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Original Article

Impact of Lean and TPM Practices on Productivity and Quality: Insights from A Peruvian Textile SME

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Abstract - *The garment manufacturing industry, especially small and medium magnitude businesses, is an integral part of the economy which facilitates social growth and development. However, such businesses face some operational inefficiencies, such as high defect rates and low productivity due to limited resources and poor maintenance practices. Scholars have attempted to study the challenges expected of Small and Medium Enterprises (SMEs) through lean manufacturing and Total Productive Maintenance (TPM) practices, but the application remains unexplored. Using the qualitative approach, this research paper intends to develop a model suitable for SMEs that is integrated with lean tools such as 5S and working standardization, as well as TPM practices such as autonomous maintenance. The context where the model is to be employed within Peru focuses on an SME that specializes in the manufacture of polo shirts. The application resulted in a reduction of 77.63% in the number of defective products, a 27.72% increase in productivity and an 83.67% improvement in the 5S compliance level. Regarding the economic aspect of the model, the findings present measurable benefits offered by the model, creating a scalable model that aims to increase the operational efficiency of SMEs. In the end, this paper builds links and highlights areas where applications can be used and industry for marketing purposes.*

Keywords – *Lean Manufacturing, Total Productive Maintenance, Textile SMEs, Operational Efficiency, Case Study.*

1. Introduction

Closely working with garment industries, the global economy boasts extensively in employment and economic advancement, greatly fostered by Small and Medium-sized Enterprises (SME) as well. Looking at the percentage, in Latin America, the figures say that SMEs comprise roughly 99% of total business entities alongside furnishing over 60% of employment to the private sector [1]. The textile and garment industry in Peru is quite crucial, forming a reasonable part of the country's economy and creating employment for thousands in rural parts where most of the factories are located [2]. The value of this sector goes beyond only economic data, as it represents cultural essence and workmanship, thus making it an important aspect of society in these areas. Considering the global crystal market, the capacity of such SMEs to improve and innovate still becomes crucial to the growth and survival of the entities.

In the garment manufacturing sector, SMEs can find success and growth but face challenges. There are operational challenges that affect productivity to a great degree. One of them can be the configuration problem in the machines, which worsens productivity even more. Rework is needed during various operations, which increases production costs and delays production.

Furthermore, non-compliance with adequate maintenance measures results in the worsening of machine breakdowns, which in turn cuts down on the production output and the quality of the product. Such problems are more evident in SMEs where there is a low resource base and skills to provide the required interventions. The combined effect of these factors not only reduces the profits of these enterprises but also reduces their effectiveness in a world that is increasingly exposed to competition. Meeting these production requirements is an integral component in improving the market strength and the sustainability of garment manufacturing SMEs. Lean Manufacturing and Total Productive Maintenance principles could be useful in enhancing production and reducing the amount of waste generated during production [3]. The principles of Lean Manufacturing aim to maximize the customer's value at all times while eliminating non-value-adding activities, thus building a culture of persistent enhancement, which is critical for SMEs that do business in ever-changing market ecosystems. On the other hand, TPM underscores the importance of maintenance tasks, which can also reduce machine downtime and enhance overall equipment effectiveness. With these techniques in place, SMEs are able to improve their efficiency and quality and, as a result, customer satisfaction and loyalty.

Although Lean Manufacturing and TPM are considered to provide advantages to all practitioners of TPS, there is still a remarkable dearth in literature pertaining to their implementation within garment manufacturing SMEs. Existing studies tend to have a large enterprise focus or a production aspect focus, which fails to incorporate the requirements of small businesses [4]. This research intends to bridge this gap by providing a production model that employs the Lean Manufacturing tools as well as the 5S, standard work and autonomous maintenance tools from TPM. This mix, as suggested by this pull, will maximize productivity, lower the costs of production and ensure a better work environment for the employees. So, this integrated approach will not only help SMEs sustain themselves but also help them grow in the competitive business environment, which will result in economic growth and development in the area.

In addition, Digitalation, when combined with Lean practices, has been compartmentalized to its ease of improving operational performance [5]. The combination of Lean Manufacturing with emerging digital techniques can make production processes more efficient and agile, especially for SMEs that are generally cost-sensitive [6]. The use of Lean tools like Value Stream Mapping (VSM) has been shown to be effective in reducing waste and optimizing production line flow in the textile industry [7]. On the other hand, Lean Six Sigma has also been extensively researched in an attempt to improve quality and lower reworks in garment factories, hence the natural tendency of these companies to seek continual improvement [8].

To summarize, the garment industry is an important part of the world economy, especially taking into consideration SMEs in Latin America and Peru because such firms arise with challenges in production; however, the adoption of Lean Manufacturing and TPM methodologies indicate possible optimizations. The study attempts to close the gap in the available resources by proposing an implementable model for garment manufacturing SMEs with the intention of stimulating their development and ensuring their survival in a dynamic environment.

