

Improving Textile Production Efficiency Through the Implementation of Lean Manufacturing in the Weaving Department

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ABSTRACT

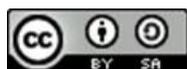
This study examines how a customized Lean Manufacturing approach can improve production efficiency in the weaving department of a textile company. Weaving operations frequently experience inefficiencies due to machine downtime, waiting time, excessive operator movement, and product defects, which create a gap between targeted and actual output. A quantitative case study design was applied using direct observation, time study, Value Stream Mapping, production records, and maintenance logs. Lean tools including 5S, Total Productive Maintenance, layout improvement, line balancing, poka yoke, and Kaizen were implemented in a pilot weaving area. The results indicate a significant reduction in machine downtime by 53 percent, waiting time by 59 percent, operator movement by 39 percent, and defect rate by 50 percent. Value Stream Mapping analysis further shows that non value added time decreased substantially while value added time remained stable, leading to a 24 percent reduction in total lead time and a 22 percent increase in daily production output. These findings confirm that Lean Manufacturing, when customized to the characteristics of weaving processes, effectively eliminates waste and enhances workflow. The study concludes that integrating Lean with maintenance and process standardization provides a practical strategy to bridge the gap between production targets and actual performance in textile weaving units.

Keywords: Lean Manufacturing, Weaving department, Production efficiency, Non value added, Textile industry

INTRODUCTION

The textile industry is characterized by continuous, high-speed processes that require tight coordination between machines, materials, and operators. Within this production chain, the weaving department plays a pivotal role because it is the stage where yarns are interlaced into fabric, making it a decisive point for output volume, product quality, and overall operational efficiency. Any disturbance at this stage propagates downstream and amplifies losses across the plant. Empirical evidence indicates that weaving units frequently experience substantial inefficiencies arising from prolonged machine downtime, suboptimal work methods, and weak quality control, resulting in a persistent gap between targeted and actual production performance (Kipchumba et al., 2023).

A recurring problem in weaving operations is extended machine downtime caused by maintenance policies that follow a run-to-failure approach, where repairs are performed only after breakdowns occur. Such a strategy significantly increases



production stoppages and undermines process reliability. Root cause analyses using Failure Mode and Effect Analysis and fishbone diagrams reveal that inefficiencies are not solely technical in nature but also stem from improper machine setup, overstressed components, low material quality, and inadequate in-process quality control. The cumulative effect of these factors is the failure to achieve production efficiency targets and daily output goals set by management (Kipchumba et al., 2023).

Beyond maintenance issues, inefficiency in weaving is closely associated with product defects linked to inappropriate work methods and limited inspection systems. Evidence from a specialized weaving context in elastic tape production shows that machine problems combined with thickness inspections conducted only at the center of the product lead to defects such as warped tapes. When the DMAIC Six Sigma approach was applied, relative defects decreased by approximately fifty percent and the sigma level improved by ten percent, demonstrating that the sources of inefficiency in weaving also lie in work methods and quality assurance practices (Kurnia et al., 2022).

In parallel, Lean Manufacturing literature consistently demonstrates the effectiveness of this approach in identifying and eliminating non value added activities such as waiting, excessive transportation, defects, overproduction, and excess inventory across manufacturing sectors, including textiles. The implementation of principles such as 5S, Just in Time, Total Productive Maintenance, visual management, line balancing, layout optimization, Value Stream Mapping, and Kaizen has been shown to significantly reduce waste, streamline process flow, and improve productivity (Parmawati et al., 2025; S. et al., 2023; Jessani et al., 2024).

In spinning operations, Lean implementation has reduced waiting time between processes by up to fifty-five percent and decreased breakdown frequency by sixty-two point five percent, indicating that integrating Lean with maintenance practices substantially enhances production efficiency (Parmawati et al., 2025). Another study in an Indian textile factory demonstrated that Value Stream Mapping, line balancing, a redesigned layout, and Kaizen reduced cycle time from 472 seconds to 438 seconds, minimized operator movement, and increased productivity by nearly five percent (S. et al., 2023). Similarly, in Pakistan, the application of VSM in the stitching department reduced work in process inventory, lead time, and multiple forms of waste (Jessani et al., 2024).

