

Optimization of the Manufacturing Process in a Peruvian Textile Workshop Under the TPM Philosophy and the 5s Tool

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Abstract

The textile sector plays a significant role in national economies, both in small and large-scale operations globally. In Peru, the textile industry contributes 1.9% to the gross domestic product. Based on this, the improvement project was developed in a textile manufacturing workshop with the objective of enhancing product quality and overall operational performance. The project began with an analysis of the company's key indicators, which were compared with industry benchmarks to identify improvement opportunities. A state-of-the-art review was also carried out to examine the impact of Lean tools implemented in similar organizations. Subsequently, the methodology was carried out, encompassing the entire production process and divided into four phases. The expected results of the implementation will bring benefits such as a reduction in defective products, electricity consumption, and an increase in productivity. After developing the methodology, the results obtained include a 12% increase in productivity, a 17% decrease in electricity consumption, and an 11.5% better utilization of installed capacity. With these results, a reduction in the technical gap was achieved, demonstrating the economic viability of the project. This project shows its contribution by demonstrating that small workshops are capable of applying the lean methodology and obtaining very beneficial results.

Keywords

Lean Manufacturing, 5s, Total Productive Maintenance, Textile Industry and Productivity Improvement

1. Introduction

The textile and clothing sector represents one of the largest economic activities in Peru and the world (Candelario et al, 2023). According to the Ministry of Production of Peru (PRODUCE, 2020), the global textile GDP decreased at an average annual rate of 5.2% over the last five years, with a severe contraction of 31.8% in 2020 as a result of the COVID-19 pandemic. These effects were particularly pronounced in industries characterized by high fragmentation and dominated by small production units, leading to the temporary or permanent closure of approximately 24% of textile companies during this period.

At the national level, the textile industry is one of the most important in the country, as it has a significant economic impact in Peru, providing jobs to 75% of the economically active population and being the largest manufacturing sector in the country (Zamora et al., 2021). The clothing textile sector represents one of the main non-extractive activities in Peru, accounting for 1.9% of the national GDP and just over 10% of total manufacturing production (Loayza et al., 2020).

Furthermore, a significant barrier of competitiveness is that only 47.1% of Peruvian textile firms hold any type of certification, limiting their capacity to meet international quality expectations (PRODUCE, 2020).

Operational inefficiencies—such as defective products, rework, waste generation, and inconsistent process performance—continue to affect production outcomes, generating losses associated with unmet orders, additional labor, and transportation costs (Khan et al., 2021). To address these challenges, Lean manufacturing has been widely recognized for its ability to enhance productivity and efficiency in various industries, including textiles (Tejada et al., 2024). Nonetheless, its implementation remains limited among small Peruvian workshops.

This study focuses on Azumys S.A., a Peruvian company established in 2013 dedicated to the production of clothing and the sale of jeans, including products such as boyfriend jeans, baggy jeans, mommy jeans, skinny jeans, shorts, vests, among others. Although the company initially operated by retailing clothing from other workshops, in 2018, it began manufacturing its own clothing and expanded its operations to wholesale, resulting in a 25% increase in profits since then.

Despite this growth, the organization faces challenges in efficiency. The chosen Key Performance Indicator (KPI) for assessing the technical gap is the productivity percentage. A comparative analysis between the company's values and those of the sector revealed that the current productivity of the company is 1.25, translating to a 25%. This indicator implies that the company earns 25 cents of profit for every sol invested in resources. Through value stream mapping (VSM), the production process of the company is visualized, aiding in the identification of the amount of waste produced. The VSM is presented below in Figure 1.

