ISBN: 978-628-96613-3-0. ISSN: 2414-6390. Digital Object Identifier: https://dx.doi.org/10.18687/LACCEI2026.1.1.2063

Optimization of OEE in a Peruvian Textile Spinning Plant: An Empirical Study Based on the Integration of TPM and 5S

Joseph Cristopher Alva-Ramírez, BSc[1] Nayeli Patricia Arenas-Berrocal, BSc[2] Rafael Chavez-Ugaz, PhD[3] and Juan Carlos Quiroz-Flores, PhD[4]
[1,2,3]Carrera de Ingeniería Industrial, Universidad de Lima, Perú.
20183555@aloe.ulima.edu.pe[1] , 20183594@aloe.ulima.edu.pe[2] , rchavezu@ulima.edu.pe[3] ; jcquiroz@ulima.edu.pe[4]

Abstract-*The Peruvian textile sector faces increasing pressure to improve its operational efficiency due to its high dependence on machinery, the inherent variability of the spinning process, and recurrent failures that interrupt production continuity. These limitations reduce the industry's responsiveness to demand and hinder compliance with international efficiency standards. Although operational stability is critical in the spinning process, previous studies addressing these issues through TPM and 5S are still scarce or present only partial applications, highlighting the need for a more technical and structured approach. The spinning mill analyzed showed an OEE between 63.4% and 64.1%, well below the international benchmark (>80%), revealing a critical performance gap associated with mechanical and electrical failures, fluctuations in spindle flow, and a lack of standardization. The study developed an integrated Lean-based model grounded in TPM, 5S, and standardized work, with the aim of increasing equipment reliability and reducing operational variability. Validation was carried out through a hybrid strategy combining a pilot test with scenario comparison and discrete-event simulation in Arena. The results showed significant improvements: OEE increased to a range of 83.79%, achieving a gain of 20.4 percentage points, along with reductions in mechanical failures, unproductive time, and operational variability. The proposed model provides practical guidelines and a structured, replicable framework for other spinning mills seeking to improve their performance through accessible, high-impact methodologies. The study encourages future research integrating flow analysis, advanced simulation, or predictive maintenance to further strengthen the competitiveness of the textile sector.*

Keywords: Process standardization, Production efficiency, Textile sector, TPM, 5S.

I. Introduction

The textile industry continues to be a key manufacturing sector worldwide due to its economic contribution, employment generation, and the sustained demand for textile products. Nevertheless, several studies have reported recurring problems associated with operational variability, unexpected machinery stoppages, and limitations in the reliability of critical equipment, particularly in spinning processes, where interruptions often originate from mechanical stresses and variations in material flow [1]. These conditions directly impact the productive efficiency of plants, reducing effective operating time and affecting key performance indicators.

In Latin America, these challenges tend to manifest with greater intensity. Low levels of digitalization, a high dependence on manual tasks, and the limited adoption of formal continuous improvement practices generate production environments that are highly vulnerable to inconsistencies and operational fluctuations [2]. As a result, many plants operate at efficiency levels below the international standards commonly accepted in the manufacturing industry, which hinders performance stability throughout production shifts and reduces operational reliability.

The situation in Peru follows this same pattern. Despite the economic relevance of the textile sector at the national level, numerous spinning plants exhibit inactive spindles, frequent unplanned stoppages, and work areas with low levels of standardization, which limits their ability to reach international benchmarks of operational efficiency [3]. In the plant under study, the average value of the Overall Equipment Effectiveness (OEE) indicator was 63.35%, a value significantly lower than the reference standard of 80% used in the textile industry. This low level of productive efficiency constitutes a critical problem, as it negatively impacts the overall performance of the plant and generates estimated annual economic losses of 8,703,000, equivalent to 9.74% of the total economic impact associated with the operation.

Recent studies indicate that the absence of documented routines, a reduced level of autonomous maintenance, and insufficient monitoring of basic operational tasks increase internal losses and negatively affect key indicators such as equipment availability and performance [4]. When preventive maintenance and inspection activities are not adequately established, mechanical failures and micro-stoppages occur more frequently, reducing the effective operating time of spinning lines and decreasing overall process efficiency [5]. Likewise, disorganized workspaces and deficient cleaning practices generate operational delays, hinder visual control, and limit the productive capacity of work areas [6].

Several studies have shown that the implementation of Total Productive Maintenance (TPM), the 5S methodology, and standardized work can contribute to improving equipment availability, reducing variability between shifts, and increasing machinery reliability, especially in production environments with limited resources and a high dependence on operational continuity [7]. However, most of these applications have been developed in contexts with higher levels of automation and digital support, which highlights the need to adapt these continuous improvement approaches to realities characterized by aging machinery, low levels of standardization, and labor-intensive operations, as found in many Peruvian spinning plants.

In this context, the present study proposes an integrated improvement model based on TPM, 5S, and standardized work, aimed at increasing equipment availability, reducing unproductive time, and improving operational stability in a Peruvian spinning plant. The proposal is grounded in the positive results reported in recent literature and seeks to adapt these methodologies to the technical and organizational characteristics of the context under analysis [8].

II. Literature review

A. Lean Manufacturing Applications in the Textile Industry

Recent literature indicates that the textile industry faces significant challenges related to operational variability, high waste levels, and fluctuations in product quality, which has encouraged the progressive adoption of Lean Manufacturing methodologies across different stages of the production chain [9]. Empirical studies conducted in spinning and weaving environments report reductions in cycle time, improvements in process visibility, and better control of critical operations through the application of tools such as value stream mapping, visual management, and waste elimination [10].

