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Original Article

Implementation of Lean-TPM Strategies to Improve Sewing Efficiency: A Case Study in a Peruvian Garment Manufacturer SME

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Abstract *- Peru's garment manufacturing industry faces significant operational inefficiency challenges, characterized by disorganized workplaces and frequent machine breakdowns. This study addressed these issues by implementing a production model combining Lean Manufacturing and Total Productive Maintenance (TPM). Key tools such as 5S, work standardization, and autonomous maintenance were employed to enhance productivity. Results showed an 11.73% improvement in sewing efficiency, a 16% reduction in cycle time, and a 54% decrease in machine breakdowns. These findings highlight the model's potential to boost competitiveness and sustainability, offering valuable insights for SMEs in similar contexts and inviting further research.*

Keywords *- Lean manufacturing, Standardization, Autonomous maintenance, Textile industry, SMEs.*

1. Introduction

The garment industry, especially in terms of small and medium-sized enterprises, is important to the world economy. There is a high level of labor and value addition in the countries within this industry, and it is also an engine for growth for many developing countries. In Latin America, small and medium-sized garment manufacturers' employment and poverty alleviation contributions are significant and become the backbone of the local economy [1]. In Peru, the clothing industry is not only an economic activity but also portrays the culture and nationality of Peru. Per the Ministry of Production, SMEs in the textile and clothing sector create thousands of jobs and are an important player in the industry in terms of the export of goods [2]. These companies are very important, but they have great challenges that affect their capacity to grow and be competitive in the international market.The most important issue that small and medium-sized garment manufacturers face is their production processes, marked by low operational efficiency. Such inefficiency is evidenced by accumulated debris at the workstations, which makes production slow and increases incidences of work-related injuries and diseases among employees [3]. In the absence of standardized systems in the operations, standard procedures cannot be adhered to as job practices will differ and errors needing correction will occur[4]. Furthermore, poor care and maintenance of the sewing machine, such as lack of adequate lubrication and cleaning or wrong settings of the attachments, will cause equipment breakdowns and adversely impact the end product's quality [5]. Such issues reduce output and affect the workers' morale and the working environment [6]. Many of these issues need to be addressed to enhance the competitiveness and sustainability of SMEs in the apparel sector. The adoption of strategies like Lean Manufacturing, as well as Total Productive Maintenance (TPM), can be instrumental in achieving this goal. Lean Manufacturing aims to eliminate waste and make continuous improvements, which might enable SMEs to make the best use of their operational capabilities [2]. On the other hand, in TPM, the workers maintain the machines on a self-sustaining basis, which enhances the reliability and availability of the equipment [7]. The synergistic effect of these techniques can increase output and enhance the safety and healthiness of the working environment, which is fundamental to the viability of these firms in future generations [8]. Despite the importance of these approaches, there is a significant gap in the literature regarding implementing specific Lean Manufacturing and TPM tools in small and medium-sized garment producers. Most work has been devoted to large firms or other industrial branches, meaning that SMEs are left unsupported in their attempts to put these practices into use efficiently [2]. This research addresses this concern by proposing a production model that blends certain tools of Lean Manufacturing, specifically 5S and work standardization, with the Autonomous Maintenance pillar of TPM. This model will give a blueprint for enhancing business performance and as a reference point for other SMEs in the clothing manufacturing industry with similar issues [9].

Finally, the garment industry, in particular through the lens of small and medium-sized enterprises, is an important industry with many challenges in terms of operational efficiency and sustainability. The adoption of Lean Manufacturing and TPM methodologies can help in solving these problems by not only enhancing productivity but also enhancing the livelihoods of the employees. However, more studies must be conducted in this area so that SMEs can obtain the resources and abilities required in the competitive market.

2. Literature Review

The Literature review about garment manufacturing SMEs' application of continuous improvement methodologies is important since it sheds light on how these practices can improve their processes and competitiveness. Five prominent methodologies will be discussed: Lean Manufacturing, Standardized Work, 5S, Total Productive Maintenance (TPM) and Autonomous Maintenance. It is worth noting that each approach has effectively enhanced production efficiency and limited wastage in the clothing industry and other industries.