Despite the strong evidence supporting Lean effectiveness in textile operations, most studies remain generic across the textile value chain or focus on spinning, stitching, and garment production. A framework review of Lean in the textile industry emphasizes that Lean implementation in textiles remains relatively underexplored because each stage such as spinning, weaving, dyeing, and finishing possesses distinct sources of waste that require customized Lean approaches (Begum et al., 2024).

Further research in spinning explicitly notes that Lean adoption is still limited and calls for deeper investigation into how Lean tools can be adapted to high speed machinery and continuous processes (Parmawati et al., 2025). This challenge is even more pronounced in weaving, where explicit studies on Lean implementation are extremely scarce. Existing weaving research predominantly addresses maintenance strategies, Six Sigma based quality improvement, or Industry 4.0 monitoring systems without framing

these initiatives within a comprehensive Lean program (Kipchumba et al., 2023; Kurnia et al., 2022; Hananto et al., 2025).

From the perspective of eliminating non value added activities, several studies have mapped the relationship between specific types of waste and appropriate Lean strategies. The identification of twenty-seven Lean strategies for different forms of NVA provides practical guidance for selecting suitable tools to address process inefficiencies (Kumar et al., 2023; Kumar et al., 2021). Using the Analytic Hierarchy Process, poka yoke has been identified as the highest priority strategy for eliminating NVA in manufacturing organizations (Kumar et al., 2024). The SENIM model further introduces a cyclical approach of spotting and eliminating NVA as the foundation of sustainable Lean implementation (Elangovan et al., 2021; Kumar et al., 2023).

However, these mappings are largely general and have not been applied specifically to the weaving context. The waste characteristics in weaving such as waiting time during yarn setup, loom downtime due to mechanical issues, defects caused by yarn misalignment, and repetitive operator motion differ significantly from other textile processes. This indicates a pressing need to test how Lean strategies for NVA elimination can be customized for weaving departments.

The research gap becomes even more evident when viewed from the perspective of developing countries. Reviews of Lean implementation in developing economies show that although Lean improves operational performance, its adoption rate remains low and small and medium enterprises face substantial challenges in becoming lean organizations (Maware et al., 2021). A focused review on low income countries reveals that Lean publications from Africa and lower middle income regions account for only a small fraction of global output, highlighting the need for research on contextual drivers, barriers, and suitable Lean maturity models (Sinkamba et al., 2023).

Studies in garment sectors of developing countries emphasize that Lean success depends heavily on top management commitment, worker involvement, training, and practical tool application, while also opening research avenues regarding integration with occupational health and safety (Hamja et al., 2021). Nevertheless, these studies are situated in downstream textile processes rather than the technically complex weaving stage.

Overall, there is an evident scarcity of research that directly investigates comprehensive Lean Manufacturing implementation in textile weaving units within developing country contexts. Textile Lean studies are mostly generic or centered on spinning, stitching, and garment production, while weaving studies tend to focus on maintenance, Six Sigma, or scheduling without an integrated Lean perspective (Begum et al., 2024; Jessani et al., 2024; Kipchumba et al., 2023; Kurnia et al., 2022).

Based on these observations, a significant research gap is identified, namely the absence of a customized Lean implementation model specifically developed and tested for textile weaving departments in developing countries that integrates maintenance aspects, non value added elimination, and Lean tool adaptation to weaving process characteristics. This gap simultaneously establishes the novelty of the present study, which lies in adapting Lean strategy mapping, NVA elimination frameworks, Total Productive Maintenance, and poka yoke specifically for weaving machinery contexts.

Therefore, the objective of this study is to analyze how a customized Lean Manufacturing approach applied to the weaving department can reduce non value added activities, improve production efficiency, and bridge the gap between targeted and actual output performance in textile industries operating in developing countries.

