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Original Article

Lean-TPM Integration for Quality and Efficiency Improvement in Peruvian Textile SMEs: A Study on Defect Reduction and Equipment Effectiveness

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Abstract *- The garment manufacturing industry, particularly in Small and Medium-sized Enterprises (SMEs), plays a crucial role in economic growth and employment generation. However, high defect rates and operational inefficiencies limit the competitiveness of textile SMEs in emerging economies. Earlier research has analyzed the advantages of Lean Manufacturing and Total Productive Maintenance (TPM). However, very few studies have looked into their combination within the context of Peruvian SMEs. This study attempts to fill that void by formulating a structured model of production that integrates Lean and TPM principles. Adopting 5S, standardized work procedures, and autonomous equipment maintenance led to a 60.52 % reduction in production defects and a 36.61% increase in Overall Equipment Effectiveness (OEE). These results highlight the continuous improvement efforts that can be made to process optimization and cost reduction. This research supports industrial engineering literature by creating a flexible model for small and medium enterprises. Further research is needed to incorporate tools from Industry 4.0 to improve productivity and efficiency further*.

Keywords *- Continuous improvement, Operational performance, Manufacturing processes, Production waste, Work standardization.*

1. Introduction

The garment manufacturing industry, particularly the Small and Medium Enterprises (SMEs) sector, is pivotal to the global economy. Not only does it contribute to job creation, but it also has social and economic impact in several regions, including Latin America and Peru. In Latin America, clothing SMEs contribute significantly to the textile production sector and provide a major source of employment for millions of people, thus benefiting the economy [1]. In Peru, the textile industry is one of the pillars of the economy, where SMEs carry out a large share of the garment production and export business. The textile and apparel sector is important to the economy because the Ministry of Production indicates it represents nearly 10% of the GDP [2]. However, these firms are confronted with serious difficulties that hamper their competitiveness in the global arena despite their importance.

One of the most challenging issues marked by garment SMEs is the high percentage of defective outputs, which results in economic loss and customer dissatisfaction to some extent. Deficiencies in inspection, sewing, cutting, and handling of raw materials account for such defects. Some identified problems that lower the quality of the final product are uneven cuts, stitch defects, loose threads, and soiled garments [3]. These production shortages affect the company image and increase production costs due to rework and material scrapping [4]. It has been observed that applying Lean Manufacturing and Total Productive Maintenance (TPM) methodologies can help focus on these issues through waste reduction and continual improvement of processes [5].

Not placing a premium on dealing with such production issues can have dire consequences. Quality is one of the defining features of emerging SMEs competing in the international arena. Failure to deliver on basic quality standards can lead to customers and businesses [6]. Continual improvements also increase efficiency, which can help lower costs while increasing profits [7].

Adopting Lean Manufacturing tools like 5S, work standardisation, and TPM can help SMEs optimize their processes and improve product quality [8]. This benefits individual companies and contributes to the sustainable development of the textile sector. Despite the growing body of literature on implementing Lean Manufacturing and TPM in the industry, there is a significant gap in knowledge regarding how these methodologies can be specifically adapted and applied in the context of garment SMEs in Peru. Most existing studies focus on large companies or different contexts, limiting the applicability of their findings to SMEs [9]. This study seeks to address this gap by proposing a production model that combines Lean Manufacturing and TPM tools for SMEs in the Peruvian textile industry. This model will emphasize reducing defects and improving quality, including personnel training and fostering a continuous improvement mindset in the workplace [10].

This contribution's novelty lies in its practical context, which seeks to apply tools for improvements and to seek a change in culture within SMEs. This study differs from previous studies that have analyzed the implementation of Lean and TPM in a business by offering an integrated approach that considers the relationships between various production processes and the role of the personnel in implementing the initiatives [11]. It is hoped that comparing the results of this research with other studies will prove that a comprehensive approach designed considering the characteristics of SMEs will improve product quality and operational efficiency [12]. Ultimately, important issues require immediate attention in Peru's garment manufacturing industry. The SMEs' competitiveness in the international market is restrained by the high incidence of defective products and other production complications, which also impact profitability. While adopting Lean Manufacturing and TPM methodologies presents a potential solution, these tools must be tailored to SMEs' context. The purpose of this work goes beyond covering a gap in the research literature; it proposes a model to be put into practice. Such actions would help achieve the sustainable development of Peru's textile industry.

