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Research Article

Improving Sewing Efficiency in Garment SMEs: A Lean-TPM Production Model Adapted to the Peruvian Context

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Abstract: *Small garment manufacturing companies in Peru face persistent inefficiencies in their sewing operations, often exacerbated by limited resources and a lack of structured methodologies. Previous studies have addressed Lean and TPM applications, yet few have contextualized these tools for small-scale firms in Latin America. This research tackled those challenges by proposing a production model integrating 5S, autonomous maintenance, and standardized work routines within the PDCA cycle. The model was implemented in a Peruvian SME and tailored to its specific constraints. After four months, sewing process efficiency increased by 14.15%, Overall Equipment Effectiveness rose by 21.35%, and both rework and disorder-related losses dropped significantly. These results suggest that Lean-TPM integration can generate measurable benefits even in low-resource environments. The study contributes to closing a gap in practical applications for small apparel firms and offers a replicable approach. Future research should explore long-term effects and expand validation across diverse production settings.*

Keywords: *Lean Manufacturing, Total Productive Maintenance, Sewing Process Efficiency, Garmen Industry Standardized Work.*

I. INTRODUCTION

The Small And Medium-Sized Enterprises (SMEs) within the garment manufacturing industry are particularly important globally, especially in Latin America and Peru. Furthermore, it is estimated that SMEs in the textile and garment industry account for a considerable proportion of economic activity and employment. As the International Labour Organization pointed out, this sector has a competent coverage of employment opportunities, especially in developing economies where more than 60% of formal employment is generated by SMEs, as observed by Garzoni et al. [1]. In Latin America, textile manufacturing is a major contributor to both income and jobs, particularly in Peru, where the industry not only supports national GDP but is also important for exports. For example, Peru's textile and garment industry is estimated to grow at an annual rate of 7%, demonstrating the possibility of further economic development. Nevertheless, several key issues emerging from low productivity and inefficient processes pose the most significant challenge in the context of development and competitiveness.

The foremost problem confronting garment manufacturing SMEs is low operational efficiency. Recurrent problems with productivity are linked to a lack of organization within workstations and the absence of process sewing standardization. Bizuneh et al. [2] argue that increased work area disorder results in longer production times, delayed deliveries, and diminished product quality. Moreover, Fatmah et al. [3] attribute operational inefficiency to poor lubrication, bad cleaning practices, and incorrect assembly of sewing machines. Failing to address these issues could result in significant costs regarding the production process and product quality [4]. This shifts the burden of problem-solving and mitigation, as well as market competitiveness, on the shoulders of these companies, as described by Sidhu et al. [5].

Improving the garment sector's image requires problem-resolution efforts targeting operational efficiency. The adoption of TPM and Lean Manufacturing paradigms aims to improve the processes. Industrial processes can be continuously improved, and waste can be minimized by Lean methods such as 5S and work standardization, as proven by Divrik & Baykal [6].

Implementing these methodologies aims to transform how SMEs operate, enabling improvements in efficiency and product quality, ultimately resulting in greater customer satisfaction, as pointed out by Sidhu et al. [7]. Moreover, through autonomous maintenance, TPM ensures that machines remain operational and in optimal condition, which is critical for uninterrupted production, as explained by Kotthaus et al. [8].

Despite the relevance of these approaches, there is a significant gap in the literature regarding the application of these methodologies, specifically in garment manufacturing SMEs in Latin America. Most existing studies focus on larger industries, and it is acknowledged that there are limitations in the emphasis on SMEs in local contexts, as stated by Velmurugan et al. [9].

This research proposes a production model adapted to the characteristics of these SMEs, using Lean Manufacturing tools such as 5S and work standardization, along with TPM as a maintenance model. This model aims to improve operational efficiency and contributes a theoretical and practical framework to fill the gap identified in the existing literature, as proposed by Molla & Dunne [10]. The originality of this approach lies in its contextualization of the specific realities and challenges of Peruvian SMEs, thus enabling the sector to reach levels of competitiveness that currently seem unattainable.

In comparison to other work, this model can enhance the operational efficiency of the firm as well as rectify the peculiarities and issues of the particular sector. SMEs can now extend their boundaries towards holistic, productive performance by integrating continuous improvement and maintenance tools into one framework. Thus, this research solves a particular problem and tries to devise a way to sustain and grow small industries that will, in turn, greatly impact local and global economies.

II. LITERATURE REVIEW

The research began with an extensive review of scholarly literature published within the last five years, intending to identify gaps in the research and determine the most suitable approach. This analysis developed a new maintenance management model that integrated Lean and TPM and was designed specifically for the case.