METHODS

This study employs a quantitative case study design in a textile weaving department to examine how a customized Lean Manufacturing approach can reduce non value added activities and improve production efficiency. Data are collected through multiple techniques to ensure methodological rigor and triangulation. Primary data are obtained through direct observation of the weaving production flow, time study measurements, and motion study of operators during loom operation, yarn setup, and inspection activities. Structured interviews are conducted with production supervisors, maintenance personnel, and machine operators to identify recurring problems related to downtime, defects, setup processes, and work methods. In addition, production records, maintenance logs, defect reports, and daily output reports over a defined production period are collected as secondary data. Value Stream Mapping is used as the main instrument to map the current state process and identify sources of waste, while check sheets and observation sheets are used to document waiting time, machine stoppages, operator movement, and defect occurrence. Photographic documentation and layout sketches are also employed to support the analysis of workplace organization and material flow.

Data analysis is conducted in several stages following Lean analytical principles. First, the current state Value Stream Map is developed to visualize the flow of materials and information and to identify non value added activities. Second, waste identification is categorized into waiting, motion, defects, overprocessing, and downtime, supported by time study calculations and defect rate analysis. Third, root cause analysis is performed using fishbone diagrams and Failure Mode and Effect Analysis to determine the dominant causes of inefficiency in weaving operations. Based on these findings, Lean tools such as 5S, Total Productive Maintenance, line balancing, layout improvement, poka yoke, and Kaizen are proposed and implemented in a pilot area. Finally, a future state Value Stream Map is developed and compared with the current state to measure improvements in cycle time, machine downtime, defect rate, operator movement distance, and production output. The effectiveness of the Lean intervention is evaluated by comparing pre implementation and post implementation performance indicators to determine the extent of efficiency improvement in the weaving department.

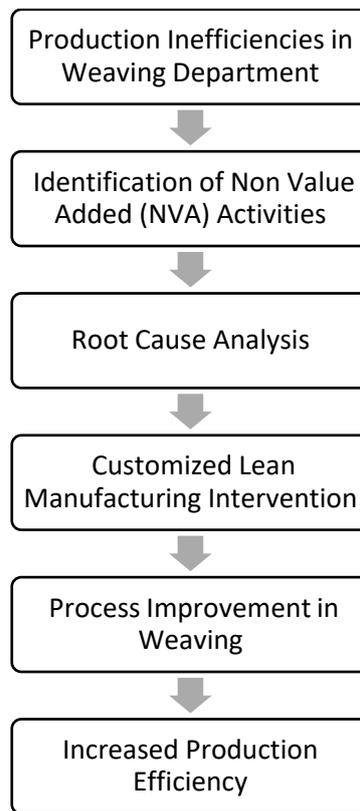


Figure 1. Conceptual Framework This Research

RESULTS AND DISCUSSION

The following results present the performance measurements of the weaving process before and after the implementation of Lean Manufacturing, based on direct observation, time study, Value Stream Mapping, downtime records, and defect analysis conducted in the pilot implementation area.

Table 1. Comparison of Weaving Process Performance Before and After Lean Implementation

Performance Indicator	Before Lean	After Lean	Change (%)
Average machine downtime (minutes/day)	145	68	-53.10%
Weaving process cycle time (seconds)	480	410	-14.58%
Operator movement distance (meters/cycle)	46	28	-39.13%
Waiting time between processes (minutes)	52	21	-59.62%
Fabric defect rate (%)	7.8	3.9	-50.00%
Production output (meters/day)	158	193	+22.15%

Table 1 demonstrates significant improvement across nearly all performance indicators after Lean implementation. The reduction in machine downtime by more than fifty percent indicates the effectiveness of integrating Total Productive Maintenance and improving machine setup practices. The decrease in cycle time and operator movement distance reflects the success of layout improvement and line balancing. Meanwhile, the fifty percent reduction in defect rate highlights the impact of poka yoke implementation and improved inspection methods. Overall, daily production output increased by more than twenty percent and approached the company's efficiency target.