However, several authors agree that Lean implementation in textile small and medium-sized enterprises (SMEs) is frequently partial and limited to isolated initiatives, without a structured monitoring system that ensures sustainability over time [11]. This situation prevents the consolidation of continuous improvement results and reduces the long-term impact of Lean practices in production performance.

These limitations highlight the need for more comprehensive and structured Lean approaches capable of stabilizing machinery-intensive processes and reducing operational variability in spinning operations, particularly in emerging economies where resource constraints are common [12].

B. Total Productive Maintenance (TPM) in the Spinning Process

Total Productive Maintenance (TPM) is widely recognized as an effective strategy to maximize equipment efficiency and improve process reliability through operator involvement and systematic maintenance practices [13]. In the textile sector, where production continuity depends on machines exposed to high mechanical stress, TPM implementation has been shown to reduce recurrent failures, minimize micro-stoppages, and increase operational availability, leading to improvements in Overall Equipment Effectiveness (OEE) [14], [15].

However, evidence also indicates that many SMEs face limitations such as lack of standardization, low levels of training, and shortage of performance indicators, which hinders the consolidation of TPM as a stable and sustainable system over time [16]. Recent studies in textile manufacturing show that workplace organization practices such as 5S contribute to improvements in ergonomics and operational accessibility [17].

C. 5S Methodology and Workplace Organization in the Textile Industry

The 5S methodology remains a fundamental tool for improving order, cleanliness, and accessibility in manufacturing environments, particularly in the textile industry, where waste accumulation, loose fibers, and disorganized materials generate minor losses that negatively affect process efficiency [18]. Recent studies emphasize that a disciplined application of 5S contributes to reduced setup times, improved operator ergonomics, and better access to tools and inspection points [19].

Nevertheless, evidence indicates that 5S implementation is often limited to initial improvement campaigns without continuous monitoring or auditing mechanisms, which leads to a gradual return to disorder and the loss of the gains achieved [20]. This pattern is especially common in SMEs with high personnel turnover and limited managerial follow-up.

Consequently, multiple authors highlight the importance of integrating 5S with standardization practices and performance control systems to ensure its long-term sustainability and to prevent the deterioration of workplace organization over time [21].

D. Standardized Work and Process Stability

SStandardized work constitutes a key element to ensure that operational activities are performed in a consistent, repeatable manner and aligned with quality requirements, particularly in processes where small operational variations can significantly affect performance, as is the case in spinning operations [22]. The application of standardized work has been shown to reduce variability between shifts, facilitate operator training, and improve early detection of process deviations [17].

Although there is extensive literature on the isolated application of Lean tools, several studies point out that evidence regarding integrated models combining standardized work, TPM, and 5S in spinning processes remains limited [23], [24].

Several recent studies indicate that, although Lean tools such as TPM, 5S, and standardized work have been widely analyzed individually, there is still limited evidence regarding their integrated application in spinning processes [25], [26]. This lack of holistic approaches is particularly evident in textile SMEs, where resource constraints and high operational variability hinder the consolidation of robust improvement systems [27]. Consequently, the absence of integrated Lean models adapted to the textile sector limits the ability to systematically reduce internal losses, stabilize production flow, and improve key performance indicators such as OEE, especially in emerging economies such as Peru [28].

III. METHODOLOGY

A. Model Justification

The proposed model is justified by the need for an integrated approach that directly addresses the main causes of instability in the spinning process, such as inactive spindles, unplanned stoppages, and the absence of clear routines for maintenance, order, and cleaning. The isolated use of continuous-improvement tools does not allow for coherent intervention on these simultaneous causes, limiting both the impact and the sustainability of the results. The proposed model combines TPM, 5S, and standardization within a sequential structure specifically designed for the current configuration of the spinning mill under study. Its relevance is strengthened through hybrid validation, which incorporates an on-site pilot and an Arena simulation, ensuring that the improvements are consistent, replicable, and aligned with real operating conditions.

B. Comparison witch previous models

To contextualize the proposed model, a comparison with previous studies was conducted considering the main Lean Manufacturing tools used to improve operational efficiency and OEE. As shown in **Table I**, most approaches apply tools such as TPM or 5S individually rather than within an integrated framework.

The model is based on the diagnostic results of the spinning mill, where operational losses were identified due to low equipment availability, inactive spindles, mechanical failures, and process variability, affecting OEE.

Based on these findings, the model is structured into three stages: analysis, intervention, and validation. It begins with the identification of initial conditions and inefficiencies, followed by the implementation of TPM, 5S, and standardized work, and concludes with a validation stage supported by simulation and performance indicators to ensure sustainable improvements.

C. Proposed Models

The development of the model is based on the needs identified in the spinning mill diagnosis, where operational losses were observed due to low equipment availability, inactive spindles, mechanical failures, and high variability in the spinning flow. These conditions revealed that the operation lacked systematic mechanisms to stabilize the process and ensure productive continuity, directly affecting the utilization of installed capacity and the OEE. In response, the need was defined to structure a methodological approach that organizes the stages of analysis, intervention, and verification using Lean tools adapted to the textile context. The model is organized into a logical sequence that begins with the identification of the initial operating conditions (Input), followed by a detailed analysis phase in which failures and existing variability are characterized. It then incorporates an intervention block based on TPM, 5S, and standardized work to mitigate the root causes identified in the diagnosis. Finally, a validation stage supported by simulation and indicator monitoring is included, allowing the evaluation of the improvements' impact and ensuring their sustainability. The construction of the model responds to the need for a methodological framework applicable to spinning mills that face recurrent problems of operational stability. Likewise, it aims to facilitate decision-makingbyintegrating diagnostic tools, standardization, and visual control into a coherent and replicable structure. Under this approach, the model serves as a practical guide to reduce internal losses, stabilize the production flow, and improve the overall performance of the spinning process.