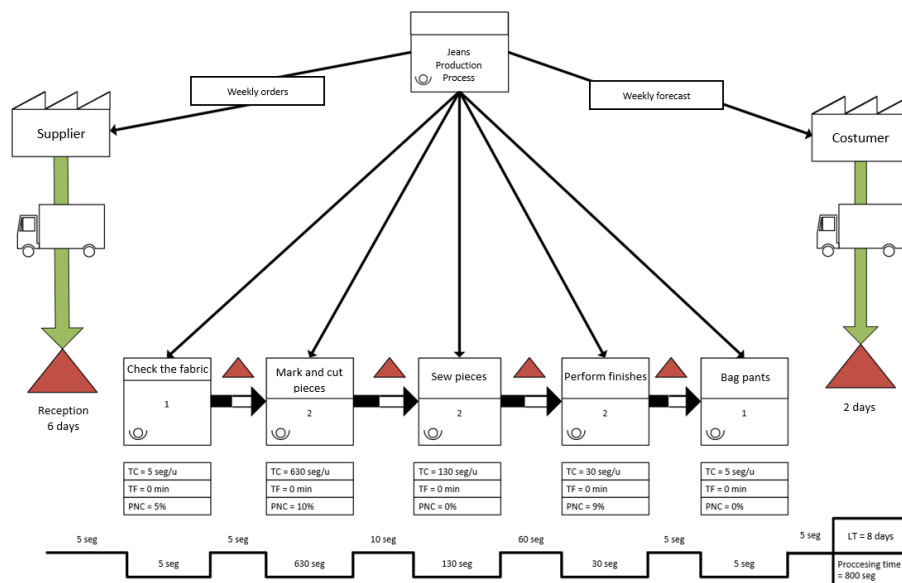


Figure 1. Value Stream Mapping

The main problem identified in the organization is the low productivity, which has consequences in terms of profitability and competitiveness. The root causes include a lack of training among the personnel due to resistance to change, leading to errors and delays in production. Additionally, the difficulty in locating work tools is identified as a second cause, resulting in time loss and reduced worker efficiency. Lastly, the lack of maintenance for embroidery machines, sergers, and cutters, among others, impacts the quality of the final product.

To present the quantitative analysis of the causal factors that directly and indirectly contribute to the problem, an Ishikawa diagram was created. This tool serves to identify and categorize the causes and effects of the central problem, as shown in Figure 2. Based on the issues outlined, this study seeks to address the following research question: Is the implementation of lean tools viable for optimizing the garment production area in a Peruvian textile workshop?

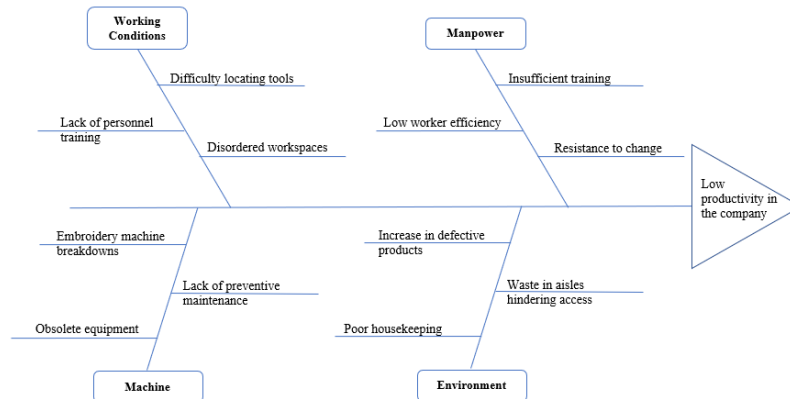


Figure 2. Ishikawa Diagram

1.1 Objectives

The primary objective of this research is to design and validate an improvement proposal aimed at optimizing the sewing process of a Peruvian textile workshop through the application of Lean methodologies, specifically 5S and Total Productive Maintenance (TPM). To achieve this goal, the following specific objectives have been defined:

- To perform a detailed diagnostic analysis of the current process using Lean analytical techniques
- To formulate and structures improvement proposals targeted at enhancing operational performance
- To validate the proposed solution by assessing its economic feasibility and its impact on relevant stakeholders

2. Literature Review

This study employs a systematic literature review to identify and characterize primary research related to the implementation of Lean Manufacturing tools in the textile industry. The review followed inclusion criteria that considered only open-access journal articles and conference papers published in the last five years in Scopus and Web of Science databases. Selected publications were required to focus specifically on Lean methodologies applied to textile production for productivity improvement.

Across the reviewed literature, two recurrent problems were identified. The first is the lack of organization and limited adaptation to Lean philosophy. Many textile firms prioritize production quantity over workplace organization, resulting in inefficient processes and increased waste (Loayza et al., 2020). The second problem concerns the difficulty of adapting Lean practices to diverse manufacturing environments. Although Lean is widely applied in global manufacturing (Abbes et al., 2022), textile production involves complex, labor-intensive operations that depend heavily on operator skills (Silva et al., 2021). Consequently, there is no universal approach for implementing Lean, and misapplication often leads to limited or nonexistent improvements.