2.1. Lean Manufacturing in SME Garment Manufactures

Lean Manufacturing is centered on eliminating waste and improving processes pertinent to small and medium scale apparel companies in a competitive market. Studies indicate that the integration of lean methodologies leads to great operational efficiency and raises the level of customer gratification. For instance, Potjanajaruwit [10] revealed in his research that SMEs that embrace the practice of lean can increase their productivity and minimize their operating costs. Furthermore, evidence shown by Johnson and Schaltegger [11] indicates that the infusion of Management systems techniques such as Lean in SMEs resolves issues like resource deficiency and process inefficiency. Incorporating lean manufacturing also boosts firm repositories of practice since it breeds improved processes that rectify practices within the lean culture, which has great short- and long-term benefits for the survivability of these firms[11].

Moreover, Johnson and Schaltegger's research shows that, in order for SMEs to adjust to the present market demands, integrating sustainability management tools, which are normally in line with Lean, is critical for them. Lean implementation has also effectively reduced cycle times and improved product quality, which is important in the clothing industry as speed and quality are major determinants of success. Lean methodology is therefore not only understood as a solution to operational and managerial efficiency but also as a strategic tool more capable of affecting the culture of small and medium-sized garment manufacturing enterprises.

2.2. Standardized Work in SME Garment Manufactures

The next concern as dai-ott one turned to small and medium-sized garment industries is standard garment making. This approach involves creating standard operating procedures that help ensure consistency and quality in production. Wang et al. [13] suggested that with standard operating procedures in Grips for all workers, there is less variation and a higher likelihood of good outcomes for the final product. Studies by Legg et al. [14] in the United States have also confirmed that setting working standards can improve operational safety and performance in this sector. Furthermore, standardized work enables companies to identify and eliminate inefficiencies in their processes, which is key to competitiveness in an ever-changing environment [15].

Moreover, this is further supported by Mbah and Obiezekwem [16], who argue that greater standardisation improves efficiency in processes and the 'most' important aspects of employee training in the clothing industry, where workforce changes are widespread. This also leads, in many cases, to the reduction in the cost of operation by having trained staff. Instead, it is a factor in the general management policy of the SME sector. To summarise, working constituencies indeed represent a great potential for improving small and medium sized garment industries since they provide the potential for improvement in all aspects of processes.

2.3. The Portrayal of Methodology 5 S in SMEs

Fifth-S methodology forms part of the fundamental principles of workplace appearance in the small and medium scale clothing manufacturing industry. This promotes a cleaner and safer work environment and minimizes the time wasted searching for tools and materials. In their research, Witjes et al. [17] suggest that 5S implementation can greatly enhance the productivity and morale of employees. In addition, the research done by Alves and Medeiros [18] suggests that adopting 5S in micro and small enterprises would also increase eco-efficiency, which is pertinent in the sada garment manufacturer anticipating the emergence of a conceptual model. The methodology has also been claimed to improve product quality as employees work in a neat and organized atmosphere where they can focus on their tasks better [18]. In addition, the Torugsa et al. [15] study also shows that using 5S could improve the potential for using other settled procedures of continuous improvement enhancing results. It, therefore, follows that 5S is not only the employment of space organizations but also enhances the intensity of continuous improvement strategies in small- and medium-scale clothing manufacturers.

2.4 Together with the Above, Total Productive Maintenance (TPM) in the Context of SMEs

Total Productive Maintenance, or TPM, aims to increase the equipment's efficiency with the least time lost. In the case of small and medium–sized garment industries, machines and equipment always have to be in working order, and TPM is one of the tools that assist in that. The research of Dušak and Jelačić [19] revealed that TPM practices positively influence maintenance and equipment modification costs, leading to lower maintenance expenses and increasing the availability of the equipment. Furthermore, the research done by Soliman et al. also outlines that TPM ensures that all employees contribute towards the maintenance of the equipment, which translates to ownership and more commitment from the staff [20]. Particularly, TPM practices have also been said to positively impact product quality since properly maintained equipment reduces the number of defective items produced [19]. Additionally, due to the work by Ortiz-Avram et al. that advances the chances of increasing the popularity of the private sector, TPM should be widely adopted as sustainable waste to energy solutions can contribute to waste minimization and energy efficiency [21]. Therefore, it is demonstrated that TPM is necessary for small and medium enterprises that deal in garments to enhance their operational level and competitiveness.