TABLE I
COMPARATIVE TABLE OF THE ELEMENTS OF THE PROPOSED MODEL AND THOSE FOUND IN THE LITERATURE REVIEW.

Criteria / Study	Improving equipment efficiency through TPM implementation in textile industry (Kumar & Suresh, 2019)	Impact of TPM on operational efficiency in textile industries (Ferreira et al., 2020)	Application of 5S methodology to reduce waste and improve workplace organization (Pinto et al., 2020)	Integration of standardized work and maintenance in manufacturing systems (Ribeiro, 2021)	Workplace organization and efficiency improvement using 5S in manufacturing (Pawlak et al., 2023)	Proposed model to increase OEE in the textile sector using TPM, 5S and standardized work with hybrid validation (Alva & Arenas, 2026)
TPM	✓	✓	✕	✓	✕	✓
5S	✕	✕	✓	✕	✓	✓
Standardized Work	✕	✕	✕	✓	✕	✓
OEE as metric	✓	✓	✕	✕	✕	✓
Hybrid validation	✕	✕	✕	✕	✕	✓
Applied sector	Textile	Textile	Manufacturing	Manufacturing	Manufacturing	Textile

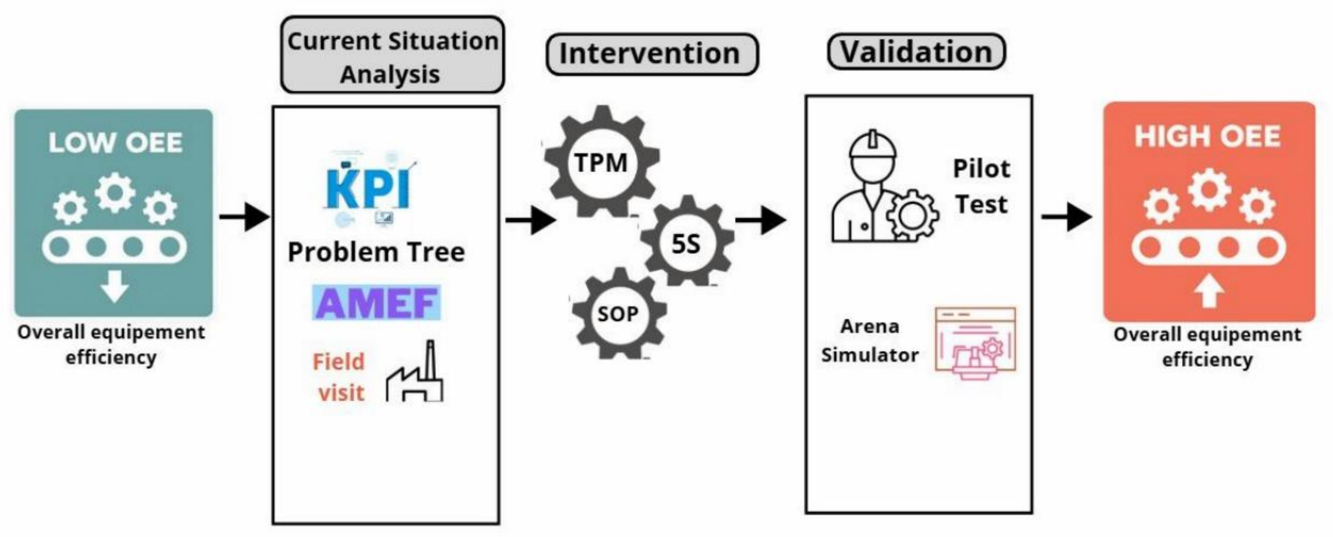

Fig. 1 Proposed innovative model

D. Model components

Component 1: Analysis and Diagnosis of the Process

This component focuses on identifying and characterizing the losses that affect the efficiency of the spinning process. The diagnosis identified low equipment availability, spindle inactivity, mechanical failures, and reprocessing as the main sources of OEE deterioration. To structure this analysis, diagnostic tools such as Failure Modes and Effects Analysis (FMEA) for critical equipment, Pareto charts of failures and spindle inactivity, operational KPI analysis, and direct observation on the shop floor were applied. This component establishes that any Lean-based intervention must begin with a systematic understanding of root causes, since the variability of the spinning flow and recurrent interruptions cannot be reduced without a structured diagnostic approach.

Component 2: Implementation

Based on the diagnostic results, the model integrates three interrelated tools: Total Productive Maintenance (TPM), the 5S methodology, and standardized work (SOPs). TPM addresses unplanned stoppages and mechanical failures through the establishment of inspection, cleaning, and basic maintenance routines, increasing spindle availability and reducing downtime. The 5S methodology focuses on order, classification, and systematic cleaning of the spinning area, reducing losses associated with material searching, operational interference, and waste accumulation. Finally, standardized work consolidates critical activities into clear and repeatable procedures, stabilizing the spinning flow, reducing variability, and ensuring the continuity of improvement actions. The sequential integration of these tools enables interventions on both physical and operational causes of inefficiency.