Regarding Lean tools, the literature highlights 5S as the most frequently implemented methodology. Luque and Rojas (2021) argue that 5S is foundational for any improvement initiative, as an organized and clean environment is essential for successfully deploying Lean projects. Its adoption in textile companies has been associated with increased efficiency and reduced non-value-adding activities (Alanya et al., 2020). Another commonly used tool is Value Stream Mapping (VSM), which shows all the activities needed to convert the raw material into a final product by mapping the entire production process (Saravanan et al., 2023). Additionally, Total Productive Maintenance (TPM) is highlighted as a relevant approach for improving equipment effectiveness, preventing failures, and supporting environmental and safety objectives.

The reviewed studies consistently report that Lean implementation generates improvements in productivity, working conditions, material planning, and waste reduction. These outcomes positively influence quality performance and occupational safety. Zamora et al. (2021) highlight the importance of worker training to ensure effective implementation and to achieve operational cost reductions. Similarly, employee empowerment has been shown to enhance workers' decision-making capabilities and support capability development (Sahoo,2022).

However, the literature also identifies significant barriers. The most prominent is resistance to change, both from employers—concerned about cost and implementation risks—and from employees, who often exhibit rigidity towards changing established work habits (Palange & Dhatrak, 2021). This aligns with Loayza et al. (2020), who note that employee commitment is essential for developing metrics and deploying production indicators. Furthermore, small and medium-sized enterprises face resource limitations, which restrict their ability to adopt new management models and technologies.

3. Methods

This research was categorized as an applied improvement case study with a pretest-posttest design. The case analyzes the productivity of a Peruvian textile company, focusing on the garment manufacturing process. The improvement was achieved through the implementation of Lean Manufacturing tools (5S and TPM). Initially, an Ishikawa diagram was employed to diagnose the main problem within the company: low productivity in the garment manufacturing process. Based on this analysis, the root causes were linked to the appropriate improvement tools, as summarized in Table 1, which presents the methodological structure developed in four components: analysis, implementation, validation and improvement.

Table 1. Methodological structure

Phase	Scope	Tool/Technique	Validation
Phase 1	Analysis (Pretest)	Indicator analysis, VSM, Ishikawa diagram, radar chart (before).	Confirmation by company staff and methodological triangulation.
Phase 2	Implementation	5S and TPM tools.	Triangulation through expert critical judgment (SME manager, Lean Manufacturing specialist).
Phase 3	Validation	Audit, 5S board, periodic reviews, radar chart (after).	Confirmation by company staff and methodological triangulation.
Phase 4	Improvement (Posttest)	Indicator analysis, comparative matrix, improvement plan, training sessions.	Confirmation with participants and methodological triangulation.

The following section provides a detailed explanation of the four components of the improvement project, highlighting their relevance and impact.

3.1 Phase 1: Analysis (Pretest)

The first component is the analysis (pretest), where the most recurring problems in the cutting and sewing areas of the company were identified, along with the main improvement opportunities. To develop this component, the company's environment was observed to detect initial issues. Data collection followed, including time studies and the creation of a Value Stream Map (VSM), which helped establish the company's baseline indicators. Industry benchmarks were also analyzed to determine the technical gap. Once this gap was identified, an Ishikawa diagram was used to pinpoint the root causes of the company's main problems. To assess the company from the perspective of the 5S methodology, an initial test was conducted using a radar chart. This tool allowed visualization of the current state of the company and comparison with the desired future state. Target indicators were set on the radar chart to measure whether the implemented improvements had an impact on the selected processes.

3.2 Phase 2: Implementation

This phase is implementation, where the selected Lean tools for the improvement project—5S and TPM—were applied. In order to correctly apply TPM, it is necessary that the 5S methodology has been implemented beforehand, as it acts as a solid foundation and can be successfully integrated with other quality tools (Silva et al. 2022). For 5S, the steps followed were: sort, set in order, shine, standardize, and sustain. Each step had to be completed correctly before moving to the next, so after every activity, a verification was carried out. If the expected results were not met,

adjustments were made and the step was re-evaluated. Subsequently, TPM was developed through a simulation model and planning approach.