2. Literature Review

The literature review focuses on continuous improvement methods in Small and Medium-sized Enterprises (SMEs) involved in garment manufacturing, which is important in determining how these enterprises can improve their production. In this regard, Lean Manufacturing has received particular attention. This methodology aims to eliminate process waste and improve organizational efficiency and effectiveness while reducing costs. Moeuf et al. explain that adopting Lean Manufacturing in SMEs enables flexibility, which is important when meeting market requirements, especially in fashion, where market trends are rapidly changing [13]. Furthermore, Jeong et al. indicate that innovation in products and processes is brought about by adopting lean practices, which is essential for SMEs' competitiveness in the textile industry [14]. There are reports that Lean Manufacturing in SMEs leads to better operational performance, customer satisfaction, and brand loyalty [15]. Lastly, Deepthi and Bansal proposed that combining Lean and Industry 4.0 technologies promotes greater effectiveness in garment production, thus increasing responsiveness and flexibility of the environment [16]. With respect to the Standardized Work methodology, its use in SMEs in the textile sector has yielded positive outcomes. This is developed on the formulation of standard operating procedures to maintain uniformity and quality in the production processes. As noted by Sidhu et al., the operational efficiency and inconsistency in production processes can be greatly improved by applying standardized work practices [17]. Also, Ligarski et al.'s research claims that standardized work improves productivity and contributes to safety in the workplace, which is particularly important in the textile industry [18]. In addition, standardized work improves employee training, leading to a knowledgeable and dedicated workforce [19]. Finally, Hossain et al. note that SMEs using this approach are better placed to respond to market needs, which is very important in the ever-changing fashion world [15].

The 5S model, which emphasizes organization and orderliness of the workplace, has also been explored in the area of garment SMEs. It improves the operational productivity of an organization and enhances the safety and health levels of the workplace. In a study conducted by Sidhu et al., the application of 5S in SMEs in Northern India was useful in decreasing idle time and increasing the employees' attitude towards work [17]. Moreover, Chen's works suggest that the practices of 5S are likely to enhance the adoption of other continuous improvement processes and, therefore, result in a positive cycle of improvement in the quality and productivity of an organization [20]. Also, the research by Velmurugan et al. underscores that implementing 5S can achieve "green" goals, which is an increasingly important issue in the fashion industry. Lastly, Piller's findings indicate that the 5S framework provides the groundwork for textile SMEs to gradually adopt the principles of the circular economy [21].

Total Productive Maintenance (TPM) is another crucial practice that has been studied in the case of garment SMEs. This approach is concerned with optimizing the effective use of equipment while reducing idle time. Jain et al. noted that adopting TPM in SMEs is associated with considerable improvements in machine availability and Overall Equipment Effectiveness (OEE) [23]. Moreover, Sidhu et al. also note that the effects of TPM are not only confined to improvement in operational efficiency but also lead to the attainment of employee engagement and ownership, which is very important for the sustainability of SMEs [19]. Furthermore, Velmurugan et al. argue that the use of advanced technologies, particularly the Internet of Things (IoT), together with TPM, can facilitate the real-time monitoring of the condition of machines and thus increase productivity [22]. Lastly, research done by Dobrosavljević et al. draws attention to the fact that the implementation of

TPM must be regarded as a key determinant of competitiveness for textile SMEs in the international arena.

Autonomous maintenance is a practice that stems from the TPM methodology, which focuses on equipment maintenance by operators themselves. This practice benefits garment SMEs by giving them more freedom and initiative towards maintenance management. In addition, Sidhu et al. highlight how maintenance costs can be drastically lowered while equipment availability increases due to autonomous maintenance implementation [17]. Moreover, Chen's work claims that this practice enhances operational performance and improves the overall work climate by making it more friendly, collaborative, and motivating [19]. Furthermore, Hossain et al.'s study suggests that SMEs adopting autonomous maintenance will likely improve product quality due to increased operator participation in production [14]. Finally, Velmurugan et al. note that autonomous maintenance is likely to facilitate the digital transformation of SMEs in the context of Industry 4.0, which is a shift towards digital technologies. In closing, the review of relevant literature shows that adopting Lean Manufacturing and Standardized Work, 5S, TPM, and Autonomous Maintenance methods in garment SMEs can help improve operational efficiency, product quality, and customer satisfaction. These measures are vital not only in improving the competitiveness of the SMEs in the textile industry but their relevance in sustaining these firms in the ever-increasing challenging global market is invaluable.

3. Contribution

3.1. Proposed Model

The proposed model aligns strongly with Lean Manufacturing principles and Total Productive Maintenance (TPM), aiming to build operational effectiveness while mitigating faults within the textile production system, as shown in Figure 1. The model included three essential factors for advancing the work environment, boosting process control, and instituting equipment upkeep. The 5S methodology aided in creating a clean and orderly workspace, which helped eliminate waste and enhance productivity. Standardization of work processes also reduced variability in production tasks, thus ensuring consistency and minimizing waste during manufacturing. Operators' autonomy also contributed to their empowerment due to the sense of ownership regarding their machine's maintenance, enabling early detection of potential failures and thus averting defects on the final garments. The combined effect of these strategies was observed in the significant reduction in sub-standard asymmetrical fabric cuts, garment stains, open seam defects, and loose threads. Such a strategy not only enhanced the product quality but also integrated the fundamentals of constant improvement into the production processes and built a culture of efficiency and accuracy in the factory.

3.2. Model Components

The designed production model aimed to reduce faults in the textile production process while improving productivity through Lean Manufacturing and Total Productive Maintenance (TPM) model guidance. Figure 1 shows the implemented solution design, which seeks to resolve recurrent problems on the production line, like uneven fabric cutting, clothes staining, and defective sewing. A strategy focused on working environment enhancement, work procedural standardization, and developing a proactive maintenance framework was specified. The model's components were important for workflow optimization and waste minimization so that the set quality standards of the end products were attained.