Component 3: Validation and Monitoring

The third component focuses on verifying the impact of the implemented improvements on the spinning process. Validation is carried out through a hybrid approach that combines an on-site pilot test with discrete-event simulation using Arena, allowing the system behavior to be replicated and comparisons to be made between the As-Is and To-Be scenarios. Simulation enables the evaluation of changes in downtime, number of active spindles, capacity utilization, and failure frequency, providing a comprehensive view of how Lean interventions affect production flow. In addition, this component incorporates the monitoring of key performance indicators such as availability, production rate, reprocessing, and OEE, which function as feedback mechanisms for performance evaluation. Finally, standardized control is incorporated to ensure that the implemented routines related to TPM, 5S, and standardized work are sustained over time and to prevent the reappearance of variability, supporting the long-term stability of the improved spinning process.

E. Model indicators

To analyze the performance of the spinning process, Overall Equipment Effectiveness (OEE) was used as the main indicator. OEE is divided into three factors: availability, performance, and quality, which make it possible to identify where the main process losses are concentrated. The relationship between these factors is shown in Equation (1):

$$OEE(\%) = Disponibilidad \times rendimiento \times calidad \qquad (1)$$

Under the initial operating conditions, the process showed an OEE of 63.35%, indicating a low level of efficiency and the presence of clear opportunities for improvement

Availability was calculated as the ratio between actual operating hours and scheduled production hours, as shown in Equation (2):

$$Disponibilidad = \frac{Operating\ Hours}{Scheduled\ Hours} x\ 100 \qquad (2)$$

The initial availability value was 82.94%, mainly affected by unplanned stoppages and idle time..

Performance was determined based on the relationship between the number of active spindles and the total number of installed spindles, as expressed in Equation (3):

$$Rendimiento(\%) = \frac{Active\ Spindles}{Total\ Spindles} \times 100 \qquad (3)$$

Initially, the performance reached a value of 80.40%, reflecting partial utilization of the spinning system.

Quality was calculated as the percentage of conforming yarn relative to the total yarn produced, as shown in Equation (4):

$$Calidad = \frac{Conforming\ Yarn\ (Kg)}{Produced\ Yarn\ (Kg)} \times 100 \qquad (4)$$

The initial quality value was 95.00%, indicating that the main problems of the process were not related to product quality, but rather to operational efficiency.

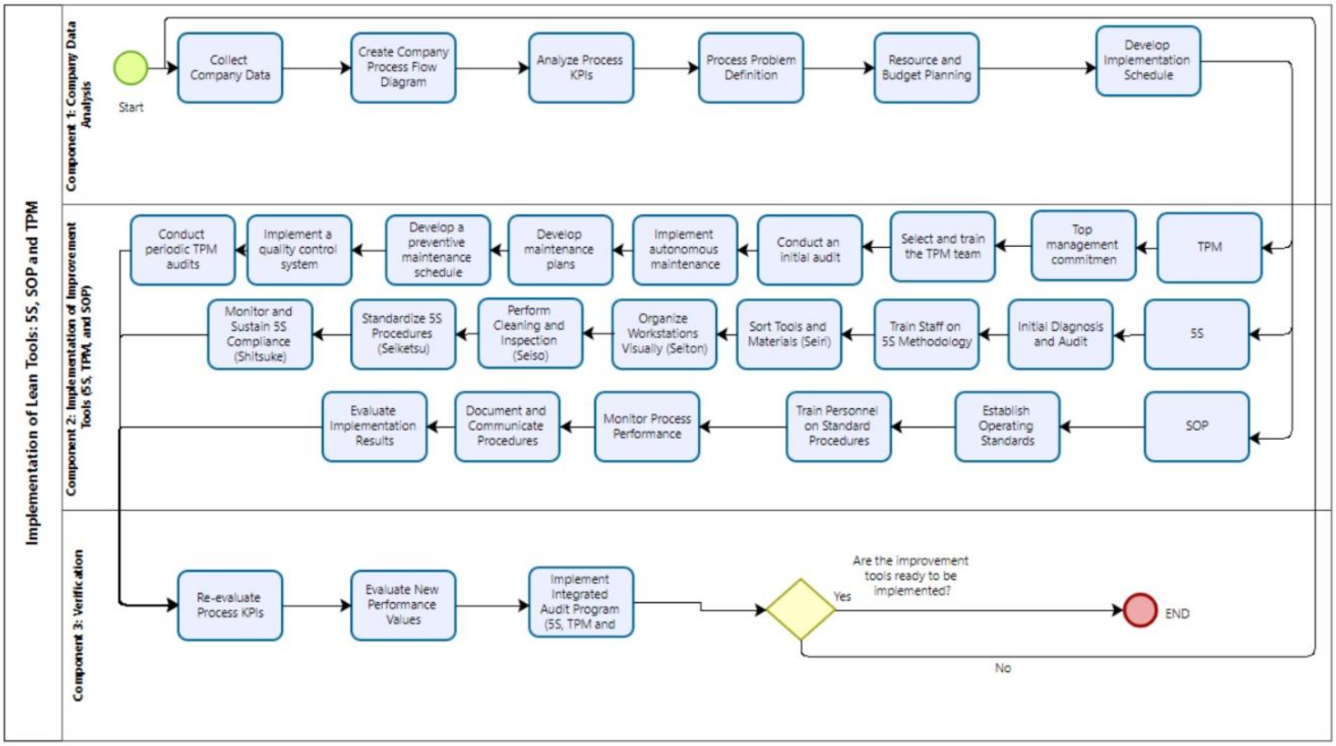

Fig. 2. Flow of the proposed method

IV. RESULTS

A. Description of the scenario

The study was conducted in a textile company dedicated to the cotton spinning process. Prior to the implementation of the proposed improvement model, the production system recorded an OEE of 63.35%, which was below the sector's performance standard. This efficiency level resulted in an estimated annual economic impact of S/ 8,703,000, equivalent to 9.74%, attributable to losses caused by operational inefficiencies and suboptimal use of productive resources. The factors explaining this performance level are summarized in the problem tree presented in Figure 3, which identifies as main causes the recurrent occurrence of equipment failures, limitations in maintenance management, and the absence of standardized operating procedures. The interaction of these factors compromises process stability and restricts the achievement of higher efficiency levels within the production system.