3.3 Phase 3: Validation

The third component involved validation. In this phase, the implementation carried out in the previous component was monitored. Audits played a key role in ensuring proper follow-up of the implemented actions. Additionally, radar charts were created again—one to track the progress of the 5S tool within the company and another for TPM. It is important to note that although both charts share a similar format, the criteria used for their development are completely different.

3.4 Phase 4: Improvement (Post test)

Finally, the fourth component focused on improvement. In this phase, radar charts were compared to verifying whether the established targets had been achieved. If the goals were met, the improvement process did not stop there; efforts continued to reach the highest possible percentage for the indicators shown in the radar diagrams. However, if the targets were not met, adjustments were made to improve the KPIs associated with the implementation of the 5S and TPM tools. These adjustments were incorporated into an improvement plan, which included enhanced training sessions to ensure that personnel could perform effectively under the selected Lean tools.

4. Data Collection

To obtain qualitative and contextual information about workstation organization, routine delays, and machine issues, interviews with workers from the cutting and sewing area were conducted. These interviews informed the selection of Lean tools and confirmed observed operational problems. Complementing internal data, sector indicators were gathered from external reports and used to calculate the technical gap between the company and the Peruvian textile industry. Finally, additional data were collected through a baseline 5S audit, which characterized the initial level of workplace organization and provided reference values for later validation of improvements.

To address the organizational deficiencies identified in the baseline audit, the 5S methodology was implemented adhering to the institutional guidelines for laboratories and workshops (Universidad de Lima, 2021). A 5S Committee was established to lead the initiative, beginning with an introductory training session to raise personnel awareness regarding the tool's importance and benefits. Following the initial diagnosis and training, the execution of the 5S stages proceeded as follows:

- **1S: Seiri (Sort):** In this stage, elements that are deemed unnecessary were identified, and corrective actions were taken based on established criteria (recoverable, obsolete, unusable, and in custody) to free up workspace. This process involves the use of internal 5S cards that outline the action plan following the criteria mentioned. Additionally, a designated area was assigned to place unnecessary items identified with red cards and marked with red tape.
- **2S: Seiton (Set in Order):** Necessary items were organized based on usage frequency and assigned specific locations to ensure quick retrieval. Additionally, machinery perimeters were visually outlined with yellow tape, maintaining a 3cm margin.
- **3S: Seiso (Shine):** A daily cleaning routine was established to prevent waste accumulation. The 5S Committee conducted inspections to verify tool functionality and compliance with the cleaning schedule.
- **4S: Seiketsu (Standardize):** The objective is to sustain the improvements achieved in the previous stages. For this, the 5S Committee developed visual control tools that allow the manager to monitor adherence to the new standards. This stage focused on maintaining the sorting, organizing, and cleanliness protocols established in previous steps.
- **5S: Shitsuke (Sustain):** The aim is to instill habits in workers to follow established procedures because without discipline, the improvements achieved can deteriorate. To achieve this, a 5S indicator board was implemented, a tool that allows the recording of progress and results obtained according to each phase (See Figure 3).

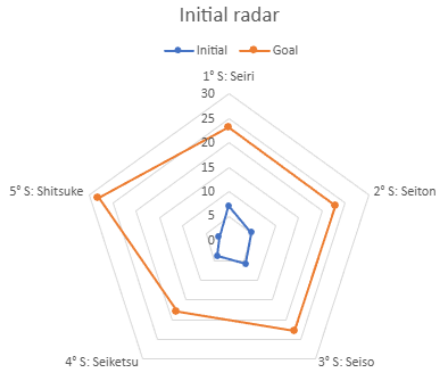


Figure 3. Initial radar chart

On the other hand, to develop the simulation of the TPM philosophy, it was strictly necessary to gather all the information related to the machinery used during the production process and the maintenance processes carried out during one month of production. The design and implementation require the deployment of six phases, which will be explained below.

Phase 1: Identify the equipment's life history. The information was collected regarding the production capacity the equipment would have if it were new. Additionally, it was necessary to determine how many times the equipment had experienced a breakdown. This information is crucial because it provides the opportunity to identify improvement areas in maintenance processes.

Phase 2: Standardize processes. Once the maximum capacity of the equipment in its best condition was known, it was necessary to standardize production processes. To do this, the production process was analyzed, repetitive tasks were identified, and standards were established to optimize the time machines are in use.