3.2.1. Workplace Optimization Through the 5S Methodology

The 5S method was deployed as the first component of the model to create a safer and more streamlined working environment. This component helped to eliminate waste organize, and clean the workplace to enhance productivity. Efforts were made to categorize and catalogue materials properly to avoid clutter while ensuring easy access to tools and raw materials. Moreover, cleanliness and maintenance of the production area were given considerable attention to minimize contamination of garments and reduce stains on finished products. Moreover, instituting order and discipline in the workplace made it easier to detect faults during production, thus enabling rapid response to possible declines in product quality.

3.2.2. Process Standardization to Reduce Variability and Waste

Building work standards for control purposes was the second component of the model. In establishing work standards, my goal was to eliminate variability in work methods, as well as to optimize the use of resources. Inefficient fabric cuts due to the absence of standardization on the production line resulted in assembly defects in non-conforming products. To manage this problem, comprehensive operational guides were developed to control the degree of variability in the work done by operators. Every task was clearly defined and specified, such as the time to execute them, machine parameters, and quality control requirements. Such a process reduced asymmetrical cuts and defects in garments manufactured, making the final product's quality much better. Additionally, standardization facilitated employee training, ensuring that new staff adapted quickly to the established procedures.

3.2.3. Autonomous Maintenance for Failure and Defect Prevention

The third and final component of the model focused on implementing an autonomous maintenance program, aiming to involve operators in preserving the machinery used in the production process.

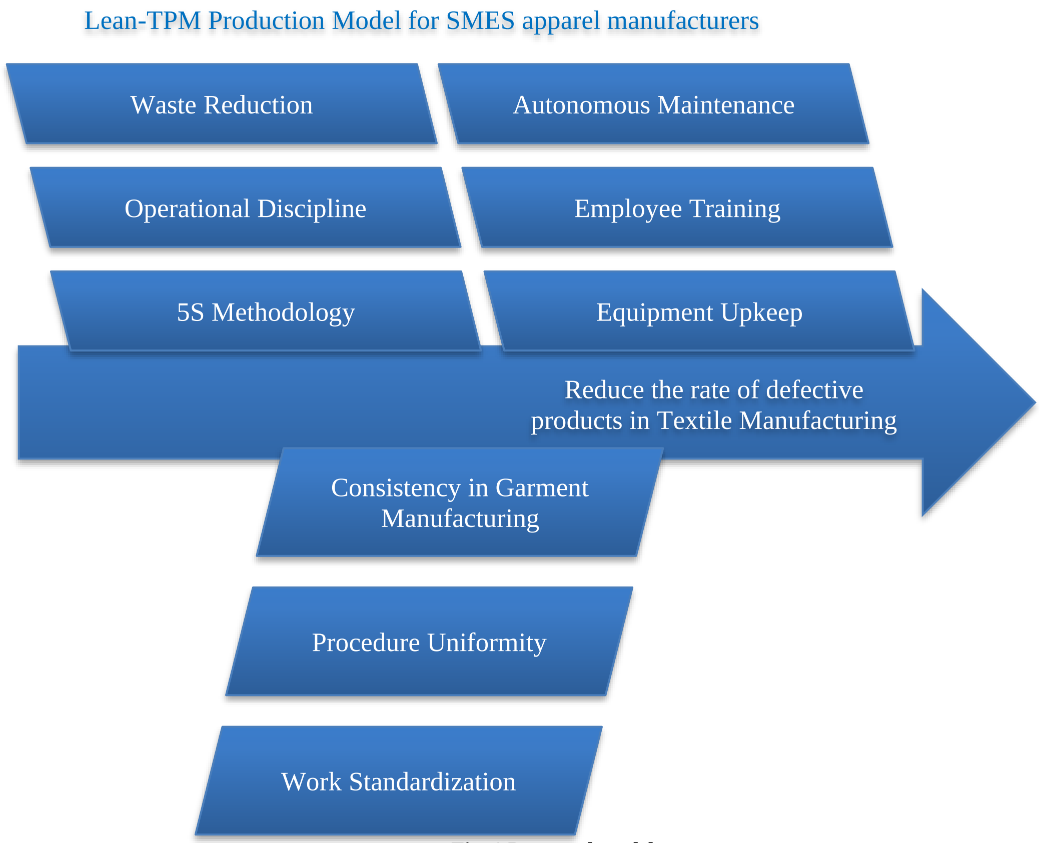

Fig. 1 Proposed model

The lack of preventive maintenance in equipment led to garment defects such as open seams and loose threads, affecting product quality and production efficiency. To mitigate this problem, employees were trained in early fault detection and executing basic maintenance tasks, such as cleaning and lubricating mechanical components.

Moreover, periodic inspection routines were established, allowing timely identification of wear and preventing unexpected production line stoppages. The integration of autonomous maintenance contributed to extending equipment lifespan and reducing defects in finished products, thus reinforcing a culture of continuous improvement within the organization.