A) Lean Manufacturing in the Garment Industry: A Path Towards Efficiency

Implementing the Lean Manufacturing methodology in Small And Medium-Sized Enterprises (SMEs) in the garment sector is useful for enhancing operational efficiency and reducing waste. There are several cases in the literature where SMEs have adopted lean practices in their sewing operations. For instance, one textile study found that applying Lean principles, such as eliminating non-value-adding activities and improving workflows, was directly linked to improved productivity and reduced cycle times [11], [12]. This underscores the importance of adapting Lean in a manufacturing environment—where standardization is known to reduce process variability and enhance overall product quality [13]. SMEs also stand to gain from the Lean-provided training on developing a continuous self-improvement culture so that even the smallest organizations can compete in the market [14]. This is imperative in the fashion and apparel industry, where speed and adaptivity are vital, particularly for SMEs who need quick and effective sewing operations.

B) Work Standardization: Key to Quality and Productivity

In order to guarantee quality and efficiency, a clearly defined and measurable work procedure is critical, which has been proven in the garment industry with the application of standardized work methods. The study of standardized work implementation in small and medium manufacturing indicates that creating operation manuals improves product quality and reduces rework costs [15]. In garment factories, case studies indicate that documenting each step of the sewing process and creating visual aids to guide the sewing process reduces process variability and enhances training to achieve higher levels of customer satisfaction [16]. In addition, research has shown that companies can utilize standardized performance metrics to pinpoint operational inefficiencies and make swift modifications to streamline processes to improve performance [17]. The detailed study of the impact of standardized work in garment SMEs highlighted the need for flexibility with fixed procedures to respond effectively to demand changes [18].

C) 5S: Organizing the Workplace for Efficiency

The 5S principles, Sort, Set in Order, Shine, Standardize, and Sustain, have been used by textile SMEs to optimize organization and minimize wastage in the sewing section. The 5S method has improved orderliness in work areas, improving safety and efficiency within the organization [19]. An empirical study illustrates that arrangement and systematic organization of the workplace boost employee morale and decrease time spent searching for needed materials [20]. Additionally, factories employing 5S report being able to pinpoint problems and carry out continuous improvement processes with greater ease [21]. Evidence supports the notion that fostering a clean and orderly undertaking enhances productivity and quality, not just as a perception in the garment production chain [22]. The application of this methodology has been significantly linked with the increase in production errors and delivery time, which is especially important in the fashion industry, where deadlines are strict and competition fierce [23].

D) Total Productive Maintenance (TPM): A Comprehensive Strategy for Productivity

Assisting in boosting Overall Equipment Effectiveness (OEE) and downtime in SMEs within the garment sector, Total Productive Maintenance (TPM) is gaining popularity as a needed approach for the sector. Apparently, TPM not only improves the availability of machines; it also enhances the participation of employees in the maintenance work on machines, thus fostering an atmosphere of collective responsibility [24]. More recent studies reveal that those factories that adopted TPM seem to enjoy substantial productivity improvements resulting from reduced mechanical failures and resource wastage [25]. One further analysis indicates that achieving TPM goals motivates employees to participate actively in assigned tasks, such as preventive maintenance, thus lowering the cost of operation [26]. Indeed, reports from firms adopting TPM express that more and better efficiency is achieved together with marked improvements in the quality of the products, which enhances the competing ability of these SMEs in a more sophisticated market [27].

E) Autonomous Maintenance: Empowering Personnel in Equipment Upkeep

Self-maintenance is crucial for improving the performance of garment-oriented SMEs as it enables employees to take part in equipment maintenance. This approach diminishes production halts, enables personnel empowerment, and augments employee engagement in quality [28]. Observations in garment factories revealed that operators trained in self-maintenance can identify and fix problems, minimizing downtime [29]. In addition, it is proposed that self-maintenance gives workers greater knowledge of the equipment, which improves its effectiveness and reduces mistakes during production [30]. Other studies captured that self-maintenance enhances the operations' performance and creates an efficient collaborative work environment where employees become more responsible for their tasks [31].

III. CONTRIBUTION

A) Proposed Model

Figure 1 illustrates a production model for a small garment manufacturing company, paying particular attention to optimizing the sewing section. This was developed in line with the principles of Lean Manufacturing and Total Productive Maintenance (TPM) and aimed to improve the flow of processes by eliminating unanticipated halts along with process variability. The model was organized around the Plan-Do-Check-Act (PDCA) cycle, which served as an efficient framework for implementing improvement objectives. In planning, the team focused on analyzing the inefficiencies and their roots, as well as setting particular goals for improvement. During execution, three core practices were implemented: 5S for order and visibility improvement at their workstations, machine care independent maintenance to involve the sewing operators in the basic upkeep of the machines, and standardized routines to bring consistency across tasks performed. After implementation, tracking and assessment of the outcomes were conducted, which enabled the validation of progress and necessary adjustments. Gradually, the focus was shifted towards strengthening the changes, fostering the practices, identifying new areas for sustainable continuous improvement, and making them routine. The model served not only as a technical tool but also aided in prompting a change in practices and thinking, enabling daily tasks to be aligned with strategic objectives to improve efficiency in a resource-constrained environment.