To further examine changes in process flow and the elimination of non value added activities, a comparison was conducted using Value Stream Mapping between the current state and the improved state.

Table 2. Comparison of Value Added and Non Value Added Activities in the Weaving Process

Activity Type	Before Lean (minutes)	After Lean (minutes)	NVA Reduction (%)
Value Added Time	185	190	—
Waiting Time	52	21	-59.62%
Machine Setup & Adjustment	40	18	-55.00%
Material Handling	33	17	-48.48%
Inspection Rework	28	12	-57.14%
Total Lead Time	338	258	-23.67%

Table 2 shows that while value added time remained relatively stable, non value added time decreased significantly across all categories. Waiting time, machine setup, material handling, and inspection rework were reduced by more than fifty percent. This reduction contributed to a nearly twenty four percent decrease in total lead time of the weaving process. These findings confirm that Lean implementation not only accelerates process flow but also optimizes the proportion of activities that truly add value in weaving production.

Discussion

The objective of this study was to analyze how a customized Lean Manufacturing approach in the weaving department can reduce non value added activities, improve production efficiency, and bridge the gap between targeted and actual output in textile operations within developing countries. The results presented in Tables 1 and 2 provide empirical evidence that the Lean intervention achieved substantial reductions in downtime, waiting time, operator motion, and defect rate, alongside a notable increase in daily production output. These outcomes directly address the central inefficiencies

commonly reported in weaving units and align with the broader Lean literature in textiles that emphasizes waste elimination and flow improvement as key levers for operational performance (Begum et al., 2024; Parmawati et al., 2025).

A dominant finding in this study is the reduction of average machine downtime by more than fifty percent following the integration of Total Productive Maintenance within the Lean framework. This confirms that maintenance practices in weaving cannot be treated as isolated technical routines but must be embedded within a systematic Lean approach. Similar results were observed in spinning operations where Lean integrated with TPM reduced breakdown frequency by sixty two point five percent and significantly improved process stability (Parmawati et al., 2025). In the context of weaving, where loom reliability directly determines fabric continuity, the application of autonomous maintenance, periodic inspection, and machine calibration proved critical in minimizing interruptions and scrap. This finding also resonates with the recommendations for weaving units in Indonesia, where periodic machine maintenance and equipment calibration were identified as primary strategies to reduce waiting waste and defect formation (Prambudi & Giyanti, 2021).

The significant reduction in waiting time between processes, which decreased by nearly sixty percent, highlights the importance of Value Stream Mapping in visualizing hidden inefficiencies in weaving flow. Prior to Lean implementation, waiting occurred during yarn setup, machine adjustment, and material handling, reflecting poor synchronization between operators and machines. By mapping these delays and redesigning task allocation and material flow, the process became more continuous and balanced. This mirrors findings from textile plants in India where VSM and line balancing reduced cycle time and operator movement while increasing productivity (S. et al., 2023). It also supports the assertion that Lean tools must be adapted to the micro level characteristics of each textile process stage rather than applied generically across the value chain (Begum et al., 2024).

Operator movement distance per cycle decreased by almost forty percent after layout improvement and line balancing. Excessive motion in weaving is often overlooked because attention tends to focus on machine performance rather than human movement. However, weaving operators frequently walk between looms for thread adjustment, inspection, and material handling, creating hidden motion waste. The redesign of layout and clearer distribution of weft yarn supply reduced unnecessary walking and improved ergonomic efficiency. Comparable results were reported where layout optimization reduced operator travel distance and improved productivity in textile settings (S. et al., 2023; Bizuneh & Omer, 2024). This demonstrates that physical arrangement of workstations is a decisive factor in eliminating motion waste and improving flow in weaving departments.