3.2.4. Integration of Strategies for an Efficient Production Model

The proposed model, represented in Figure 1, proved to be an effective solution for optimizing textile production, significantly reducing defect generation and increasing process efficiency. Applying the 5S methodology improved working conditions and minimized sources of garment contamination. Product manufacturing variability was limited due to work standardization, which ensured process uniformity. Lastly, the application of autonomous maintenance deepened the prevention culture while reducing the impact of equipment breakdowns. These factors, cumulatively, made it possible to attain a production model integrated with Lean Manufacturing alongside TPM, which conceived a strong platform for ongoing enhancement and sustainability in the textile sector.

3.3. Model Indicators

The effectiveness of the Lean and TPM Production model in reducing defects in garment manufacturing SMEs was assessed using a quality and productivity-focused set of parameters. This model allowed for comprehensive tracking of the production cycle, facilitating problem detection and process improvement throughout the cycle.

Integrating waste-reduction lean strategies and proactive equipment maintenance through TPM enabled better control of factors affecting product quality. Such approaches assisted in making rational decisions based on observed facts, thus improving certainty and consistency of production, decreasing defects, and enhancing the competitiveness of small and medium enterprises in the textile industry.

3.3.1. Defective Products Rate

This indicator measures the percentage of defective products in terms of total production. A lower value reflects improved process control and higher quality standards.

$$\text{Defective Products Rate} = \left(\frac{\text{Defective Products}}{\text{Total Products Manufactured}}\right) \times 100$$

3.3.2. Defective Products Due to Asymmetrical Cuts

This metric quantifies defects caused by irregular fabric cuts, which impact garment fit and quality. A reduction indicates enhanced cutting precision and improved standardization.

$$\text{Defective Products Due to Asymmetrical Cuts} = \left(\frac{\text{Defective Products from Asymmetrical Cuts}}{\text{Total Products Manufactured}}\right) \times 100$$

3.3.3. Defective Products Due to Stains

This indicator assesses the percentage of garments with stains, a key aspect of visual quality control. Lower values suggest improvements in material handling and workplace cleanliness.

$$\text{Defective Products Due to Stains} = \left(\frac{\text{Defective Products from Stains}}{\text{Total Products Manufactured}}\right) \times 100$$

3.3.4. 5S Compliance Level

This metric evaluates adherence to the 5S methodology, which enhances workplace organization and efficiency.

A higher percentage signifies improved implementation of sorting, setting in order, shining, standardizing, and sustaining.

$$\text{5S Compliance Level} = \left(\frac{\text{5S Compliant Audits}}{\text{Total Audits Conducted}}\right) \times 100$$

3.3.5. Defective Products Due to Open Seams and Loose Threads

This indicator tracks defects related to poor stitching, affecting garment durability. A decrease reflects enhanced machine maintenance and process standardization.

$$\text{Defective Products Due to Open Seams and Loose Threads} = \left(\frac{\text{Defective Products from Stitching Issues}}{\text{Total Products Manufactured}}\right) \times 100$$

3.3.6. Overall Equipment Effectiveness (OEE)

OEE measures manufacturing productivity by evaluating availability, performance, and quality. A higher value indicates greater efficiency and minimized downtime.

$$\text{OEE} = (\text{Availability} \times \text{Performance} \times \text{Quality}) \times 100$$

4. Validation

4.1. Validation Scenario

The validation scenario was conducted in a case study corresponding to a micro and small enterprise (MYPE) in Peru's textile and apparel sector. The company in Lima specialized in garment manufacturing and faced challenges related to product defects, primarily occurring in the cutting and sewing stages. Despite having over a decade of experience in the market, the organization encountered operational difficulties that impacted its productivity and final product quality. Its organizational structure included a small team of workers who played key roles in production and management. The company sought to improve its processes to reduce defect rates in garment manufacturing, optimize operational efficiency, and strengthen its market competitiveness. This context motivated the implementation of a continuous improvement-based approach to address the identified deficiencies.

4.2. Initial Diagnosis

The diagnosis in the case study revealed a high rate of defective products, reaching 12.74%, representing a technical gap of 8.61% compared to the industry average. Two primary sources of defects were identified: failures in the sewing process, which accounted for 52.06%, and failures in the cutting process, responsible for 42.02%. Among the sewing defects, the presence of stains on garments represented 28.38%, while defects related to open seams and loose threads reached 23.68%. On the other hand, within the cutting process failures, asymmetrical cuts were the most significant issue, accounting for 34.36%, followed by torn fabric at 7.66%. Additionally, 5.92% of defects were attributed to other factors. These deficiencies resulted in an estimated economic impact of 116,960 PEN for 2023, representing 9.55% of the company's annual revenue.

4.3. Validation Design

The suggested production model, which incorporates Lean and TPM technologies, was validated through the pilot validation process. The implementation of this method spanned four months in the case study, encompassing all the suggested techniques. This includes the 5S method, work standardization, and self-discipline maintenance. Each of these is detailed below.

The case study centred on a specific production model that sought to minimize the defects in a textile product using Lean Manufacturing and Total Productive Maintenance (TPM) techniques. This initiative was developed to address the poor quality of the cutting and sewing processes, which was a major contributor to defective products. To meet this objective, there was a detailed action plan that comprised three fundamental parts: using the 5S technique to enhance the working conditions, standardizing the processes to minimize variations in production, and applying self-discipline maintenance to mitigate equipment breakdowns.