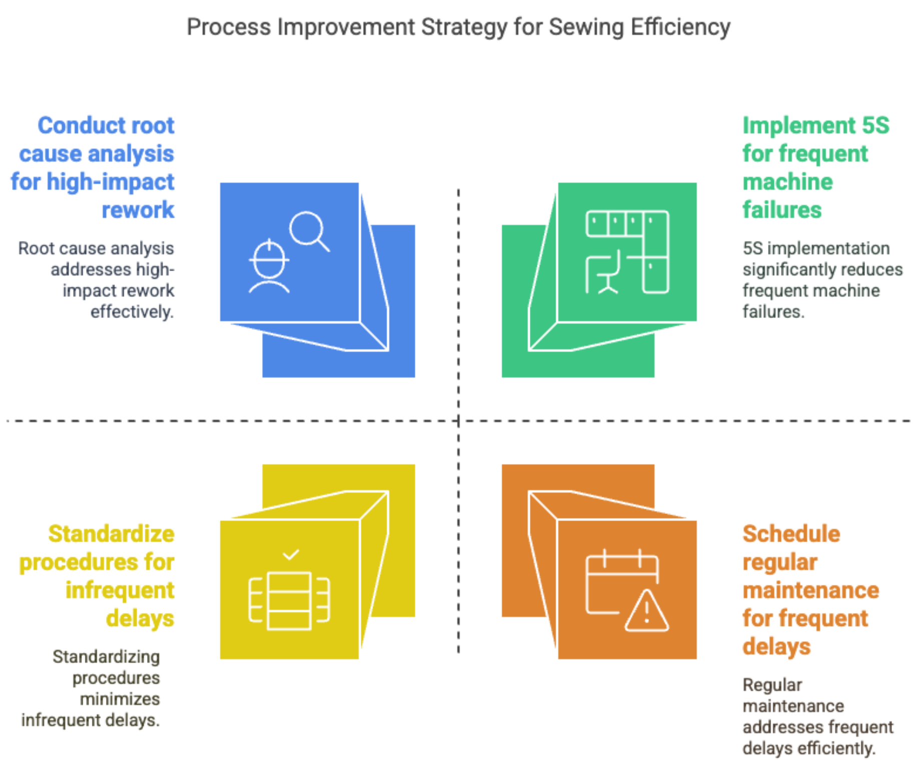

Fig. 1. Proposed Model

B) Model Components

The sewing process in garment-manufacturing companies was observed to be operationally inefficient, and a response to these issues is displayed in Figure 1. Small-scale garment workshops, operating within an intensely competitive and often resource-constrained context, confront major issues in productivity, quality, and the continuity of operations. This approach aims to answer such problems by codifying the response and blending Lean Manufacturing principles with Total Productive Maintenance (TPM) practices within a PDCA (Plan-Do-Check-Act) continual improvement cycle.

The practical utility of this model applies to uncontrolled environments if frequent machine stoppages, materials retrieval delays, highly iterative processes, and rework are commonplace. The model seeks to integrate organizational strategies with everyday operational practices to achieve this goal. Also, the cyclic structure of the PDCA cycle assures the sustainability of changes by providing repeated feedback.

a. Initial Diagnosis: Characterization of the As-Is Scenario

Prior to starting the improvement cycle, the model focuses on the current state of the sewing process ‘as is’ with a comprehensive account. This diagnosis uncovers the following areas as the main concerns: high machine downtime, chronic delays caused by material locating, and a high volume of rework. These conditions illustrate the absence of cohesive and integrated orderly work in operations. In addition, there are no written procedures and standards, material control systems, operator control systems, or standard capabilities that are inefficient.

This as-is analysis highlights the primary areas of gain and loss and establishes the basis for defining goal-oriented project objectives. Direct observation, operator feedback, and empirical data collection are critical in shaping a realistic understanding of the production system at this stage.

b. Planning Phase: Cause Analysis and Goal Definition

The planning phase marks the starting point of the PDCA cycle. During this stage, the company's current situation is thoroughly analyzed using insights from the diagnostic stage. The precise identification of problems allows for delineating root causes associated with machine failures, internal logistical delays, and poor control over quality standards.

Based on this analysis, specific improvement goals are set, focused on increasing the efficiency of the sewing process. These objectives are formulated to be specific, measurable, and achievable, considering the organization’s technical and human resource constraints. Key performance indicators are also established to evaluate the actions' effectiveness.

c. Execution Phase: Implementation of Lean and TPM Tools

The “Do” phase in the PDCA cycle contains three foundational components: 5S, autonomous maintenance, and work standardization. These tools are applied in a step-by-step collaborative manner, which leads to visible short-term results.

Workplace Organization: F1 - 5S Methodology

5S aims to make work areas more organized, clean, and efficient. Removing unneeded items, classifying tools and materials, establishing cleaning routines, and maintaining visual discipline greatly minimize the search time for materials and workflow disruptions. This fosters an improvement in operational safety, encourages worker commitment, and promotes an overall enhancement in the organization.