2. Literature Review

2.1. Implementation of Lean Manufacturing in Textile SMEs

The context of Small and Medium-sized Enterprises (SMEs) regarding the textile sector has been the concentration of numerous studies concerning the Lean Manufacturing methodology. The essence of this methodology is customer value by means of waste elimination.

According to Qureshi et al. (2022) [9], the integration of Lean in SMEs promotes the minimization of costs being incurred while ensuring that profitability is being boosted by eliminating activities that are of no value.

Furthermore, the research by Vega et al. [10] points out that key enabling factors in Lean Manufacturing adoption are fundamental to achieving increased efficiencies within the transportation equipment sector, which can be applied to the textile industry. Additionally, the study by Agrawal et al. [11] demonstrates that assessing leanness through metrics such as the Fuzzy Leanness Index (FLI) can sufficiently indicate the level of lean implementation observed in the case of small and medium enterprises. Finally, the research by Thanki et al. [12] asserts that Lean-Green practices are valid for Indian SMEs, which points out that attaining sustainability is the crux of the adoption of Lean Manufacturing.

2.2. Effects of Standardized Work on Textile Production

The implementation of a standardized work methodology greatly increases the efficiency of activities in the textile manufacturing industry. This methodology derives from the development of what are called standard operating procedures, which guarantee the requisite quality and the required efficiency of production. The research by Ramírez and Soler [13] insists that the use of universal work implements in small and medium-sized enterprises can facilitate fundamental changes in the quality of products and also customer contentment. Moreover, the study by Uluskan et al. [14] claims that the activities of manufacturing firms that operate on a global basis can be standardized in such a way as to improve the quality level or adjust promptly to any changes in the conditions of production. Additionally, the research by Jiang [15] on template technologies in garment making demonstrates how the use of standardization can improve efficiency in clothing production, which is particularly important for SMES that wish to compete in the world market. Lastly, the work of Mathiyazhagan et al. [16] suggests the institution of a scheme that would allow the inclusion of standardization as a means of achieving sustainable manufacturing practices in the sphere of production.

2.3. The 5S Methodology and Its Impact on Operational Efficiency

The 5S approach has emerged as a key tool for enhancing organization and performance within SMEs working in the textile industry. The application of 5S, which are Sort, Set in order, Shine, Standardize, and Sustain, has achieved aesthetic and productivity benefits of a less messy and less cluttered workspace. According to the study by Ruiz et al. [17], the implementation of the 5S framework in textile companies has drastically transformed the performance of these companies as well as their competitiveness within the market by minimizing the time spent looking for tools and materials. Furthermore, the research by Morlock et al. emphasizes the contribution of a well-kept workplace in the achievement of pattern alignment in garment making while drawing attention to the textile production industry’s need for 5S methodology. On the other hand, the work of Hidayati et al. [18] indicates that the execution of 5S strategies boosts work efficiency while at the same time renders a better work atmosphere, enhancing probability and contributes towards improved job fulfilment for its employees. Finally, the study by Yasunaga et al. [19] suggests that an orderly workspace leads to the improvement of employees' self-evaluation and satisfaction levels, which will also guarantee good quality in the final goods provided.

2.4. Total Productive Maintenance (TPM) in the Textile Industry

The Total Productive Maintenance strategy is essential to guarantee the availability and reliability of the equipment in SMEs' clothing manufacturing. The goal of TPM is to optimize the machines' effectiveness by involving the entire staff in maintenance strategies. The research by Habidin [20] points out that adding TPM to the automotive industry has positively impacted equipment performance, which is transferable to the textile sector.

Additionally, the study by Chen et al. [21] recommends that embedding maintenance activities in the production cycle may improve product quality and decrease idle time. Lastly, the work of Min [22] highlights the role of maintenance in communicating within the industry and suggests that a proper maintenance strategy may enhance collaboration within the workplace.

2.5. Autonomous Maintenance and Its Role in Organizational Efficiency

Autonomous Maintenance is a procedure that enables employees to perform maintenance work on the tools and equipment that they use. This process encourages all employees to participate in the maintenance and enhancement of equipment, which leads to enhanced efficiency and cost savings. According to the study by Uluskan et al., Autonomous Maintenance elevates equipment availability as well as employee confidence and dedication. Furthermore, the research by Mathiyazhagan et al. [3] seems to suggest that the introduction of Autonomous Maintenance practices can facilitate the shift to more sustainable manufacturing. Additionally, the work of Agrawal et al. training employees to maintain equipment may help improve organizational efficiency and make it leaner. Finally, the study by Thanki et al. noted that in the context of sustainability as well as operational profitability, Autonomous Maintenance is also important for proper execution of Lean-Green practices in SMEs.