These strategies were validated through a case study based approach utilizing evidence from the data regarding their impacts and costs.

4.3.1. Initial Diagnosis and Formation of Work Teams

Before implementing the solution, a comprehensive company diagnosis was conducted to identify the main factors affecting product quality.

It was found that 12.74% of production had defects, exceeding the industry average by 8.61%. The most common defects included asymmetrical cuts (34.36%), stains (28.38%), and open seams or loose threads (23.68%).

The lack of preventive maintenance also led to frequent machine failures, reducing overall efficiency. Based on these findings, specialized work teams were formed to oversee the application of each improvement tool.

Supervisors and operators were assigned specific roles to implement Lean and TPM principles effectively. Training sessions were conducted to familiarize workers with new procedures, emphasizing problem-solving techniques and best practices in production management.

4.3.2. Workplace Optimization with the 5S Methodology

The first phase of implementation involved applying the 5S methodology to improve organization and cleanliness in workstations. Prior to implementation, 5S audit compliance was recorded at 64%, highlighting deficiencies in space management, storage of tools, and cleanliness standards. These inefficiencies contributed to quality issues, particularly stains caused by inadequate handling of materials.

After implementing the 5S methodology, which involved removing unnecessary materials, properly labelling tools, systematic cleaning protocols, and developing standardized workstations, compliance levels increased to 95%.

As a result, defects related to stains were reduced from 28.38% to 19.08%, demonstrating the effectiveness of maintaining a well-organized production environment. The improvement also facilitated a smoother workflow, as workers experienced fewer disruptions due to misplaced tools and untidy workspaces.

In Figure 2, the company's situation after the implementation of the 5S methodology is shown. A well-organized workspace, with neatly arranged tools, classified materials on shelves, and efficient product storage, is evident. The application of this method has improved cleanliness, quick access to supplies, and space optimization, fostering a more productive and safer environment.

Fig. 2 Workplace organization after 5s implementation

4.3.3. Process Standardization to Reduce Variability

The unstandardized procedures practiced by the company led to discrepancies while cutting the fabric, resulting in defects during garment assembly. Differences in the cuts made, and the precision of the cuts led to increased material wastage and an increased need for rework, which hindered productivity.

Standard operating procedures referencing industry best practices, particularly NCPT-003-TGPPV-V1-2015, were designed to address the issue. The SOPs defined specific limits on the critical parameters for cutting fabric into required shapes, alignments, and finishing procedures. Adopting standard procedures reduced the variability in the processes, which reduced asymmetrical cuts of fabric from 34.36% to 23.10%. Also, operators reported better confidence when performing their duties due to the provided SOPs because they provided order and structure to how the operators performed their work.

In addition, new employees could adapt to the production processes more quickly and with fewer mistakes due to the standardized processes, which increased standardization efficiency.

The workflow of the proposed model is shown below, as shown in Figure 3. The process begins with analyzing the current cutting process and developing a technical sheet and staff training. Then, activities are standardized, reducing process variation and promoting continuous improvement. Finally, the application of the tool is evaluated to determine its suitability for definitive implementation.

In Figure 4, the company's situation after the implementation of work standardization is shown. A detailed technical sheet for measuring polo shirts allows precise control of dimensions and tolerances. Additionally, standardized documentation facilitates uniform production and enhances the final product's quality.