Operational Autonomy: F2 - Autonomous Maintenance

Autonomous maintenance allows sewing machine operators to perform basic inspection, cleaning, and adjustment tasks. This practice allows for faults to be detected in the early stages, decreases reliance on maintenance personnel, and prolongs the machine’s operating life. Moreover, it deepens the ownership culture and promotes continuous improvement among operators.

Process Consistency: F3 - Work Standardization

The third practice emphasizes work standardization. This tool captures existing work conditioning. It also lays out the optimum sequence of operations and measurable quality parameters. Standardization reduces the inconsistency of outcomes caused by different employers; rework, correctional processes done post-completion of work, and the time required to reliably and quickly bring new staff up to speed are enhanced.

d. Verification Phase: Results and Indicator Assessment

After the improvement actions addec has aptec, it determines how useful these actions have been in the verification phase. In this phase, results are confirmed, previously established indicators are assessed, and efficiency in the process is evaluated. The pre and post-intervention comparison model provides objective evidence of impact.

This analysis is limited to quantifiable data and evaluations from the staff concerned with the process, which helps identify any form of deviation or resistance that would require change in the subsequent cycle.

e. Act Phase: Sustainability and Continuous Improvement

The last step of the PDCA cycle concentrates on systematizing all the implemented measures found to be effective while considering other measures to be added. The elimination of root causes, integration of best practices, and creation of defined practices to monitor procedures for achieving results for a protracted period are designed to ensure lasting results.

In addition, the model fosters an organizational culture that considers improvement a perpetual endeavor and leads the employees to actively participate in the search for new avenues for inefficiency. This allows the model to serve as a tool for organizational learning rather than a static, one-time intervention.

f. Desired Scenario: Characterization of the To-Be State

Achieving the defined goal of the model sets the future scenario (To-Be) expectations as substantially reduced machine failures, streamlined delays in material retrieval, and diminished rework rates. In turn, these factors bolster the overall efficiency of the sewing processes, thereby augmenting customer satisfaction and enhancing organizational competitiveness.

Moving from the As-Is to the To-Be state encompasses the expected technical aspects and a culture shift that appreciates operator expertise, operational order, and unwavering commitment to the outlined performance standards. Here, the proposed model significantly adds to the design of more intuitive, efficient, and sustainable production systems in garment manufacturing.

C) Model Indicators

The efficiency of garment manufacturing SMEs implementing the proposed production model, grounded in Lean and TPM principles, was evaluated through a structured set of performance indicators designed for this context. These indicators were adapted to reflect the operational dynamics of the sewing process and enabled systematic performance monitoring throughout the model's application. This analytical approach provided a reliable framework for assessing progress and identifying areas for further improvement, thus reinforcing the model's effectiveness in driving continuous enhancement within resource-constrained manufacturing environments.

a. Overall Equipment Effectiveness (OEE) (%)

OEE measures the combined effect of equipment availability, performance rate, and product quality. It is a comprehensive indicator to evaluate how effectively the sewing equipment operates over time.

$$\text{OEE (\%)} = \text{Availability} \times \text{Performance} \times \text{Quality} \times 100 \quad (1)$$

b. Efficiency (%)

This indicator reflects the proportion of actual output achieved relative to the theoretical production capacity. It helps assess how well the sewing process meets its planned productivity under normal working conditions.

$$\text{Efficiency (\%)} = \frac{\text{Actual Production}}{\text{Theoretical Production}} \times 100 \quad (2)$$

c. Time Lost Due to Disorder (%)

This metric indicates the percentage of productive time lost because of disorganization or inefficiencies at the workstation. It highlights how disorder can affect the total operational time.

$$\text{Time Lost Due to Disorder (\%)} = \frac{\text{Lost Time}}{\text{Total Working Time}} \times 100 \quad (3)$$

d. Rework Rate (%)

The rework rate tracks the proportion of garments that require correction after initial production. It reflects quality issues and the impact of process instability within the sewing operation.

$$\text{Rework Rate (\%)} = \frac{\text{Number of Reworked Pieces}}{\text{Total Garments Produced}} \times 100 \quad (4)$$

IV. VALIDATION

A) Validation Scenario

The validation scenario was conducted in a case study involving a Small-Sized Enterprise (SME) in the garment manufacturing sector located in Lima, Peru. This company began operations in 2012 and specialized in the wholesale and retail distribution of clothing items at the national level, including shirts, blouses, skirts, pants, t-shirts, and leggings. It operated under a make-to-order system, receiving weekly production requests from its planning area. With 15 employees across various departments, it was classified as a small enterprise based on its annual sales volume. The research focused on the short-sleeved shirt production line, which was identified through an ABC analysis as the most profitable product. Operational diagnosis revealed significant inefficiencies within the sewing stage, highlighting it as the critical point in the production process. These limitations in productivity and organization reflected a broader challenge common to many SMEs in the Peruvian apparel sector, underscoring the need for structured improvement initiatives.