B. Initial diagnosis

The initial diagnosis showed that the company operates with a global efficiency of 63.35%, below the expected standard for spinning processes. The analysis identified three critical dimensions within the OEE: availability, performance, and quality. Availability, with an initial value of 82.94%, was affected by mechanical and electrical failures that reduced effective operating hours, revealing weaknesses in preventive maintenance and spare-parts control. Performance, measured at 80.4%, was limited by recurring issues such as misaligned rings and breakages in the transitionbelt, which decreased operational speed and reduced the number of active spindles. Quality, with an indicator of 95%, was impacted by inadequate cleaning practices and impurities found in the raw material, both of which contributed to higher rejection rates and reprocessing. The interaction of these factors is summarized in the problemtree, which clarifies how operational failures, lack of standardization, and insufficient maintenance practices converge to limit overall efficiency. This diagnosis provided the foundation for selecting improvement tools aimed at increasing availability of equipment, stabilizing operational performance, and ensuring consistent product quality.

C. Design and validation results

Component 1: Validation method

The improvement proposal was validated in two stages. In the first stage, a pilot implementation was carried out in the spinning process, where improvement actions based on TPM and 5S were applied to observe their direct effect on the operational behavior of the system and to make the necessary adjustments. During this phase, indicators related to failure occurrence, intervention times, and process stability were analyzed. Subsequently, the outcomes obtained from the pilot were used as input for a simulation-based validation using the Arena software, incorporating parameters such as the mean time between failures (MTTF) and the mean time to repair (MTTR). This second stage made it possible to compare system performance before and after the implementation of the improvements, providing an objective assessment of the proposal's impact.

Component 2: Pilot Test

To validate the effectiveness of the activities proposed in the pilot, a specific LUP was applied to the Continúa process. This standardization made it possible to visually and sequentially document each critical operation, ensuring that the personnel carried out the cleaning and adjustment procedure of the compact drum in a consistent manner. The inclusion of this LUP within the pilot aimed not only to reduce operational variability, but also to verify whether standardization directly influenced the reduction of failures and the improvement of process performance.

Fig. 3. Standardized Compact Drum Cleaning Procedure (LUP)

The implementation of the LUP showed an immediate improvement in the operational consistency of the area. Personnel executed the procedure without deviations, fiber accumulation was reduced, and errors related to drumhandling decreased. This standard became integrated into the normal workflow, demonstrating that standardization is a key foundation for sustaining OEE improvement on the line.

Likewise, as part of the pilot validation, a comparative photographic record of the area's condition before and after the operational improvements was carried out. This visual analysis made it possible to verify the effectiveness of the implemented changes, particularly in aspects related to order, cleanliness, material accumulation, and physical flow within the production process.

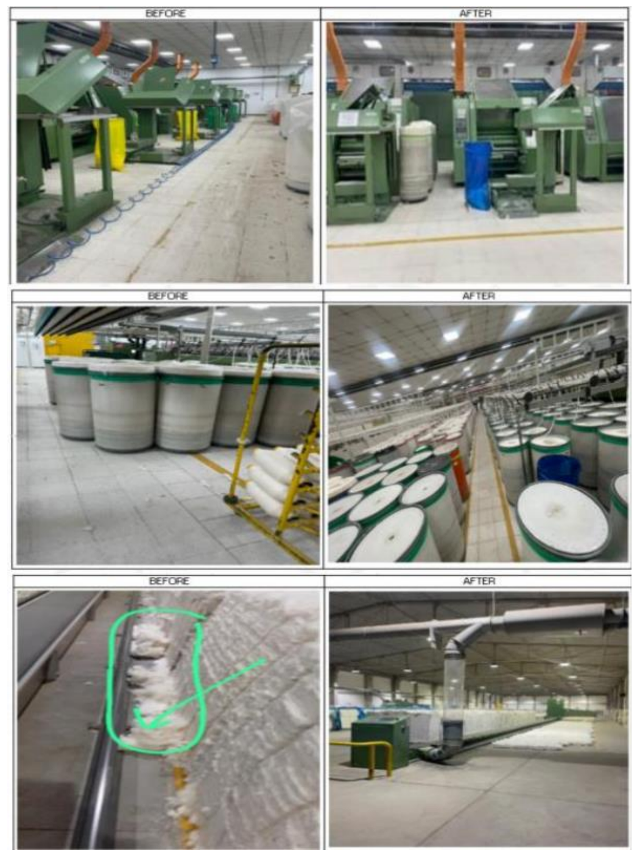

Fig. 4. Visual comparison of the initial and final state after the implementation of 5S

The After images show a significant reduction in visible waste, better material distribution, the elimination of congestion points, and greater clarity in the operational flow. These changes not only improved the visual appearance of the area but also facilitated personnel mobility and the early identification of deviations. The results confirm that the pilot actions generated a more controlled environment, conducive to maintaining process stability.