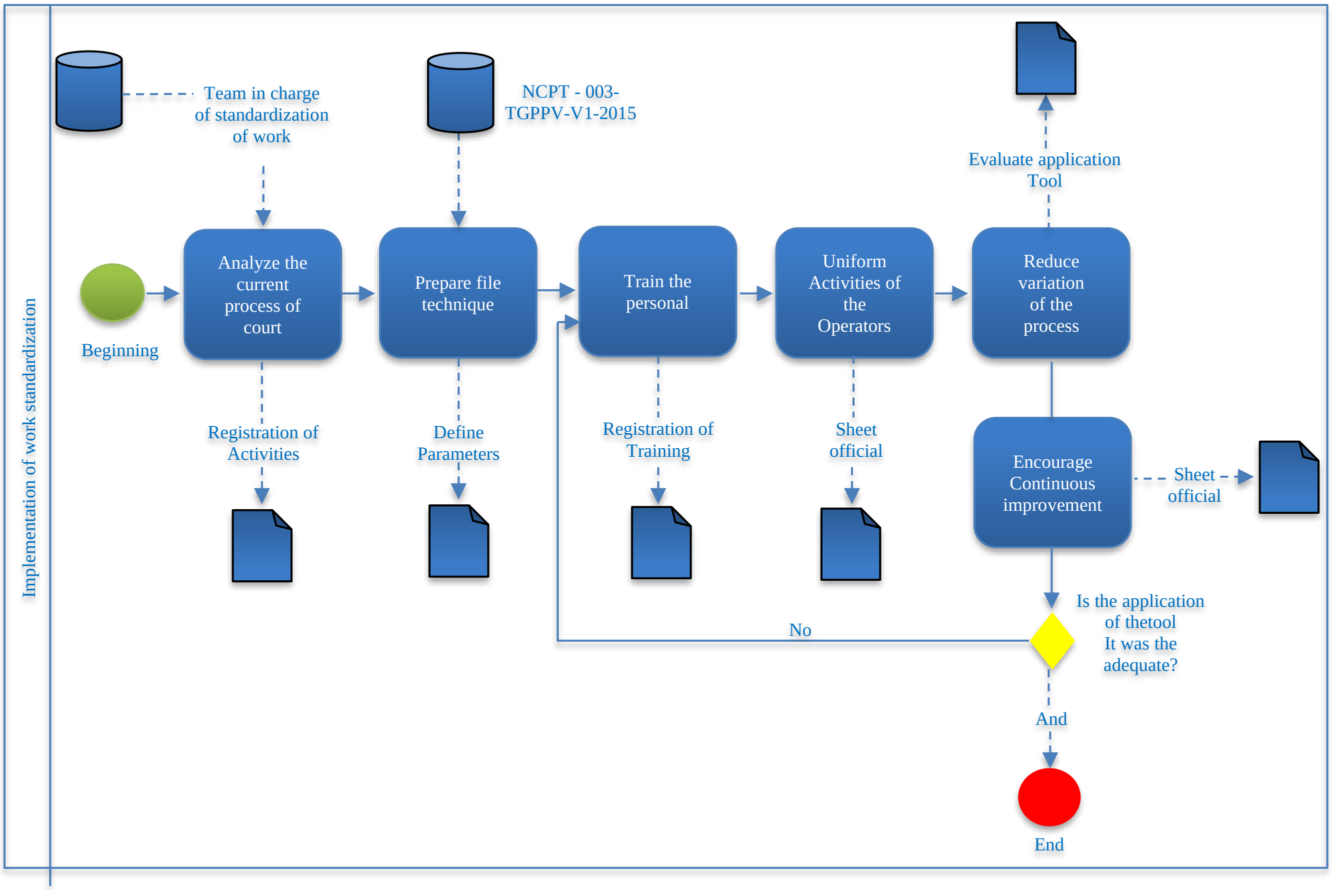

Fig. 3 Work standardization implementation process

Fig. 4 Technical Measurement Sheet for Polo Shirts

4.3.4. Autonomous Maintenance to Prevent Machinery Failures

The prevalence of corrective maintenance in the company resulted in frequent machinery failures, unplanned downtime, and quality defects. The absence of structured maintenance schedules led to excessive wear on sewing and cutting machines, reducing their efficiency and lifespan. An autonomous maintenance program was introduced to address this, following the guidelines of NCPT-002-TDPT-V1-2015-CN01, a Peruvian technical standard. Operators were trained to conduct routine inspections, lubrication, and minor repairs to prevent unexpected breakdowns. This initiative not only empowered workers but also increased equipment reliability. As a result, defects caused by open seams and loose threads were reduced from 23.68% to 15.64%. Implementing proactive maintenance strategies also substantially increased Overall Equipment Effectiveness (OEE), which improved from 65.88% to 90.00%. The improvement in OEE reflected enhanced machine availability, optimal performance, and reduced production disruptions, ensuring a more stable manufacturing process.

In Figure 5, the flowchart of TPM implementation with a focus on autonomous maintenance is shown. The process begins with analyzing the condition of the machines, followed by the development of technical sheets and the maintenance plan. Subsequently, operators are trained, and autonomous maintenance is carried out using checklists. Finally, indicators such as OEE and quality are calculated to assess the effectiveness of the process, determining whether the tool was applied correctly for its consolidation.

Figure 6 shows the company's situation after the implementation of autonomous maintenance. A detailed lubrication control record is observed, reflecting greater discipline in inspections. Additionally, visual standards are implemented, demonstrating organized and accessible documentation for operational personnel.

