tends to be more dominant because firms often experience limited forecasting accuracy and weaker supply chain integration. Conversely, large-scale industries are

more likely to experience waiting time and coordination inefficiencies due to multiple production lines, hierarchical decision-making systems, and broader operational networks. This finding indicates that production waste should not be viewed solely as a technical inefficiency issue, but also as a consequence of organizational structure and managerial capability. The literature further demonstrates that several lean manufacturing tools are repeatedly adopted because of their practical effectiveness and broad applicability across manufacturing sectors.

Among these tools, 5S is identified as the most fundamental strategy because it improves workplace organization, cleanliness, discipline, and workflow efficiency. Kaizen promotes incremental improvement through continuous employee participation, while JIT focuses on synchronizing production activities with customer demand in order to reduce inventory levels. VSM is widely used to identify waste across the production value chain, whereas TPM emphasizes preventive maintenance to reduce machine downtime and improve equipment reliability.

Table 2. Most Applied Lean Manufacturing Strategies

Lean Tool	Primary Objective	Reported Benefit
5S	Workplace organization	Faster workflow
Kaizen	Continuous improvement	Process innovation
JIT	Reduce inventory	Lower stock cost
VSM	Identify waste flow	Better process mapping
TPM	Improve machine reliability	Reduced downtime
Standardized Work	Process consistency	Higher quality

Source: Synthesized by Researcher From Reviewed Literature

The findings suggest that medium-sized industries generally prioritize 5S and Kaizen because these approaches require relatively lower financial investment and rely heavily on employee participation rather than advanced technological infrastructure. Their implementation is also more compatible with flexible organizational structures commonly found in medium enterprises. In contrast, large-scale industries more frequently adopt TPM, JIT, and digital monitoring systems because their production environments require stronger coordination mechanisms and integrated operational control. From a managerial perspective, this difference demonstrates that lean manufacturing implementation is strongly influenced by organizational readiness, technological capability, and resource availability rather than by technical considerations alone. Therefore, the effectiveness of lean manufacturing should be understood as context-dependent and adaptive to organizational scale. Across the reviewed studies, lean manufacturing implementation was consistently associated with measurable improvements in production efficiency. These improvements include shorter lead times, lower defect rates, reduced machine downtime, improved labor productivity, leaner inventory systems, and more reliable delivery schedules. Several studies also reported smoother production flow and faster operational responsiveness after lean implementation due to reduced bottlenecks and improved interdepartmental coordination.

Table 3. Efficiency Improvements After Lean Implementation

Indicator	Before Lean	After Lean	Improvement
Lead Time	High	Lower	Significant
Defect Rate	Moderate/High	Lower	Significant
Machine Downtime	Frequent	Reduced	Moderate
Inventory Level	Excessive	Leaner	Significant
Productivity	Standard	Higher	Significant
Delivery Accuracy	Inconsistent	Improved	Moderate

Source: Synthesized by Researcher From Reviewed Literature

These findings indicate that lean manufacturing contributes not only to waste reduction but also to the creation of integrated operational efficiency throughout production systems. Improved machine reliability and process standardization increase production consistency, while lower inventory levels enhance operational flexibility and cash flow management. This supports the argument that lean manufacturing should be viewed as a socio-technical management system integrating operational processes, workforce behavior, and organizational culture.

Firms that implement lean merely as a collection of technical tools often fail to achieve sustainable improvement because they neglect the importance of cultural transformation and long-term organizational commitment. The literature also reveals significant differences in lean manufacturing implementation between medium and large-scale industries. Medium-sized firms generally demonstrate faster decision-making processes and greater flexibility when introducing new operational systems. Their organizational structures are typically less bureaucratic, allowing lean initiatives to be implemented more rapidly through direct communication and employee involvement.

However, these firms often encounter limitations related to financial resources, technological capability, training budgets, and specialized expertise. In contrast, large-scale industries possess stronger financial resources, advanced technological infrastructure, and more formalized management systems capable of supporting integrated lean implementation. Nevertheless, the reviewed studies indicate that large organizations frequently experience greater resistance to organizational change because of hierarchical structures, coordination complexity, and rigid bureaucratic procedures.

Table 4. Comparative Lean Implementation by Industrial Scale

Aspect	Medium Industry	Large Industry
Decision Making	Faster	Slower
Resource Availability	Limited	Strong
Flexibility	High	Moderate
Technology Access	Moderate	High
Bureaucratic Complexity	Low	High
Lean Sustainability	Variable	Strong if managed well

Source: Synthesized by Researcher From Reviewed Literature

From an organizational and change management perspective, these findings suggest that lean manufacturing implementation is closely related to organizational structure and institutional readiness. Medium industries may adapt more quickly because they possess simpler coordination systems and stronger operational flexibility. Meanwhile, large-scale industries benefit from superior technological and financial capabilities but often face implementation inertia due to organizational complexity. This finding challenges the assumption that lean manufacturing can be implemented uniformly across all industrial contexts. Instead, successful lean transformation requires adjustment to organizational scale, managerial structure, and workforce characteristics. Although lean manufacturing has been widely recognized for improving operational performance, the reviewed literature also identifies recurring implementation barriers.

The most frequently reported barriers include lack of top management commitment, employee resistance, insufficient training, weak communication, inconsistent monitoring systems, and short-term managerial orientation. Several studies indicate that organizations often discontinue lean initiatives because management expects immediate financial outcomes without fully understanding that lean manufacturing requires continuous organizational learning and cultural adaptation.



Figure 1. Main Barriers to Lean Manufacturing Implementation
(Source: Synthesized By Researcher From Reviewed Literature)

These barriers indicate that failures in lean manufacturing implementation are rarely caused by the lean tools themselves, but rather by weak organizational readiness and ineffective change management processes. Resistance to change commonly emerges when employees perceive lean initiatives as additional workload or managerial control mechanisms instead of improvement opportunities. Similarly, inconsistent leadership commitment can reduce employee trust and weaken implementation sustainability. Therefore, lean manufacturing should be understood as a long-term strategic transformation process requiring leadership consistency, employee engagement, communication effectiveness, and organizational culture alignment.

Overall, the findings demonstrate that lean manufacturing strategies significantly contribute to industrial competitiveness by reducing waste, improving production efficiency, and strengthening operational resilience. However, the effectiveness of lean implementation is strongly influenced by organizational scale, managerial capability, technological readiness, and workforce participation. Consequently, lean manufacturing should not be applied as a universal operational model, but rather as an adaptive and context-sensitive management strategy capable of responding to different industrial characteristics and organizational environments.

Conclusion

This study concludes that lean manufacturing strategies play an important role in reducing production waste and improving operational efficiency in medium and large-scale industries. Lean tools such as 5S, Kaizen, Just in Time (JIT), Value Stream Mapping (VSM), and Total Productive Maintenance (TPM) were consistently identified as effective approaches for minimizing non-value-added activities, improving workflow performance, and enhancing productivity. The findings also indicate that lean manufacturing implementation is influenced by organizational scale. Medium-sized industries benefit from greater flexibility and faster decision-making, whereas large-scale industries rely more on technological capability and integrated management systems. However, both industrial scales face similar challenges related to management commitment, employee resistance, and organizational readiness. Therefore, lean manufacturing should be implemented not merely as a technical operational tool, but as a long-term strategic and organizational transformation approach adapted to the characteristics and needs of each industry. This study contributes to the development of a comparative understanding of lean implementation based on industrial scale and highlights the importance of context-sensitive lean strategies for achieving sustainable operational performance.

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