To evaluate the impact of the order and standardization activities, a 5S assessment was conducted before and after the intervention. The results were represented through radial charts, allowing visualization of the level of compliance in each of the pillars: sort, set in order, shine, standardize, and sustain.

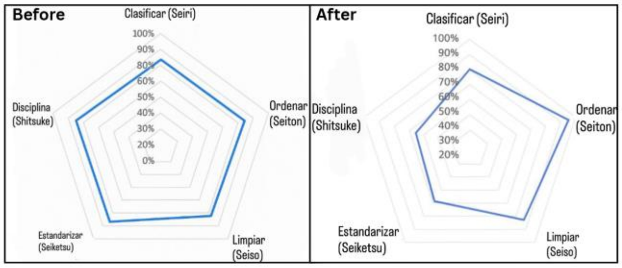

Fig. 5. Results of the before-and-after 5S intervention.

The comparison shows a notable increase across all five pillars, moving from a heterogeneous level with visible gaps in the initial assessment to a much more balanced and uniform score after the intervention. The greatest improvement was observed in Seiri, Seiso, and Seiton, which aligns with the activities carried out during the pilot. This result confirms that the combination of organization, waste elimination, and routine redesign contributed directly to a more stable and controlled operational environment.

Component 3: Simulation of the model in the Software Arena

The production system was modelled using the Arena simulation software, representing the material flow from the reception of cotton bales to the stage where the product was ready for packaging. The simulation considered an initial input of 340 kg and replicated the main spinning operations observed in the plant. To validate the differences between the As-Is and To-Be scenarios, Arena's Output Analyzer tool was applied using a 95% confidence level. The confidence intervals obtained indicated that the To-Be scenario outperformed the As-Is configuration across the main performance indicators. A paired t-test ($p < 0.05$) confirmed that the differences between both scenarios were statistically significant. Improvements were consistently observed in key indicators such as availability, quality, and overall equipment effectiveness (OEE), supporting the effectiveness of the proposed improvement model based on 5S and TPM. The initial configuration of the simulated system (As-Is) is presented in **Figure 7**, while the improved configuration (To-Be), incorporating the proposed operational adjustments, is shown in **Figure 8**.

Component 4: Simulation results

The simulation model was developed using Arena software to evaluate the operational performance of the spinning process under the current (As-Is) conditions. The model incorporated the main process flows and operational logic observed in the plant, and its statistical reliability was assessed using the Output Analyzer with a confidence level of 95%. Under the As-Is scenario, the simulation reported an Overall Equipment Effectiveness (OEE) of 63.35%, supported by an equipment availability of 82.94%, a performance rate of 80.40%, and a quality level of 95.00%. These results are consistent with the historical behavior of the system, reflecting frequent minor stoppages, limited autonomous maintenance practices, and variability in daily operations.

In the improved (To-Be) scenario, following the implementation of the proposed improvement model based on 5S and Total Productive Maintenance (TPM), the simulation results showed a substantial enhancement in all key performance indicators. The projected OEE increased to 83.79%, driven by improvements in availability to 88.06%, performance to 98.06%, and quality to 97.03%. These improvements indicate a more stable and disciplined operational environment, resulting from better workplace organization, standardized routines, and strengthened maintenance activities. The comparative results between the As-Is and To-Be scenarios are summarized in **Table 2**, highlighting the effectiveness of the proposed model.

To statistically validate the observed differences between both scenarios, a paired t-test was conducted using a 95% confidence level. The results confirmed that the improvements in OEE, availability, performance, and quality are statistically significant ($p < 0.05$), indicating that the performance gains achieved in the To-Be scenario are not due to random variation. Nevertheless, the simulation presents certain limitations, as it does not fully capture atypical operational disruptions or unplanned external events. Therefore, the results should be interpreted as representative estimates of system behavior rather than exact predictions of real plant performance.

Table II
Results of the Validation process

Indicators	**Original Model**	**Proposed Model**	**Improvement**
OEE	63.35%	83.79%	32.27%
Availability	82.94%	88.06%	6.17%
Performance	80.40%	98.06%	21.97%
Quality	95%	97.03%	2.14%