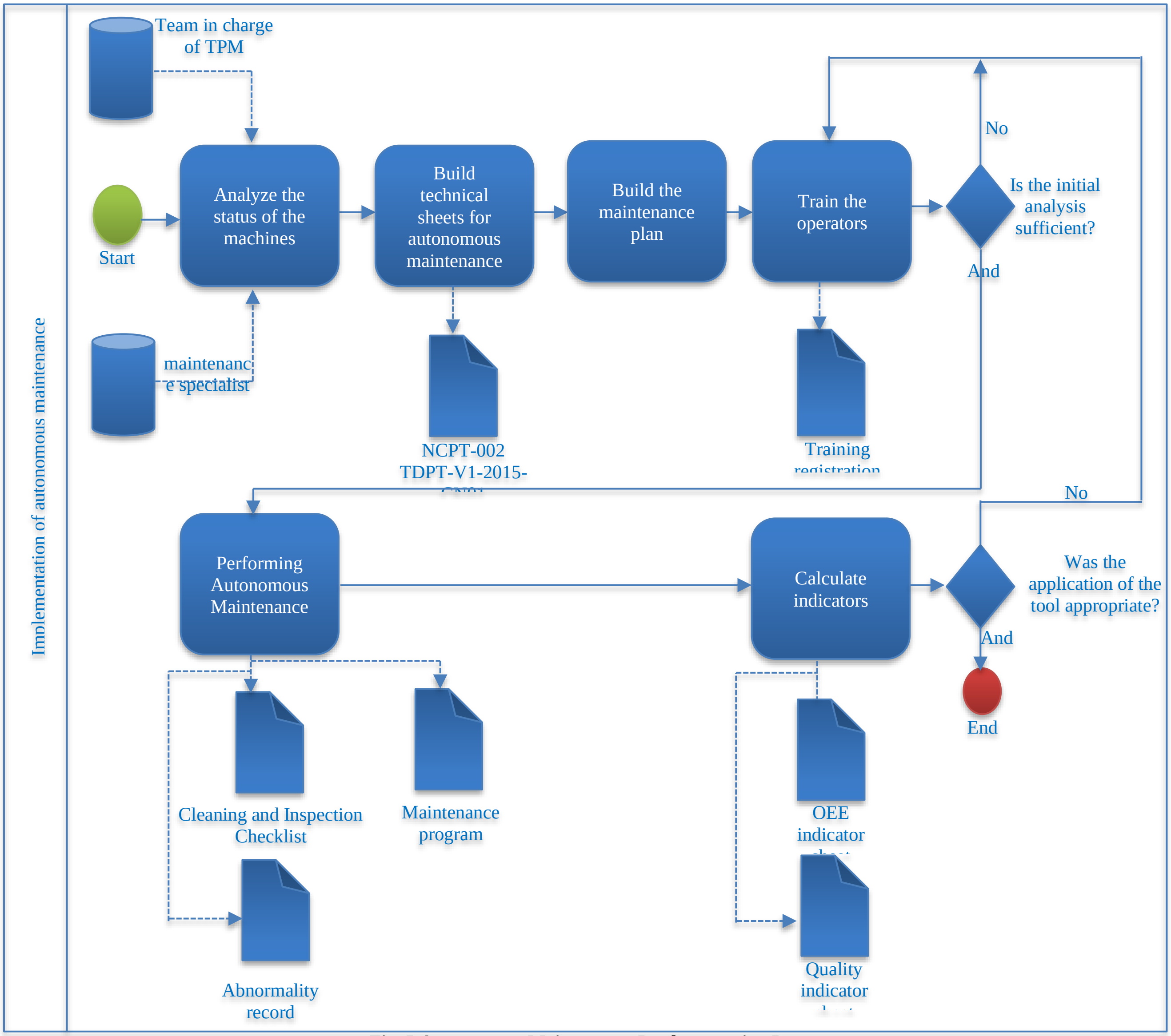

Fig. 5 Autonomous Maintenance Implementation Process

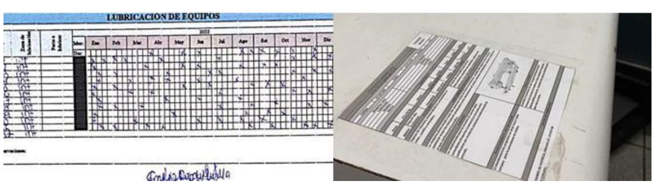

Fig. 6 Equipment lubrication control and standardized documentation

4.3.5. Integration of Continuous Improvement for Sustainable Results

Beyond addressing immediate defects, implementing Lean and TPM tools fostered a culture of continuous improvement within the company. Regular review meetings were held to assess progress, identify new challenges, and refine processes. Operators and supervisors actively participated in improvement initiatives, suggesting workflow adjustments and preventive maintenance schedules. The structured approach to problem-solving reinforced a proactive mindset among employees, ensuring that quality and efficiency gains were sustained over time. Furthermore, real-time monitoring of key performance indicators allowed for data-driven decision-making, minimizing reactive interventions and promoting long-term operational stability. Integrating Lean and TPM principles improved production outcomes and strengthened the company's competitiveness in the textile industry.

Implementing the improvement model optimized production processes in the company, achieving a 60.52% reduction in the defective product rate. Furthermore, the results demonstrated that integrating Lean and TPM tools improved product quality, enhanced operational management, and reduced rework-related costs.

To support these findings, it would be appropriate to include tables summarizing the evolution of key indicators before and after implementation and figures illustrating changes in workspace organization and machinery availability. These visual representations would reinforce the effectiveness of the adopted methodologies and provide valuable insights for future process improvements.

4.4. Results

Table 1 presents the impact of implementing the Lean and TPM-based production model on defect reduction and operational efficiency improvement. A significant decrease in the defective product rate was observed, with a 60.52% reduction, while defects related to asymmetrical cuts, stains, and open seams also showed notable improvements.

Additionally, 5S compliance increased by 48.44%, reflecting greater standardization and workplace organization. Finally, Overall Equipment Effectiveness (OEE) improved by 36.61%, confirming the effectiveness of the adopted approach in optimizing the production process.