Phase 3: Calculate Overall Equipment Effectiveness (OEE). This indicator allows us to understand the efficiency of industrial machinery and will be a key tool for maintaining a continuous improvement process. The calculation is as follows:

$$OEE = \frac{\text{Time of production}}{\text{Available time}} \times \frac{\text{Actual production}}{\text{Theoretical production}} \times \frac{\text{Good Pieces}}{\text{Actual production}}$$

Phase 4: Plan maintenance. Using the information gathered in the previous phases, maintenance strategies will be implemented with the goal of increasing OEE. These strategies may include preventive, predictive, autonomous, or reactive maintenance.

Phase 5: Organize area cleaning. This phase aims to maintain order in the workstations where machinery is present, thus preventing future breakdowns caused by dust, oil, or grease on the equipment.

Phase 6: Organize spare parts. For the maintenance planned in Phase 4 to be carried out, the company must have spare parts available on-site. Therefore, they must be purchased and organized in a space that is easily accessible to workshop staff. With all the information collected in the previous phases, the process simulation was carried out using Arena software, version 16.10.0004, with the support of three simulation experts to validate the correct modeling. Figure 4 shows the process model.

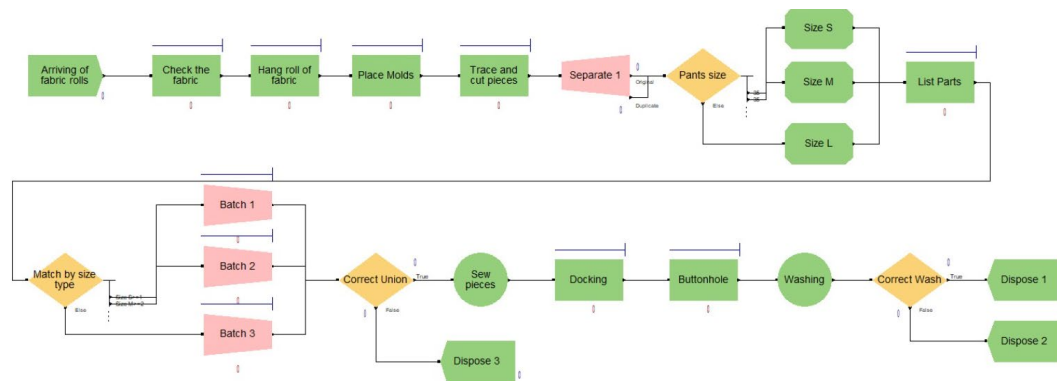


Figure 4. Simulation model

5. Results and Discussion

5.1 Numerical Results

The implementation of the 5S and TPM methodologies generated substantial improvements in the operational performance of the textile workshop. As detailed in Table 2, productivity increased from 1.25 to 1.40, reducing the technical gap with the sector benchmark of 1.42. Furthermore, electricity consumption decreased by approximately 20%, dropping from 282.7 kWh to 233.75 kWh, while installed capacity utilization increased from 56.0% to 67.5%, surpassing the textile industry reference value of 63.3%. These results confirm the effectiveness of Lean tools in enhancing efficiency, reducing waste, and optimizing the use of resources in small textile enterprises.

Table 2. KPIs Comparison

KPI	Before	After	Textile industry
Productivity	1.25	1.4	1.42
Electric consumption	282.7 kWh	233.75 kWh	150 kWh
Install Capacity	56.00%	67.50%	63.30%

The economic evaluation confirms the feasibility and profitability of the proposed improvement model. The project yielded a Net Present Value (NPV) of PEN 49,948.30, an Internal Rate of Return (IRR) of 232%, and a Benefit–Cost Ratio of 7.96, with a payback period of 1.53 years, indicating that the investment is recovered during the year following implementation. The economic funds flow, presented in Table 3, projects the financial performance over a five-year horizon.

Table 3. Economic Funds Flow for 2022-2026 (USD)

Year	2022	2023	2024	2025	2026
Operating profit		6,211.76	6,564.71	6,564.71	6,564.71
NOPAT		4,379.41	4,628.24	4,628.24	4,628.24
Investment	-2,112.06				
Depreciation and amortization		352.94	352.94	352.94	29.41
Carrying value					1470.59
Working capital					5882.35
Statement of cash flows	-2,112.06	4,732.35	4,981.18	4,981.18	12,010.59
Updated cash flow	-2112.06	4,009.41	4,220.29	4,220.29	10,175.88
Accumulated cash flow	-2112.06	1,897.35	6,117.35	10,337.65	20,513.53

To carry out the economic funds flow, a COK (Cost of Capital) of 18.03% was considered, considering inflation statistics in Peru and the USA obtained from the BCRP. With the values obtained, the following economic indicators were calculated and are presented in Table 4.