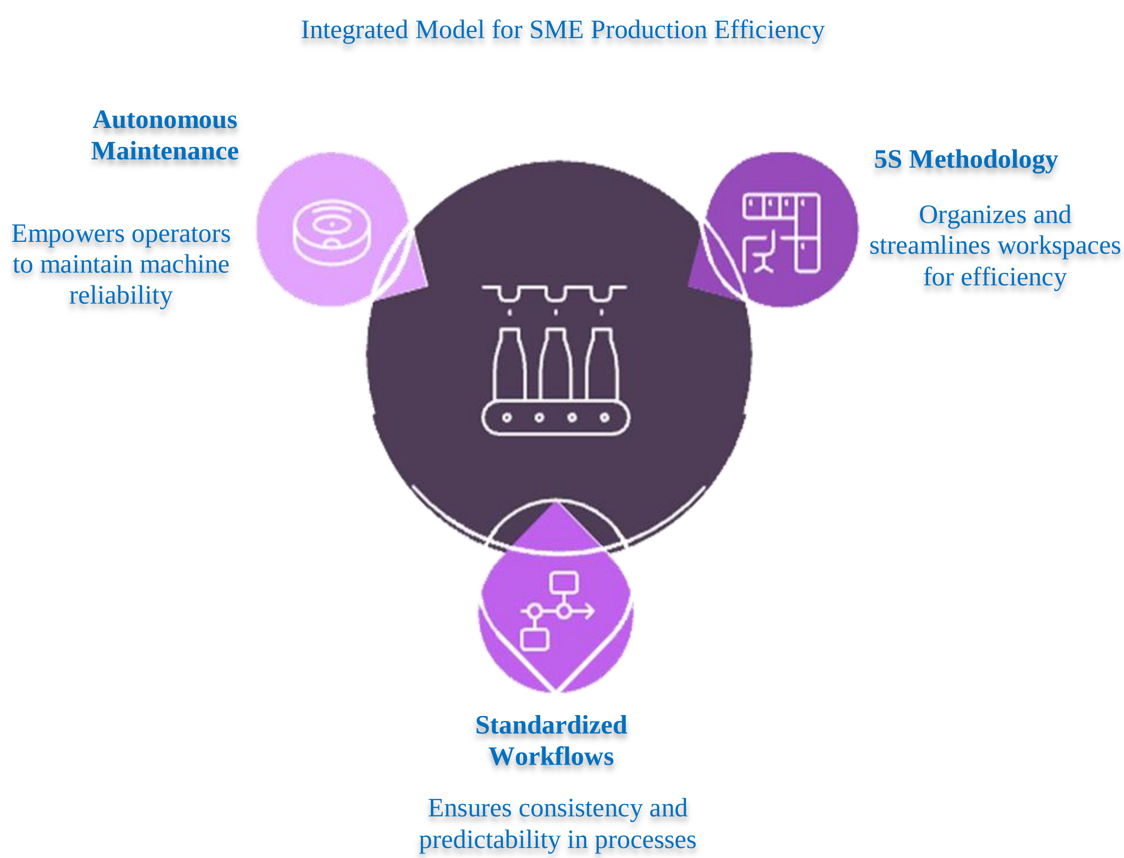

Fig. 1 Proposed model

3. Contribution

3.1. Proposed Model

The garment SME production model presented in Figure 1 combines the inventiveness and methodological components of the Lean and TPM approaches. It was specially designed for garment manufacturing medium and small enterprises. The creator of the model combined the two elements of the system, which are Lean Manufacturing and Total Productive Maintenance Engineering. The model was structured into two main parts. The implementation of operator procedures was the goal of the first component, which covered the implementation of 5S methodology aimed at enhancing order and efficiency in the workplace, as well as the implementation of standardized work systems. Those strategies contributed to maintaining an orderly workplace and procedural order, which minimized operational variability.

This is a vital factor because of the characteristics and limitations of the SMEs in the textile industry. The second component, aimed at Production Quality, included the application of autonomous maintenance. This key TPM practice trained operators to perform preventive and corrective maintenance on machines, ensuring optimal functionality and minimizing downtime. This integrated approach sought not only to meet customer requirements but also to maximize the use of technical and organizational resources within a small business, aligning with continuous improvement principles. The model efficiently linked the company's inputs to the desired outputs, such as higher quality, increased productivity, and cost reductions

3.2. Model Components

The proposed model, shown in Figure 1, is a comprehensive framework aimed at enhancing operational efficiency in garment manufacturing SMEs. Grounded in Lean Manufacturing and TPM principles, it addresses productivity and quality challenges through the integration of 5S, standardized work, and autonomous maintenance. Structured into two components—Operator Procedures and Production Quality—it offers practical solutions to streamline workflows, reduce waste, and improve machine reliability tailored to the constraints of labor-intensive industries.