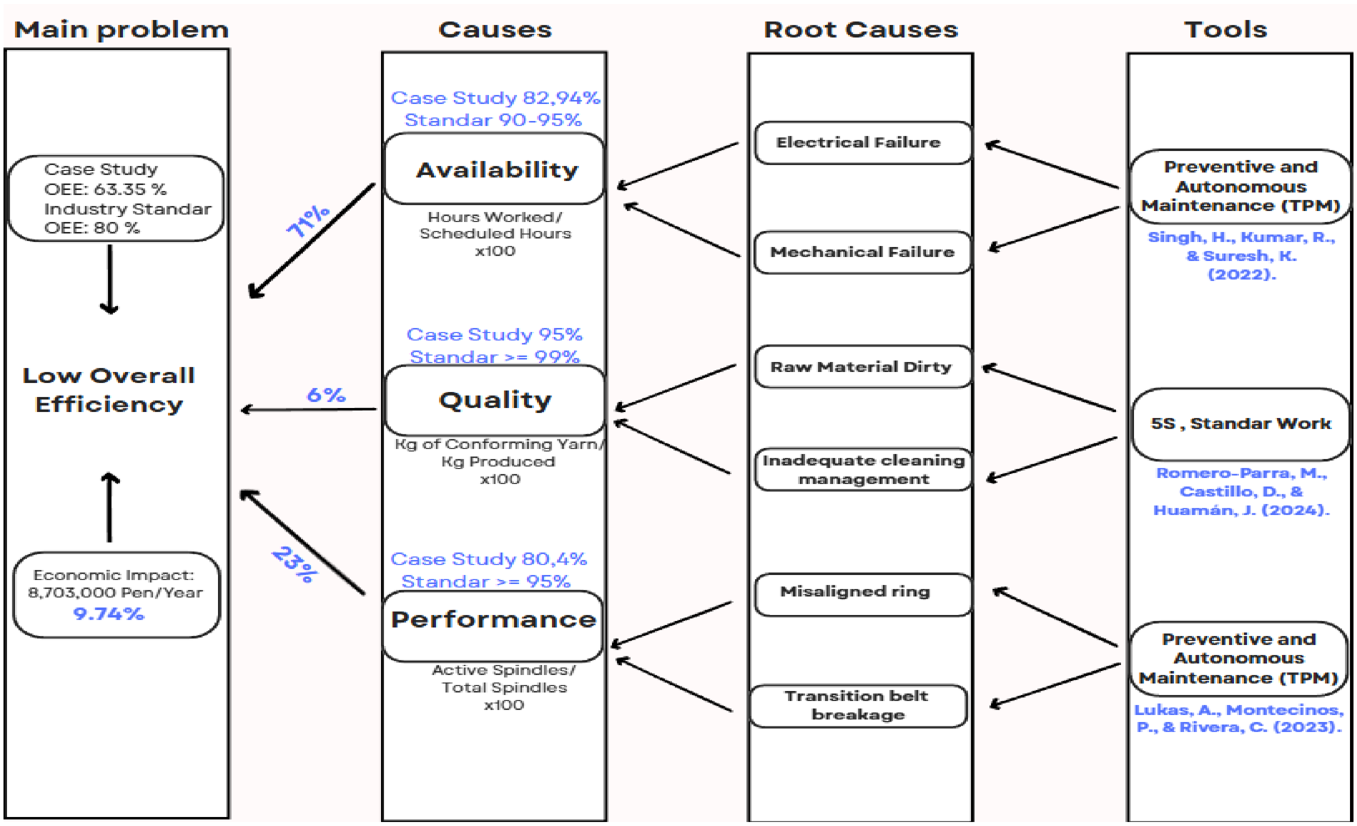

Fig. 6 Problem tree

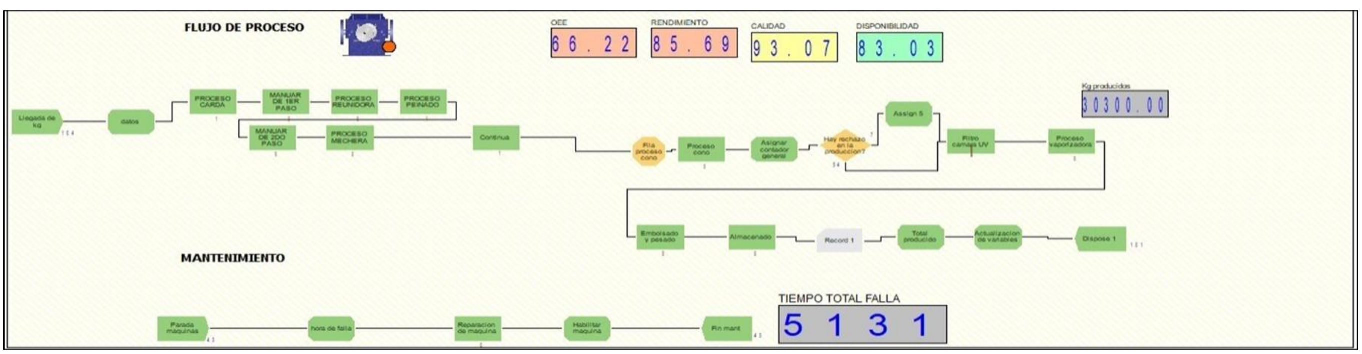

Fig. 7 Representation of the system in Arena Simulator V16.2 software before the upgrade

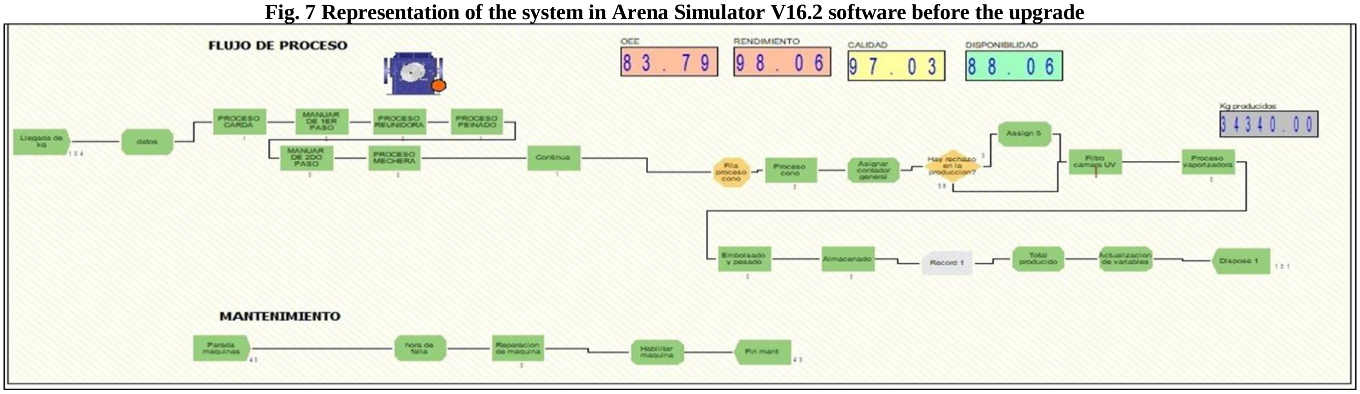

Fig. 8 Representation of the system in Arena Simulator V16.2 software after the upgrade

Component 4 : Economic Validation

The initial investment required for the implementation of the proposed improvement model was S/ 180,000, allocated to the resources necessary to apply TPM and 5S methodologies in the production area. This investment made it possible to address the main inefficiencies identified in the production process and to improve overall operational performance.