B) Initial Diagnosis

The diagnosis conducted in the case study revealed that low efficiency in the shirt sewing process was the main operational issue in the analyzed garment manufacturing company. The average annual efficiency recorded was 70.17%, while the sector benchmark stood at 90%, resulting in a gap of 19.83%. This situation led to an estimated economic impact of 42,866.06 PEN per year, equivalent to 6.93% of the company's annual revenue. Among the main contributing factors, unproductive time accounted for 64.85%, followed by rework in the sewing process at 18.33%, and other causes at 16.82%. The root causes associated with these issues were concentrated in three critical areas: machine failures, responsible for 34.29% of productivity losses; delays caused by the search for materials, parts, and tools, which accounted for 30.55%; and inadequate work methods, with a contribution of 18.33%. These findings revealed a production system affected by disorder, technical failures, and lack of standardization, reinforcing the need to design an improvement model based on Lean and TPM tools.

C) Validation Design

The proposed production model, which integrates Lean Manufacturing and TPM tools, was validated through a four-month pilot implementation in a small garment manufacturing enterprise. The model aimed to increase sewing process efficiency by applying three core practices: 5S to improve workplace organization, work standardization to reduce variability, and autonomous maintenance to minimize unplanned machine stoppages. A structured plan guided the intervention, and results were monitored using a data-driven approach to assess operational impact and economic viability. This validation process confirmed the model's relevance to performance improvement in resource-constrained production environments.

a. Introduction to the Implementation of the Model in the Case Study

Implementing the proposed model in the case study responded to the need to increase efficiency in the sewing process of a small garment manufacturing company in Lima, Peru. Like many other SMEs in the sector, this organization faced persistent problems related to unproductive time, frequent mechanical failures, and high rework rates. In response to this situation, a solution based on Lean Manufacturing and TPM tools was structured, prioritizing the cyclic approach of the PDCA (Plan-Do-Check-Act) cycle. Each stage of the model was designed considering the operational reality of the company, its limited resources, and the behavior of its production processes. The strategy progressively incorporated the 5S methodology to optimize workplace organization, the autonomous maintenance pillar to reduce machine failures, and work standardization to decrease operational errors and ensure production uniformity. This section describes in detail how each of these tools was developed and implemented and the criteria adopted to adapt the model to the specific characteristics of the short-sleeved shirt sewing process, identified as the most profitable product through an ABC analysis.

b. Planning: Initial Analysis and Preparation for the Intervention

The planning stage began with a diagnostic analysis that aimed to understand the operational challenges within the sewing process. The research team focused on identifying inefficiencies that limited productivity and quality rather than on pilot logistics or scheduling. The study revealed a predominance of non-value-added activities through field observation and process mapping, especially delays linked to machine availability and material handling. These inefficiencies were quantified using baseline performance metrics, showing an average process efficiency of 70.17%, significantly below the sector benchmark of 90%.

Three major categories of operational losses were identified: machine-related stoppages, disorganized workspaces, and inconsistent methods among operators. Each of these was addressed as a root cause of the low productivity observed. The team applied problem analysis tools such as cause-effect diagrams and ABC product classification to design an effective intervention. Based on profitability and frequency of production, short-sleeved shirts were selected as the focus of the improvement model. The planning phase concluded with the developing of a structured implementation plan tailored to the company's workflow and available resources and aligned with the operational characteristics and constraints identified during the diagnosis.

c. Implementation: Integration of Lean and TPM Tools

The execution phase focused on implementing three core tools—5S, autonomous maintenance, and work standardization—selected for their alignment with the root causes previously identified. These practices were applied sequentially and coordinated to enhance the system's responsiveness and operational discipline.

The 5S methodology was introduced as the foundational activity to organize the workstations and improve visual control. During this phase, unnecessary materials and tools were removed from the sewing area, storage zones were clearly defined, and visual labels were applied to enhance order. A cleaning schedule was also established to ensure consistent maintenance of the workspace. As a result, the time required to locate tools and materials was significantly reduced, directly addressing the 30.55% loss caused by disorganization. Employee participation was encouraged through training sessions and the creation of audit routines to reinforce the five principles: Sort, Set in order, Shine, Standardize, and Sustain.

Following the successful deployment of 5S, autonomous maintenance was introduced to mitigate the 34.29% of time lost due to machine failures. Sewing machine operators were trained to perform basic maintenance tasks such as cleaning, lubrication, and early detection of wear or damage. Simple checklists were provided to guide daily inspections, and visual boards were installed to track performance. The proactive maintenance strategy facilitated breakdown maintenance, lowered the incidence of emergency repairs, and enhanced the ownership and responsibility of the workers. Maintenance-free surveillance tasks were also added to the daily shifts without disrupting the production flow.

The final tool that was put into place was work standardization. This was to eliminate 18.33% of losses caused by inconsistent work methods associated with the sewing section. SOPs were created for every key stitching operation, and each workstation was equipped with visual work instructions. Apart from decreasing unwanted dependence on a particular operator, this also eased new employee integration through reduced training time. The standardization process also comprised setting up target cycle times and incorporating the concept of takt time for better workload distribution. In parallel, performance indicators were introduced to monitor compliance with the new standards.