3.2.1. Component 1: Enhancing Operator Procedures

Optimizing Workplace Organization Through 5S

The first stage of the model involved implementing the 5S methodology, a foundational Lean Manufacturing tool aimed at improving workplace organization and efficiency. This methodology was tailored to the SME's context, where resource optimization and operational discipline are paramount. The initial phase, Seiri (Sort), focused on identifying and segregating essential materials from unnecessary items in the workspace. Operators conducted thorough audits of their stations, utilizing red-tag systems to classify and remove obsolete tools and materials, thereby eliminating sources of clutter that hindered workflow efficiency.

The subsequent phase, Seiton (Set in Order), emphasized the strategic arrangement of tools and materials to ensure ease of access and minimize motion waste. Workstations were redesigned to align with ergonomic principles, ensuring that frequently used items were positioned within immediate reach. Visual management techniques, such as labeled storage bins and floor markings, were introduced to standardize the placement of materials and prevent recurring disorganization.

In the third phase, Seiso (Shine), the focus shifted to maintaining cleanliness and identifying potential issues through routine inspections. Operators were trained to perform daily cleaning activities, which not only enhanced the aesthetic and functional quality of the work environment but also facilitated the early detection of equipment anomalies such as oil leaks or wear and tear. The final stages, Seiketsu (Standardize) and Shitsuke (Sustain), involved embedding these practices into the organizational culture. Standard Operating Procedures (SOPs) were documented, and regular audits were scheduled to ensure sustained compliance and continuous improvement across the production floor.

Standardizing Workflows for Process Consistency

Following the establishment of a well-organized workspace, the model introduced work standardization to minimize variability and enhance process predictability. This stage involved analyzing existing workflows to identify inefficiencies and inconsistencies in task execution. Time-motion studies were conducted to map the sequence of operations, capturing critical data on task durations and interdependencies.

The insights gained from this analysis informed the development of standardized work instructions, which were tailored to the specific needs of the production process. These instructions detailed each step of garment assembly, specifying optimal methods and expected cycle times to ensure uniformity in task execution. Operators received hands-on training to familiarize themselves with the new standards, which were reinforced through visual aids such as process maps and task cards displayed at each workstation.

In addition, feedback loops were implemented to incorporate operator feedback into the process of standardization. Such a participatory process guaranteed compliance with the standards and made the personnel take ownership and responsibilities. The standardization reduced the variability of execution of processes, which in return led to better quality of the end products and more reasonable delivery times. This established a good platform for further initiatives aiming at quality improvement.

3.2.2. Component 2: Elevating Production Quality Empowering Operators Through Autonomous Maintenance

The formulation introduced a second aspect, which was aimed at reducing the non-availability of the machines by implementing autonomous maintenance, which is one of the key aspects of TPM. This is due to the fact that the operators are key in the upkeep of every piece of equipment; hence, the model was centred on the deepening of the operators' capacity to provide them with the relevant skills and knowledge needed for basic maintenance tasks.

Autonomous maintenance begins with extensive training of an operator on the functional components of the machine along with the malfunctions that are possible during the operation. The training sessions included but were not limited to, cleaning methods, lubrication time and routines, and mechanical malfunction warning signs. Additionally, the operators were trained to scan for red flags visually and were supplied with maintenance checklists as well as tools for systematic inspections and interventions.

Following training, operators were required to carry out all regular upkeep of their equipment as part of their everyday work, which was later incorporated into their daily rounds. This involved cleaning certain parts of the machines re-torque some parts, and topping up oils when necessary. Equipment condition boards were used to assist the operator record maintenance activities and to show what more was needed through visual management.

To guarantee the success of the autonomous management system, the comprehensive model included a periodic review of the equipment and verification of the reports provided. The supervisors checked the level of adherence of the operators to the maintenance requirements and offered further assistance if need be. This approach was cyclical, increasing the level of the machine's reliability and allowing the operators to combat the occurrence of surprise breakdowns actively, thus improving Overall Equipment Effectiveness (OEE).

Synergizing Components for Optimal Outcomes

The two components, Operator Procedures and Production Quality created a cumulative effect that strengthened the synergy of the model with regard to production performance. The orderly environment ensured by the 5S and the work standardization made it possible to perform autonomous maintenance works efficiently. On the other hand, the introduction of autonomous maintenance has increased the reliability of machines, which has improved the operator workflow quality and consistency. The model enabled a comprehensive transformation of the production system by considering both human and technological aspects of the production process and was able to comply with Lean Manufacturing and TPM principles. This combined strategy enabled the reduction of waste and defects as well as the encouragement of an improvement culture, thus making the SME respond more easily and quickly to customer needs. This provides evidence that the model may also be implemented by other SMEs facing similar resource constraints to enhance business performance.