Table 1. Results of the pilot

Indicator	Unit	As Is	To Be	Results	Variation
Defective products	%	12.74%	4.13%	5.03%	-60.52%
Defective products due to asymmetrical cuts	%	34.36%	23.10%	26.10%	-24.04%
Defective products due to stains	%	28.38%	19.08%	21.55%	-24.07%
5S Compliance Level	%	64.00%	95.00%	95%	48.44%
Defective products due to open seams and loose threads	%	23.68%	15.64%	17.98%	-24.07%
OEE Level	%	65.88%	90.00%	90%	36.61%

5. Discussion

The results obtained in this study reinforce previous findings on the implementation of Lean Manufacturing and Total Productive Maintenance (TPM) in the manufacturing industry, particularly in Small and Medium-sized Enterprises (SMEs) in the textile sector. Prior studies have highlighted that applying these methodologies significantly reduces production defects and improves operational efficiency [1], [2]. However, unlike these works, which have mostly been applied in industrial contexts with a more established infrastructure, this study demonstrates the effectiveness of an integrated approach in the specific context of Peruvian SMEs, which are characterized by technological and personnel training limitations. The outcomes indicated a 60.52% decrease in the defective product rate and a 36.61% increase in Overall Equipment Effectiveness (OEE), which exceeded the mean values for lean and TPM implementation in SMEs in other areas. This shows that in the textile sector, at least, an adapted implementation may be more beneficial than the standard models proposed in the literature.

5.1. Study Limitations

This study has apparent improvements regarding operational effectiveness and product quality, yet some constraints are worth mentioning. First, the investigation relies on one case study from a textile company in Peru, which limits the scope of applicability to other SMEs in the industry with different attributes. Moreover, the application of Lean and TPM techniques was dependent on the organizational culture and the readiness of the staff to accept change, which may cause inconsistency in the outcomes if logic in lower organizational commitment environments were used. In addition, the evaluation period of four months is quite short to assess some of the impacts over time, especially with regard to the sustainability of the reported improvements. Lastly, the study did not consider external factors like changes in market demand or supply chain issues that affect production processes' continuity.

5.2. Practical Implications

The results of this research have important practical considerations for the textile SMEs operational management in developing economies. First, the Integrated Lean Manufacturing with TPM enables these firms to improve their processes with little or no advanced technology investments, making them suitable for resource poor regions. In addition, customer satisfaction is enhanced as the production defects are greatly minimized, reinforcing SMEs' competitiveness in the context of the more challenging global marketplace. In addition, the culture of shared responsibility among workers is further encouraged with the improvement of equipment effectiveness through autonomous maintenance, which helps sustain the improvements made after implementing changes. Finally, the framework is designed to be modified by other SMEs to improve operational performance using continuous improvement processes that transform the industrial future in the area.

5.3 Future Works

Given that this study analyzed one textile firm, more broad scoped SME comparative case studies could be done in the sector, assessing results variability across different organizational contexts. Also, integrating Industry 4.0 tools with Lean and TPM, such as IoT equipment monitoring for improved predictive maintenance, should be studied to decrease downtime further [3],[4]. Developing these modifications sets the foundation for other important long-term studies, especially determining the financial benefits business gains post operational advancements like defect elimination and efficiency increment. The research scope could also broaden towards other manufacturing industry segments and assess the impact of Lean and TPM applications on the relatively different production processes of the automotive and metalworking industries. Lastly, a qualitative study approach on staff attitudes towards applying the said methodologies would be insightful in determining the facilitating and constraining organizational factors for the sustained use of these improvement strategies.

6. Conclusion

This investigation shows that implementing Lean Manufacturing and Total Productive Maintenance (TPM) in Peruvian textile SMEs results in great operational efficiency and improved product quality. The findings indicate a reduction of 60.52% in the defective product rate and an increase of 36.61% in Overall Equipment Effectiveness (OEE). These results testify to the success of specific Lean and TPM methodologies when tailored to the sector's needs. Applying 5S, work standardization, and autonomous maintenance systematically optimises production processes by reducing variation and eliminating equipment failure. These changes impact the reduction of costs, increase the satisfaction of customers, and improve the competitiveness of SMEs in the context of a more challenging global economy. This investigation is timely and important given the plight of textile SMEs in developing economies limited by few resources and drastically lower productivity and sustainability owing to high defect rates. For the first time, this study focuses on the unique attributes of SMEs, unlike other studies that concentrate on large corporations, and it proves that Lean and TPM can be applied in such technologically deprived settings. With Lean and TPM integrated into a simple model, SMEs can increase their production capabilities without facing a financial burden, thus making these methodologies viable for firms with operational constraints.

This research adds value to the existing body of knowledge in the field by backing up claims with data and observations on the impacts of the implemented integrated Lean-TPM model in the textile industry. Unlike conventional implementations that treat these methodologies separately, this research emphasizes their synergy, reinforcing the importance of aligning process optimization with proactive maintenance strategies. Additionally, the findings highlight the role of workforce engagement in sustaining continuous improvement efforts, underlining the significance of employee participation in achieving long-term success.

While the study yields promising results, it is limited to a single case study, which restricts the generalization of findings to other SMEs with different operational structures. Future research should expand the scope to include comparative analyses across various companies, assessing how organizational culture, technological readiness, and market conditions influence implementation outcomes. Further exploration of Industry 4.0 integration, particularly IoT-based predictive maintenance, could enhance process control and efficiency. Long-term financial evaluations and qualitative studies on employee perceptions would also provide valuable insights into the broader impact of these methodologies.

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