The coordinated application of these three tools stabilized the sewing process and created a structured environment conducive to continuous improvement. The sequence of implementation was key to the model's effectiveness, ensuring that organizational changes preceded technical adjustments and that all actions were aligned with the specific inefficiencies previously diagnosed.

Figure 2 illustrates the five phases of 5S implementation: Seiri (Sort), Seiton (Set in Order), Seiso (Shine), Seiketsu (Standardize), and Shitsuke (Sustain). Each phase promotes organization, cleanliness, and standardization to improve workplace productivity, safety, and efficiency through visual control and structured employee participation.

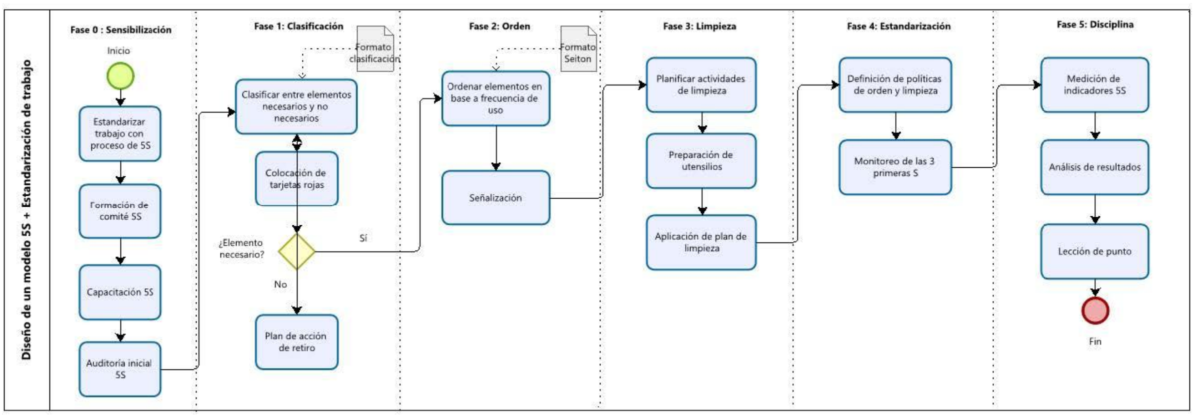

Fig. 2. Phases of 5S implementation

Figure 3 outlines the stages of implementing work standardization, divided into three phases: analysis of the current sewing process, process optimization, and standardization. It includes eliminating unnecessary transfers, balancing the line, adopting a modular system, and developing work instructions and time studies to enhance productivity and consistency in shirt manufacturing.

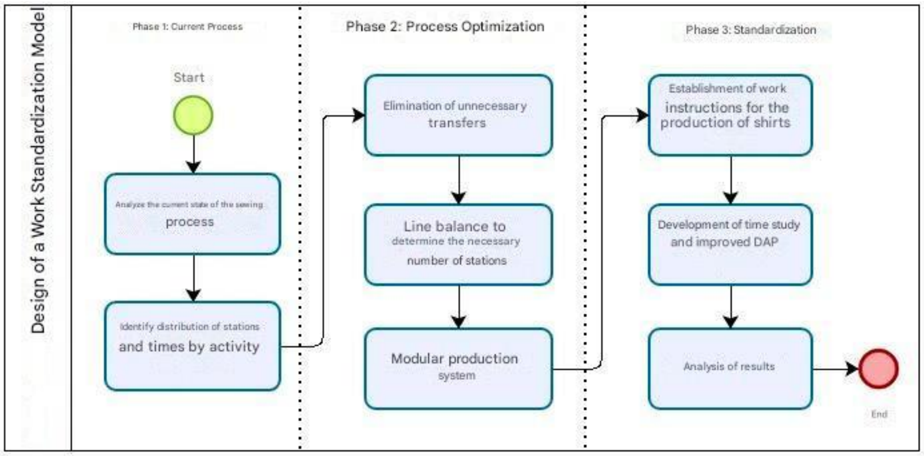

Fig. 3. Stages of the implementation of work standardization

Figure 4 presents the improved precedence diagram for the shirt-sewing process. It displays ten operations distributed across eight stations, each assigned to one operator. The layout reflects optimized task grouping and reduced transfer times, improving balance and efficiency throughout the line by implementing modular production and process standardization.