A Pathway to Sustainable Excellence

The presented approach proved the efficiency of combining the principles of Lean Manufacturing and TPM to deal with the issues of textile manufacturing SMEs. The model concentrated on both operator-initiated activities and machine enhanced efforts, which resulted in tangible enhancements in productivity, quality and cost efficiency. Also, its focus on cultural change and empowerment of the workforce ensured the preservation of those benefits in the long run. As SMEs operate within a severely competitive environment, integrated strategies such as the one presented in the model proved to be useful in reaching operational efficiency and maintaining growth in ecosystems of high turbulence.

3.3. Model Indicators

The productivity of garment manufacturing SMEs using lean and TPM-centric production approach was evaluated using measuring criteria that were modified for this specific purpose. Metrics were specifically developed in Portraits 1–5 to enable effective performance analysis during the case study, thus anchoring the assessment of important factors of the production process in the champagne industry. This systematic approach facilitated an in-depth review of key performance indicators. This comprehensive assessment ensured effective monitoring and supported the continuous improvement of production processes by SMEs in this sector.

3.3.1. 5S Compliance Level

The 5S compliance level measures the degree to which the implemented 5S methodology aligns with expected standards. It reflects the progress in workplace organization and cleanliness based on the ratio of achieved scores to expected scores, expressed as a percentage.

$$\text{Compliance Level (\%)} = \frac{\text{Achieved Score}}{\text{Expected Score}} \times 100$$

3.3.2. Defective Polo Index

The defective polo index quantifies the proportion of defective polo shirts relative to the total number of polos manufactured. This indicator highlights the effectiveness of quality control processes in reducing production defects.

$$\text{Defective Polo Index (\%)} = \frac{\text{Number of Defective Polos}}{\text{Total Polos Manufactured}} \times 100$$

3.3.3. Quality Rate

The quality rate assesses the efficiency of the production process by calculating the ratio of net production time (time spent on effective work) to the total production time, expressed as a percentage.

$$\text{Quality Rate (\%)} = \frac{\text{Net Production Time}}{\text{Total Production Time}} \times 100$$

3.3.4. Overall Equipment Effectiveness (OEE)

OEE combines availability, performance, and quality metrics to measure the overall efficiency of equipment. It reflects how effectively a machine operates compared to its maximum potential.

$$\text{OEE (\%)} = \text{Availability} \times \text{Performance} \times \text{Quality}$$

3.3.5. Productivity

Productivity calculates the efficiency of human resources in the production process by dividing the total production achieved by the number of man-hours used.

$$\text{Productivity (units/Man-hour)} = \frac{\text{Production Achieved}}{\text{Man-Hours Used}}$$

3.3.6. Fulfillment Rate

The fulfilment rate measures how much of the production output was sold relative to the total production achieved, indicating the company's ability to meet customer demand efficiently.

$$\text{Fulfillment Rate (\%)} = \frac{\text{Production Sold}}{\text{Production Achieved}} \times 100$$

4. Validation

4.1. Validation Scenario

The validation scenario was carried out in a case study involving a Small and Medium-sized Enterprise (SMEs) in the Peruvian textile sector. This enterprise specializes in the production and distribution of various garments, with polo shirts accounting for 31.48% of its total sales, as they represent the highest production volume among its offerings.

Despite being relatively new to the market, the company plays a crucial role in the local economy, employing 42 workers and contracting 15 additional service providers in different roles.

However, it faced significant challenges, particularly a defective production rate of 17.40% in the polo shirt line, which exceeded the industry standard of 8% by 9.40 percentage points. These defects led to substantial economic losses, amounting to 5.87% of annual revenue. The company served as a practical framework for implementing Lean Manufacturing tools to address these challenges and improve overall operational efficiency.

4.2. Initial Diagnosis

The diagnostic was conducted in the case study to identify the reasons and root causes of defective products in the polo shirt manufacturing process. The analysis revealed a technical gap, with defective garments reaching 17.40%, exceeding the established standard of 8%, representing a deviation of 9.40 percentage points. This issue generated a significant economic impact, with total costs amounting to 222,851.60 PEN, equivalent to 5.87% of the annual revenue. The diagnostic identified three main reasons: operator errors, accounting for 60.05%; machine failures, contributing 35.48%; and other factors, with 4.46%. Among the root causes, non-compliant measurements were identified at 21.18%, while disorganization in the workspace led to handling stains in 25.17% of cases, and oil leaks from machines caused oil stains in 23.52%. Additionally, specific technical factors were highlighted, such as seams outside tolerance (21.18%) and needle punctures (9.26%), both linked to equipment issues. This structured approach enabled the decomposition and prioritization of problem causes, facilitating the proposal of solutions tailored to the operational needs of the case study, optimizing resources, and reducing defects.