Table 4. Economic Indicators

Indicator	Value
VAN	USD 14,690.67
IRR	232%
B/C	7.96
Recovery period	1.53

Overall, the numerical results demonstrate that the application of Lean tools in small textile workshops can effectively enhance productivity, reduce energy consumption, optimize capacity utilization, and generate substantial economic returns. These outcomes support the relevance of adopting structured improvement methodologies within micro and small textile enterprises.

5.2 Graphical Results

The graphical results provide a visual representation of the improvements achieved after implementing the Lean tools in the textile workshop. Figure 5 illustrates the radar chart for posttest conditions. In this visualization, the post-intervention curve expands consistently across five evaluated dimensions (Sort, Set in order, Shine, Standardize, and Sustain). Compared to the initial diagnosis, the chart demonstrates a high level of adherence to the methodology, confirming that behavioral and environmental changes were successfully consolidated within the workshop.

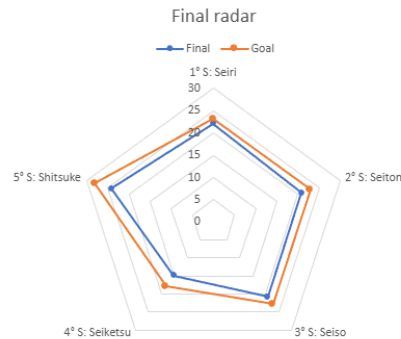


Figure 5. Final radar chart

Another relevant graphical result is the representation of finished products before and after applying TPM. The visual increase in output demonstrates the effect of improved equipment availability and reduced machine stoppages, offering an intuitive perspective of how maintenance-based actions are translated directly into higher production levels. Figure 6 reinforces the operational value of TPM by showing a tangible rise in throughput.

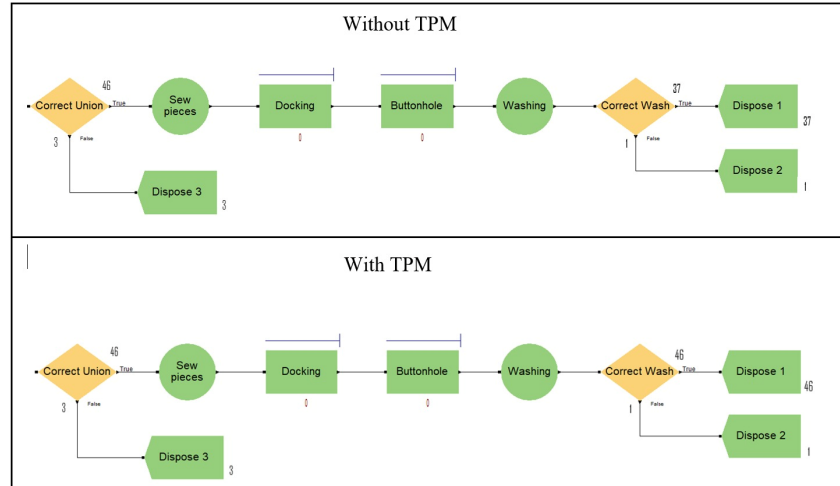


Figure 6. Impact on finished products

5.3 Proposed Improvements

Having successfully implemented the 5S and TPM methodologies, the foundation is set for more advanced improvements, which are detailed below:

- **Digitalization and Real-Time Monitoring:** Implement IoT monitors to enable tracking machine conditions, including factors such as temperature, vibration, and energy consumption. Additionally, predictive maintenance software can be implemented to complement TPM's failure reduction strategies.
- **Continuous Training:** Develop advanced technical training programs for operators and maintenance personnel, along with more detailed workshops on Lean Manufacturing, Kaizen, and Six Sigma to reinforce continuous improvement.
- **Advanced Visual Management:** Install digital panels to display key indicators and provide alerts in case of any deviations.
- **Integration with Quality Systems:** Link to the TPM philosophy with ISO 9001 and ISO 14001 standards to ensure quality and sustainability, while aiming for future certification.