The economic analysis showed an Internal Rate of Return (IRR) of approximately 145%, which largely exceeds the minimum acceptable rate and highlights the high profitability of the proposed improvement. Furthermore, the benefit–cost (B/C) analysis, evaluated through thousands of simulated scenarios, indicates that the B/C ratio remains greater than 1 in most cases, demonstrating the robustness of the project under uncertainty. Finally, the Net Present Value (NPV) reached S/ 1,475,000 PEN, confirming that the economic benefits generated by the project exceed the costs incurred.

On the other hand, the estimated payback period was 0.46 years, which indicates that the capital invested is recovered in less than a year after implementation. This rapid recovery, together with the favorable financial indicators obtained, supports the economic feasibility of the proposal and confirms its capacity to sustain positive financial performance over time. The main economic results obtained from this evaluation are presented in **Table III**.

TABLE III
RESULTS OF ECONOMIC INDICATORS

Indicators	Results
NPV	1,475,000 PEN
IRR	145%
B/CE (ROI E)	> 1(simulation based)
PAYBACK	0.46 years

The economic evaluation of the project demonstrated its long-term financial viability and profitability.

V. DISCUSSION

The results confirm that the improvement proposal generated significant operational and economic benefits in the spinning process. As shown in Table 2, the Overall Equipment Effectiveness (OEE) increased from 63.35% to 83.79%, representing an improvement of 20.44 percentage points. This increase exceeds the target value of 80% and substantially reduces the performance gap identified during the diagnostic stage, in line with efficiency gains reported in textile manufacturing systems following structured improvement initiatives [1], [8].

The performance of the OEE components demonstrates a clear alignment between the root causes identified in the problem tree and the actions implemented. In terms of availability, the initial value of 82.94% reflected losses mainly associated with recurring mechanical and electrical failures and extended downtime. The implementation of Total Productive Maintenance (TPM), through preventive and autonomous maintenance practices, reduced unplanned stoppages and increased availability to 88.06%, surpassing the established objective. Similar improvements in availability through TPM adoption have been reported in textile and continuous manufacturing environments [1], [15]

Regarding performance, the initial level of 80.4% was constrained by spindle inactivity and unstable operating conditions in continuous spinning machines. These limitations are commonly linked to mechanical misalignments and the absence of standardized inspection and adjustment procedures. The standardization of operating tasks, supported by systematic maintenance routines, stabilized the process and increased performance to 98.06%, well above the 90% target, reinforcing the role of standardized work in reducing operational variability [22], [23].

With respect to quality, although the initial indicator of 95% did not represent a critical deviation, the analysis identified losses related to rework caused by inadequate workplace organization and cleanliness. The structured application of the 5S methodology improved working conditions and operational discipline, increasing the quality indicator to 97.03%. These results are consistent with previous studies highlighting the impact of 5S on defect reduction and process stability in manufacturing environments [6], [20].

From an economic perspective, the proposal demonstrated high financial viability. With an initial investment of S/ 180,000, the economic evaluation yielded an Internal Rate of Return (IRR) of approximately 145% and a Net Present Value (NPV) of S/ 1,475,000, confirming that the economic benefits generated by the project significantly exceed the implementation costs. Comparable economic outcomes have been reported in studies analyzing the integration of TPM and Lean practices in manufacturing systems.

Nevertheless, the sustainability of the achieved results depends on the level of personnel commitment, particularly with respect to the consistent application of 5S, as well as on external factors such as periods of high demand that may limit the continuous execution of the implemented practices. In this context, it is recommended to strengthen training programs, formalize periodic audits, and progressively incorporate predictive maintenance tools to support the long-term consolidation of the efficiency gains.

VI. Conclusions

The results of this study confirm that the implementation of an improvement model based on TPM and 5S methodologies effectively enhanced the operational performance of the critical machines in the spinning process. The increase in Overall Equipment Effectiveness reflects a more stable and controlled operation, achieved through the standardization of basic activities, improved maintenance practices, and better workplace organization. These improvements allowed the process to reach and exceed the performance targets defined during the diagnostic phase.

From an economic standpoint, the validation demonstrated that the proposed solution is financially viable and attractive. The positive values obtained for the Net Present Value, Internal Rate of Return, and payback period indicate that the benefits generated by the improvement outweigh the required investment, supporting the feasibility of the project under the evaluated conditions. This confirms that operational efficiency improvements can be directly translated into tangible economic gains.

Overall, the study shows that reinforcing operational discipline, maintenance involvement, and standardized work practices plays a key role in sustaining process efficiency. The experience gained from the intervention provides a solid reference for future applications in similar industrial environments, highlighting the importance of integrating technical and organizational approaches to achieve continuous improvement in manufacturing systems.

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