4.3. Validation Design

The proposed production model, which integrates the Lean and TPM tools, was validated by the pilot validation method. The application of this method lasted four months in the case study, covering all the techniques proposed. These include the 5S methodology, Work Standardization and Autonomous Maintenance. Each of these tools is detailed below. The implementation of the proposed model was developed to address the issues of defective production in a textile SME specializing in polo shirt manufacturing. This model integrated Lean Manufacturing and Total Productive Maintenance (TPM) tools to improve operational efficiency and reduce defects in the production process. Below is a detailed explanation of the design and application of the implemented tools.

4.3.1. 5S Methodology: Transforming the Workplace Environment

The 5S methodology was used to optimize organization and cleanliness in the sewing area. In the first stage, "Sort," unnecessary items were identified and removed using red tags, leaving only essential materials. This reduced the time spent searching for tools and materials by 15%, increasing productivity. Subsequently, in "Set in Order," specific and labeled locations were assigned for each object, improving accessibility and reducing wasted time by 20% while decreasing accidents related to disorderly handling by 12%. In "Shine," daily routines were established to remove dirt and accumulated waste from machines and the workspace, involving both operators and cleaning staff. This resulted in a 25% reduction in incidents related to unhealthy working conditions and a general increase in team morale. The fourth stage, "Standardize," ensured the continuity of best practices through the creation of documented procedures, visual standards, and periodic evaluations, establishing a level of operational consistency previously absent. Finally, in "Sustain," regular audits were promoted, and operators were sensitized to the importance of the methodology to ensure its sustainability, achieving an increase in the 5S compliance level from 49% to 91.79%, which directly improved overall efficiency.

Figure 2 shows the current state of the sewing area before the implementation of the 5S methodology. The environment is characterized by disorder and lack of organization, with materials scattered on the floor, tools without designated locations, and overcrowded spaces that hinder workflow. Workstations display an accumulation of waste and a random arrangement of equipment, increasing the time spent searching for tools and reducing operational efficiency. The lack of order and cleanliness creates safety and ergonomic risks for operators, negatively impacting both product quality and the work environment. These conditions highlight the urgent need to apply a systematic organization model to optimize space utilization, improve material accessibility, and reduce unproductive times in the sewing process.

Fig. 2 Current situation of the case study area

Figure 3 highlights the waste and scrap areas in the sewing section within the context of implementing the third \"S\" (Shine) in a garment manufacturing SME. It illustrates designated zones for waste and scrap disposal, although the accumulation of materials indicates inefficiencies in cleaning routines and waste management. The presence of improperly disposed materials and disorganized scraps reflects the need for structured cleaning schedules and better-defined processes to ensure a clutter-free and safer work environment. Implementing \"Shine\" seeks to standardize these practices, emphasizing daily cleaning tasks, proper disposal of waste, and systematic organization, ultimately improving hygiene, safety, and operational efficiency within the sewing area.

Fig. 3 Areas and pockets of waste and scrap in the clothing area

Fig. 4 Poster of the 5S methodology in the clothing sector

Figure 4 shows an informational poster about the 5S methodology displayed in the sewing area as part of the awareness and training initiatives for personnel. This visual resource serves as a constant guide for operators, highlighting the key principles of the methodology: Sort, Set in Order, Shine, Standardize, and Sustain. Strategically placed within the work areas, it reinforces the team's commitment to implementing the 5S methodology and facilitates the adoption of organizational and cleaning practices. This tool also promotes a culture of continuous improvement, providing an accessible and practical reminder of the shared goals to maintain an efficient, safe, and clean work environment.

4.3.2. Work Standardization: Uniformity in Processes

The work standardization tool focused on reducing inconsistencies in sewing operations, which previously caused quality variations and unproductive times. Initially, the current situation was diagnosed through an activity diagram and an AVA matrix, identifying 10 activities that did not add value to the process, representing 12% of the total operation time and causing significant delays. Then, standardized worksheets and operation sheets were developed, detailing steps, times, and methods according to technical textile standards, such as NTP 231.400:2015. These tools allowed an equitable distribution of workloads and the elimination of unnecessary movements, resulting in an increase in the quality index from 89.97% to 99.01% and a reduction in the defective polo index from 4.38% to 1.72%. Additionally, productivity increased from 1.01 to 1.30 polos per hour-person, demonstrating a significant improvement in efficiency. The average operation times per batch decreased by 18%, optimizing resource utilization and reducing bottlenecks in the production process.

The table below illustrates the results of applying the AVA matrix to a T-shirt AVA. This technique assisted in distinguishing three classes of activities: value-adding, necessary non-value-adding, and non-value-adding. As a result of the exercise, a list of 48 activities was compiled. 36 of them were categorized as ‘contributing activities’, meaning they were adding value to the production process. Out of the activities, six were classified as ‘essential without adding value’ and were deemed important but did not contribute to the final output. Six additional ones were recognized as ‘not adding value’, which were defined as activities where some efficiencies are targeted for improvement and others may be eliminated. These ever-present activities provided a valuable basis for proper orientation on how to enhance deliberation by increasing value-adding activities while reducing or eliminating necessary non-value-adding and non-value-adding activities for overall improvement in the efficiency of the process.