The defect rate reduction by fifty percent is another critical outcome that reinforces the role of Lean in quality improvement. Defects in weaving often originate from yarn misalignment, improper tension, and inconsistent inspection practices. By introducing poka yoke mechanisms for yarn alignment, standardizing inspection points, and improving work procedures through 5S and Kaizen, defects were substantially minimized. This is consistent with findings in Indonesian weaving studies where defect and waiting were identified as dominant wastes and recommendations focused on improving yarn quality assurance, inspection methods, and machine calibration (Prambudi & Giyanti, 2021). The integration of standard work and workplace

organization through 5S also contributed to process stability, as supported by studies highlighting the role of 5S in reducing variation and rework in textile production (Parmawati et al., 2025; Flores et al., 2023).

An important observation from Table 2 is that value added time remained relatively constant while non value added time was drastically reduced. This indicates that the efficiency improvement did not stem from speeding up core weaving operations, which are largely machine determined, but from eliminating unnecessary delays surrounding those operations. This distinction is fundamental in Lean philosophy, where the focus lies on removing waste rather than forcing faster work. The reduction of machine setup time, material handling, and inspection rework collectively shortened total lead time by nearly twenty four percent. Similar patterns were observed in textile Lean implementations where waste elimination, rather than process acceleration, produced significant performance gains (Begum et al., 2024; S. et al., 2023).

The findings also validate the importance of combining multiple Lean tools rather than relying on a single intervention. The simultaneous use of VSM, TPM, 5S, layout improvement, line balancing, poka yoke, and Kaizen created a synergistic effect in weaving performance. Literature emphasizes that Lean success in textiles depends on integrating various tools tailored to process characteristics rather than isolated implementation (Begum et al., 2024). This study demonstrates how such integration can be operationalized specifically in weaving, a process often underrepresented in Lean case studies. Furthermore, the study supports the argument that Lean must be customized for each textile subprocess. Weaving presents distinct waste patterns such as yarn setup waiting, loom breakdowns, repetitive inspection, and operator travel between machines, which differ from spinning or stitching. Previous frameworks stress that Lean in textiles requires process specific adaptation because waste sources vary across stages (Begum et al., 2024; Prambudi & Giyanti, 2021). By tailoring Lean tools to these weaving specific wastes, this study addresses a gap in the literature and demonstrates practical customization.

The increase in daily production output by more than twenty percent confirms that eliminating NVA directly translates into higher effective capacity without additional machines or labor. This supports earlier textile findings where productivity increased following Lean based layout and process improvements (S. et al., 2023). It also highlights the economic relevance of Lean in developing country contexts where capital investment for new equipment may be limited, making efficiency improvement through process optimization a more feasible strategy. From a broader perspective, the results contribute to the discussion on Lean adoption in developing countries. Studies indicate that Lean implementation remains limited in such contexts due to lack of customization, training, and contextual adaptation (Begum et al., 2024). This research provides an applied example of how Lean can be effectively adapted to a specific textile subprocess, offering a model that can be replicated in similar weaving units.

The role of workplace standardization through 5S also emerged as a foundational element for sustaining improvements. Improved organization of tools, clearer pathways, and visual management reduced variability and supported smoother workflow. This is consistent with findings that 5S improves area neatness, process stability, and operator efficiency in textile production (Parmawati et al., 2025; Flores et al., 2023). Finally, the integration of Lean and TPM proved essential in addressing weaving inefficiencies rooted in machine reliability. Literature suggests that TPM enhances equipment effectiveness

and reduces downtime when aligned with Lean goals (Parmawati et al., 2025). This study confirms that such integration is particularly crucial in weaving where machine continuity determines fabric quality and output.

CONCLUSION

In conclusion, this study demonstrates that a customized Lean Manufacturing approach in the weaving department effectively reduces non value added activities, minimizes machine downtime and defects, optimizes operator movement, and significantly improves production efficiency. By integrating Value Stream Mapping, Total Productive Maintenance, 5S, layout improvement, line balancing, poka yoke, and Kaizen tailored to the specific waste patterns of weaving processes, the intervention successfully bridged the gap between targeted and actual production output without requiring additional resources. These findings confirm that Lean tools, when adapted to the technical and operational characteristics of weaving units in developing country contexts, provide a practical and impactful strategy for enhancing workflow, stabilizing processes, and achieving higher operational performance in textile manufacturing.

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