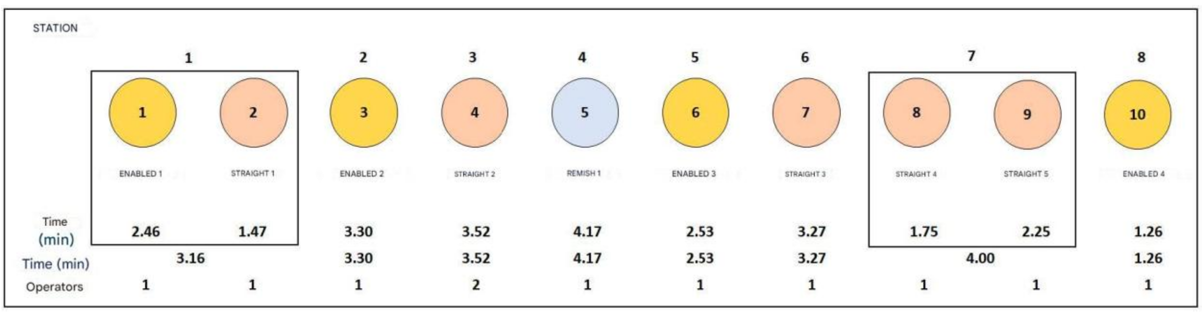

Fig. 4. Improved shirt sewing process precedence diagram

Figure 5 illustrates the design of the autonomous maintenance model, structured in three phases: initial inspection, training, and final inspection. It begins by assigning responsibilities and evaluating machine conditions. Then, staff receive training on autonomous maintenance. Finally, compliance with maintenance standards and indicator performance is verified to ensure sustained improvements.

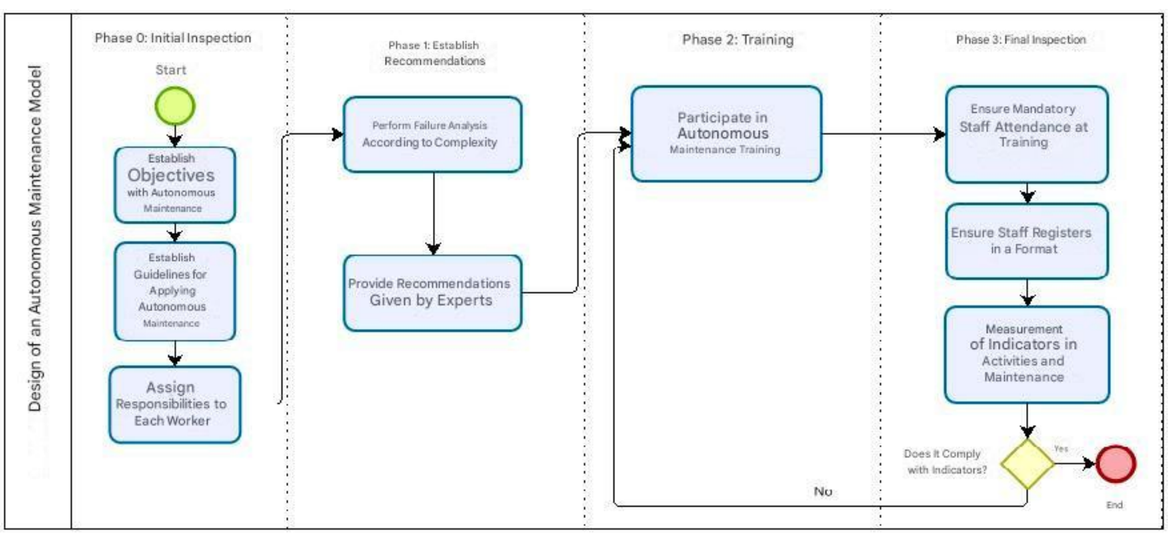

Fig. 5. Improved shirt sewing process precedence diagram

d. Monitoring and Evaluation of Operational Performance

Once the tools had been implemented, the focus shifted to evaluating the model's impact through a systematic monitoring process. Quantitative indicators were tracked to verify improvements in key performance areas such as equipment availability, work efficiency, process stability, and reduction of rework. The evaluation phase began by establishing baseline data collected during the diagnosis, which served as the reference point for comparison.

Efficiency, initially at 70.17%, was measured on a weekly basis and showed a gradual increase, reaching 80.10% by the end of the implementation period. This 9.93 percentage point improvement represented a substantial recovery in productive capacity. In parallel, the Overall Equipment Effectiveness (OEE) indicator increased from 56.21% to 68.21%, confirming gains in machine reliability and consistent performance. Rework rates, which had previously accounted for 18.33% of losses, were reduced to 11.11%, while time lost due to disorganization decreased from 11.58% to 8.00%.

These outcomes were shared and confirmed alongside management and sewing staff, thus strengthening the culture of evidence-based decision-making. Visual dashboards were designed to display updates and 'help' the operators understand their role in the organizational performance. Review meetings were held constantly to evaluate the indicators, assess the gaps, and motivate team members to think about the improvements. The simplicity and ease of understanding the graphical depiction of information heightened the efficiency of communication and, at the same time, equality and answerability within all the stages of production.

The effectiveness of the control process was not only in the numbers but also in the operator's work behavior. More discipline and increased responsibility for the work output were welcomed changes. The continuous improvement in all metrics showed the achievability in the operational setting and the initial presumed inefficiencies.

e. Sustainability of Improvements and Organizational Learning

The last step within the process of implementation dealt with reinforcing the gains that have been made and ensuring the sustainability of improvements for the long term. To this end, new standard operating procedures were established, and all documentation created because of the intervention was incorporated into the company's quality management system. Staff best practices and staff knowledge retention were achieved through a Continuous Training Program that was established to reinforce the institutionalized education vertically during the project's active phase.