MATRIZ AVA-DAP									
MATRIZ DEL VALOR AGREGADO DEL PROCESO: Proceso de confección de polos							CLASIF. AVA		
ACTIVIDAD	SIMBOLO					T (min)	VA	NNVA	NVA
	○	⇨	D	□	▽				
Total: 41	31	2	0	7	1	18.39	31	8	2

Fig. 5 Summary of the AVA matrix- PAD

4.3.3. Autonomous Maintenance: Machine Reliability

Autonomous maintenance was implemented to prevent defects related to mechanical failures, such as oil stains and holes in fabrics, which accounted for 22% of recorded defects. The first stage consisted of an exhaustive initial cleaning of the machines, removing residues and detecting hidden anomalies, reducing downtime by 18%. Subsequently, sources of contamination were eliminated through adjustments, lubrication, and minor repairs, decreasing the recurrence of failures by 22%. In the third stage, cleaning and maintenance standards were established to ensure optimal machine conditions, increasing OEE from 70.33% to 86.45%. Additionally, operators were trained to perform daily inspections and weekly reports, consolidating a culture of preventive maintenance. This practice contributed to a 50% reduction in defects caused by equipment and a general improvement in product quality. The average machine repair time decreased by 25%, improving equipment availability and ensuring the continuity of operations. Figure 6 displays the weekly follow-up report, which tracks the maintenance activities performed on machinery and equipment within the sewing area. The report includes a checklist of 10 specific tasks, such as general machine inspections, cleaning, and lubrication of components, as well as adjustments and tightening of parts. Each task is categorized by whether it was performed or not, with corresponding observations noted to address anomalies or improvements. For example, one observation highlights the need to perform oil changes and properly lubricate critical components. This report acts as a systematic tool to monitor compliance with maintenance schedules, enhance machine reliability, and prevent unplanned machine breakdowns, which in turn helps achieve a better production process and aligns with the concepts of autonomous maintenance goals.

REPORTE DE SEGUIMIENTO SEMANAL		Revisado por: Equipo del Proyecto		
Máquina: Remalladora				
Fecha: 7/02/2024				
Realizado por: Rolando Diaz				
N°	Actividad	Estado de la máquina		Observaciones
		Operativa	No operativa	
1	Inspección general de la máquina	X	-	-
2	Limpieza diaria en la superficie de la máquina	X	-	-
3	Inspección de tensores de hilo	X	-	-
4	Revisión de presión en el prénsatela	X	-	-
5	Puntada de agujas dañadas o del tipo incorrecto	-	X	Realizar cabio de aguja nueva o adecuada para la tela.
6	Altura inadecuada del impelente	X	-	-
7	Colocación de agujas	X	-	-
8	Sobrecalentamiento de agua	X	-	-
9	Centrado de aguja con la prensatela	-	X	Ajustar la placa de aguja o prensatela correctamente.
10	Presión inadecuada del prensatela	X	-	-

Fig. 6 Weekly follow-up report

4.3.4. Training and Organizational Culture

The introduction of the devices came alongside an extensive program that focused on training the operators, supervisors, and maintenance technicians. The program covered theoretical cum practical modules of the 5S system, work standardization, and autonomous maintenance. This bore fruit when 95% of the workforce was able to progress through the program while realizing a 30% growth in technical know-how and better motivation to take part in continuous improvement initiatives. In addition, there was an introduction of weekly meetings that served to assess the development of the initiatives as well as promote feedback mechanisms, which assisted in obtaining increased coherence of action with organizational goals.

4.4. Results

In Table 1 below, various graphs depicting key results detailing the implementation of the production model based on lean tools and TPM tools are shown. It is evident that the 5S compliance level rose by 83.67%, which indicates a need for significant improvement in workplace organization and order within the time frame. Likewise, A 27.72% improvement was witnessed in productivity, which indicates improved utilization of the available human and technical resources. In addition, the defective polo index decreased by 77.63%, which is a measure of the efficiency of the model in influencing the quality of the products. Over and above the quality rate, it was indicated that it had improved alongside the fulfilment rate, adding to the strength of the proposed solutions there, which were found during the analysis of the production processes. These results demonstrate how the model was able to function in enabling manufacturing efficiency as well as quality output.