5.4 Validation

To validate the results of the implementation, Risk Simulator was used, and a sensitivity analysis was performed, evaluating three scenarios: pessimistic, normal, and optimistic. In these scenarios, an increase and decrease of the key variables were considered to obtain the project's IRR. After running a simulation of 1,000 trials, the following results were obtained, as detailed in Table 5:

Table 5. Sensitivity Analysis (USD)

Scenario	Pessimistic	Normal	Optimistic
Materials cost	558.82	650.00	741.18
Energy cost	47.06	52.94	58.82
Labor Cost	529.41	602.94	661.76
IRR	1.33	2.33	2.8

It can be observed that, despite having a pessimistic scenario, the investment would be recovered in the year following implementation. Once the economic indicators have been determined and the sensitivity analysis performed, it can be demonstrated that the feasibility of implementing the proposed improvement is very high, as the IRR values obtained

are quite significant. This indicates that the investment allocated to the improvement project will be recovered within a short period of time.

Complementing this economic validation, the operational impact of the proposal shows consistency with research in similar contexts. The present implementation, utilizing some lean tools, shows a positive impact on the results. Improvements have been observed that are consistent with research in similar contexts, such as the study conducted by Silva et al (2021). These studies employed various lean tools such as Value Stream Mapping (VSM), Kaizen, SMED, and Visual Management applied to case studies in the textile sector. Both research projects achieved a reduction in the reprocessed garment rate, with percentages of 4.23% and 11.58%, respectively. These results suggest that, despite differences in the tools used compared to the current study, similar objectives are achieved in terms of reducing reprocessing due to defects.

Furthermore, the increase in productivity evidenced here bears similarity to previous research documented by Bellido and La Rosa (2018). In their analysis of a small textile business, the authors achieved a notable 35% increase in productivity through the implementation of the 5S methodology and preventive maintenance. Additionally, research by Zamora et al. (2021) demonstrates that, through the standardization process and 5S implementation, comparable results were achieved with a 20% increase. The consistency of these results is mainly related to the application of the 5S tool, which reduces material search times and mitigates downtime generated by disorder.

The results obtained in this study are consistent with previous research, such as the pilot test conducted by Torres-Luna et al. (2021) in a small polo production business, where they achieved an 11.58% reduction in waste. This is further supported by Loayza et al. (2020), whose findings confirm that a lack of organization leads to unproductive processes that generate waste.

Finally, regarding machine availability, in studies like that of Gonzales and Meza (2018), the TPM tool was implemented in the weaving area of a textile company, resulting in a 15% increase in the availability of sewing machines, as motors were previously failing due to a lack of spare parts and unplanned maintenance. The consistency of these results is attributed to the use of the same solution model, where the TPM tool aims to increase the availability and efficiency of machinery and equipment by maintaining it at an optimal service level and increasing its lifespan, as noted by Reyes (2019).

6. Conclusion

This research demonstrates that the implementation of Lean Manufacturing tools, specifically 5S and TPM, is technically and economically feasible for optimizing production processes in a textile workshop. The textile production area was characterized by a significant amount of waste, identified through a diagnostic using the Value Stream Mapping (VSM) methodology.

From an operational perspective, productivity increased from 1.25 to 1.40, electricity consumption decreased by nearly 20%, and the utilization of installed capacity exceeded the industry average. These results confirm that Lean principles can effectively address inefficiencies such as disorganization, machine downtime, and resistance to standardized processes. The integration of 5S as a fundamental tool facilitated workplace stabilization, while TPM strengthened equipment reliability and promoted sustainable performance improvements.

From an economic standpoint, the analysis reveals the project's profitability, featuring a positive Net Present Value (NPV), an Internal Rate of Return (IRR) of 232%, and a Benefit-Cost Ratio (B/C) greater than one. Notably, for every monetary unit invested, a return of 7.96 monetary units is obtained.

Overall, the proposed model not only enhances productivity and resource efficiency but also strengthens organizational culture and competitiveness. The results indicate that Lean Manufacturing can serve as a strategy to improve the sustainability and resilience of small textile enterprises in emerging economies. Furthermore, the study demonstrates that the successful adoption of the Lean philosophy does not require large investments or large-scale organizational structures, making it accessible to small and medium-sized enterprises.

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Biographies

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