Regular audits were conducted to sustain improvement and monitor the project's key performance indicators post-completion. These actions enabled the detection of deviations and timely corrective actions to be taken to avoid deterioration of results. Simultaneously, internal trainers were appointed to spearhead and guide the diffusion of the model and inculcate operational discipline as change agents in their designated areas.

Lastly, the technical outcomes achieved through the model enhanced the organizational mindset toward proactive learning and a dedicated work environment by deepening strategic alignment, initiative, and employee internal engagement with the company's interests beyond the immediate scope of their tasks.

To conclude, the sustainability phase served as the linchpin for continual improvement within the company's management system. It did not just address the lack of efficiency within the sewing operation; the model also provided a framework for sustained organizational growth and performed merit in overcoming forthcoming challenges.

D) Results

Table 1 presents the performance of key indicators after implementing the production model based on Lean and TPM tools developed to enhance the efficiency of sewing processes in garment manufacturing SMEs. The results showed a notable increase in Overall Equipment Effectiveness (OEE), rising from 56.21% to 68.21%, reflecting a 21.35 percentage point improvement. Operational efficiency also improved significantly, reaching 80.10%, representing a 14.15% increase compared to the baseline. Additionally, there was a considerable reduction in time lost due to disorder, which dropped from 11.58% to 8%, and the rework rate decreased from 40.39% to 25%. These variations confirmed the model's positive impact on process performance, validating its effectiveness in addressing the research problem and demonstrating its suitability for improving operational management in resource-constrained manufacturing environments.

Table 1. Results of the pilot

Indicator	Unit	As Is	To Be	Results	Variation
% OEE	%	56.21%	90.00%	68.21%	21.35%
% Efficiency	%	70.17%	90.00%	80.10%	14.15%
% Time Lost Due to Disorder	%	11.58%	7%	8%	-30.92%

% Rework	%	40.39%	18%	25%	-38.10%

V. DISCUSSION

Revisions in the improvement model yield results consistent with previous work on applying Lean and TPM tools in garment manufacturing SMEs. The 14.15% enhancement in efficiency and 21.35% increase in OEE parallel results reported by Sidhu et al. [5], Learn Conclusion that, underlines the importance of structured maintenance in preventing equipment failure. Also, the unison of 5S with the work standardization self-evidenced results by Divrik and Baykal [6] explain more order, less variability, and enhanced training with the application of these tools. In addition, the 38.10% reduction in rework achieved corroborates the results reported by Molla and Dunne [10], who describe the improvement in quality and consistent application of Lean techniques in textile processes.

Every study, however, has its limitations. The validation in one company single site case study design adds to these limitations, making it difficult to generalize the findings beyond a single setting. The short time frame of the pilot study does not allow for the evaluation of the sustained outcomes over time. In addition, uncontrolled external parameters, such as the demand for the product or materials needed, could bias the results.

Although these constraints exist, the findings are important for SMEs. The model proved useful in resource-poor settings because it stimulated employee participation and continually promoted improvement. The findings indicate that even small organizations can realize substantial value in their operations with coherent implementation.

To assess its generalizability, other researchers could test this model in companies with varying sizes and locations. It would be interesting to study the model's financial benefits and apply digital tools for data gathering and monitoring to strengthen the sustainability of the achieved improvements.

IV. CONCLUSION

The study validates that employing a production model rooted in Lean Manufacturing and Total Productive Maintenance (TPM) tools greatly optimizes the sewing process of garment manufacturing SMEs. The metrics show significant increases in operational efficiency and the availability of equipment, as well as large reductions in time lost because of disorganization and the rework rate. These results demonstrate the model's responsiveness to the distinctive challenges faced by small-scale production systems, particularly those with limited resources. The methodical execution of 5S alongside autonomous maintenance and standardized work leads to enhanced process, quality, and operator engagement.

This study emphasizes the usefulness of integrating Lean and TPM practices in a singular adaptive framework, the PDCA cycle, as a hands-on approach to facilitating performance improvement. The model aligns operational gains with personnel behavioral change by simultaneously achieving culture work and technical interventions. The research attempts to pragmatically address the need for more comprehensive improvement frameworks in SMEs with limited consulting service access due to cost considerations.

The primary impact is the adaptation of the definitions of industrial tools to a model focused on a sector that, despite its significance, lacks adequate scholarly attention. The model is well-founded and replicable, increasing its appeal to those in academia or industry focused on the nexus of ongoing advancement and operational strength or resilience. Additionally, it fills an identified gap in applying Lean-TPM techniques to small-scale textile enterprises in Latin America, providing tangential proof of their applicability and usefulness.

Additional research should focus on implementing longitudinal designs to study the sustained impact of the improvements over time. Its expansion in application to a wider range of production lines or different companies would increase the model's rigor. Furthermore, incorporating automated systems for real-time observation could improve model adaptability to active settings, increasing precision and control responsiveness to changing operational conditions.

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