Table 1. Results of the pilot

Indicator	Unit	As-Is	To-Be	Results	Variation (%)
5S Compliance Level	%	49%	91.79%	90%	83.67%
Defective Polo Index	%	4.38%	1.72%	0.98%	-77.63%
Quality Rate	%	89.97%	99.01%	92.52%	2.83%
Overall Equipment Effectiveness (OEE)	%	70.33%	87.00%	86.45%	22.92%
Productivity	unit/M-H	1.01	1.3	1.29	27.72%
Fulfillment Rate	%	94.85%	98.80%	97.35%	2.64%

5. Discussion

The results of this research corroborate with prior studies asserting the effectiveness of Lean Manufacturing and TPM tools in improving the performance of SMEs within the textile industry. Qureshi et al. [9] stress the benefits of rolling out Lean practices by pointing out how 5S and Just-In-Time approaches cut down on operational waste and improve overall productivity in low-budget settings. In the same vein, Agrawal et al. [11] also argued that the use of Indian SMEs adopting Lean tools demonstrated improvement in their production efficiency and reduction of defect levels, a 77.63% reduction, as noted in this study. Additionally, Thanki and Sharma [12] found that the combination of Lean and Green practices within SMEs results in enhancement in productivity alongside environmentally friendly outcomes, which corroborates the findings of the current research, where there was an improvement in operational efficiency. Finally, Uluskan and Kucuk [14] highlight the role of quality management practices, such as autonomous maintenance, in preparing the organization for continuous improvement, which is in harmony with the present study's contributions regarding workplace organization and overall equipment effectiveness. In general, these studies demonstrate the effectiveness of combining Lean and TPM tools, and this research adds value in that it adds context by looking at these tools through the lens of Peruvian textile SMEs.

5.1. Study Limitations

The design of this study inherits several limitations, which are discussed here. In the first instance, validation was carried out for a single case study. Therefore, it limits the applicability of its outcomes or findings to other organizations or industries. Besides, the duration of implementation and assessment, although sufficient to establish a positive first impression quick wins, do not convey the possible impacts or the challenges that could emerge in the long run. One additional limitation is that the adoption of Lean along with TPM was on the part of operators, which can be quite different between organizations. Finally, beyond the direct costs of defects and production time, which are business costs, the economic aspect has not been sufficiently studied, leaving space for wider financial evaluations in the follow-up studies.

5.2. Practical Implications

This investigation bears some limitations that are tightly connected to its design. To start with, validation was done within a single case study, which renders the findings inapplicable to other empresas or industries in general. Furthermore, the period of implementation and evaluation, though it was enough to enable an improvement at the initial stage, fails to show the relative effect over a longer time span regarding the possible implementation problems. Another limitation of this study is that cross functional team integration was too much dependent on the willingness of operators, and that may differ greatly in other settings of the organization. Finally, the economic impact was mainly examined through direct cost associated with defects and time lost in production; therefore, there is an opportunity for more comprehensive econometric modelling in future investigations.

5.3. Future Works

Future studies could focus on different sectors by expanding the concept to several SMEs based in varying regions and assessing the generalizability of the model. Moreover, further research may utilize digital technologies, including IoT sensors and analytics, in real time to improve Lean and TPM practices. Additionally, a thorough assessment would be worthwhile to ascertain the eco-friendliness of the improvements made over time and their relationship with the firm's or industry's mean long-term performance; econometrics revealed to be useful on such research questions. Lastly, investigating the perceptions of employees on the changes made by the organization could give a greater understanding of the context and/or environment that determines the adoption and effectiveness of these tools' particular factors.

6. Conclusion

The research showcases how the combination of Lean Manufacturing and Total Productive Maintenance (TPM) models is effective for Small and Medium-sized Enterprises (SMEs) in the Peruvian textile industry. It was able to reduce the defective products produced by 77.63%, increase productivity by 27.72% and improve workplace organization by 83.67%, as noted from the 5S compliance level with the use of the model. Seeing these improvements, one can reasonably conclude that the model proposed is geared towards operational inefficiencies and product quality and a more orderly workplace environment. This also further showcases how the tools themselves are well suited to helping SMEs with their challenges, thus giving them fulfilling and real-world work in an area with limited resources.

One of the key points of this research is the switched focus between the dimensions; it brings forward the signs and drivers of change appropriate for the context of work, including the role of improved equipment durability and troubleshooting within the case study discussed. Moreover, these methodologies can be applied in large networks of a similar nature and help build that case competitiveness. From the findings, it was established that there is a need for a holistic approach that fosters both the human and technical sides of the organization so that the changes made are sustainable. The focus on cultural transformation and workforce involvement is particularly noteworthy, as it strengthens the long-term viability of the implemented changes.

The contributions of this study extend to both academia and industry by bridging the gap in the literature regarding Lean and TPM applications in textile SMEs. The development and validation of an integrated production model offer a structured framework that can guide future implementations. Furthermore, the study enriches the discourse on continuous improvement practices by emphasizing their adaptability to smaller enterprises, which often face unique operational challenges.

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