2.5. Autonomous Maintenance in Small and Medium-Sized Enterprises

Autonomous maintenance, from the word autonomously, is an approach that encourages operators to take charge of and maintain the upkeep of their equipment. This methodology is particularly relevant in small- and medium-sized garment manufacturers, where staff training and engagement are essential for success. Xia [22] conducted a study claiming that autonomous maintenance increases operational efficiency and reduces operational costs. Besides, Karadag's research supports this claim by suggesting that this strategy promotes a culture of continuous improvement since the employees become part of the maintenance process [23]. As autonomous maintenance has access to the significant blame, some of the employee satisfaction and improvement in employee morale are achieved due to the sense of ownership that is bestowed on them over their work and tools. Further, Nazarenko and Yalian [24] indicate that this approach could increase customer satisfaction since well cared for apparatuses produce better quality items. All in all, autonomous maintenance is introduced as an improvement strategy for small and medium-sized garment manufacturers to enhance production, competence, and quality consistently. To conclude, using Lean Manufacturing techniques, standardized work, 5S, TPM, and Autonomous Maintenance within the garment confectionery SMEs enhances the firm's operational efficiency and instils continuous improvement and sustainability within its management philosophy. These strategies are essential for the concerns of the SMEs in a liberalized economy and their survival in business in future.

3. Contribution

3.1. Proposed Model

Figure 1 shows a model aimed at improving the efficiency of sewing operations with Lean Manufacturing and Total Productive Maintenance. This model was structured to address the identified issues in the system, such as poor housekeeping, losses, and unanticipated downtimes of the machines. The 5S, Set in Order, was the first aspect of the model that fostered a conducive working environment for the succeeding main strategies: work standardization and autonomous manufacturing. Work standardization encouraged consistency of the actions irrespective of the worker and, therefore, less variability and continuity of activities. At the same time, basic maintenance actions performed by the operators themselves increased machine readiness and reliability. As such, the model sought to change critical inputs of the system into desired outputs, such as increased production efficiency ranging from reduced breakdowns and operational costs, which supported the objectives of the case study and its tenets of continuous improvement and resource productivity.

3.2. Model Components

3.2.1. Incorporating the Proposed Model into Practice: Rationale and Aims

The model relates to providing quality sewing works in industrial settings by applying lean approaches and Total Productive Maintenance (TPM) as the sixth point of the model. The model was developed to give tactical directions to resource management, processes, and highly inefficient systems, such as poorly managed workplaces, downtimes, and machine malfunctions and breakdowns, and to improve the desired transformation in resource management and process performance. S also highlights the potential to integrate other complementary strategies, such as 5S, work standardization, and autonomous maintenance, which have been shown to reduce waste and improve efficiency. In addition, this method also aids in strengthening the existing body of knowledge by integrating the operational side of management with process-oriented instruments and technologies, making necessary adjustments for specific areas and production environments possible.

3.2.2. Principles of 5S Methodology: The Basis of the Model

Within the framework of the model, the 5S was in charge because it established the required degree of tidiness within the workplace. This approach concentrated on five steps: sorting, organizing, cleaning, standardizing, and sustaining, with the main objective of reducing waste and improving the workflow. This sorting step entailed discarding as much as all the non-essential items in the space, ensuring that only the bare minimum of resources was left in the working area.

Next is the second stage, scheduled to commence after the first stage, which involves arranging the workbench and tools to reduce unnecessary downtime and motion. The goals aimed to eliminate dirt and cleaning in the third stage of work. This promoted the improvement of the aesthetics of the workspace and made detecting potential or real faults on the equipment easier, which would suffice preventive maintenance interventions. The achievements obtained in the existing stages were at this stage reinforced by the endorsement of straightforward and simple duplication of measures and practices, as well as a lot and constant of quick training and supervision that made it possible to put it into practice.

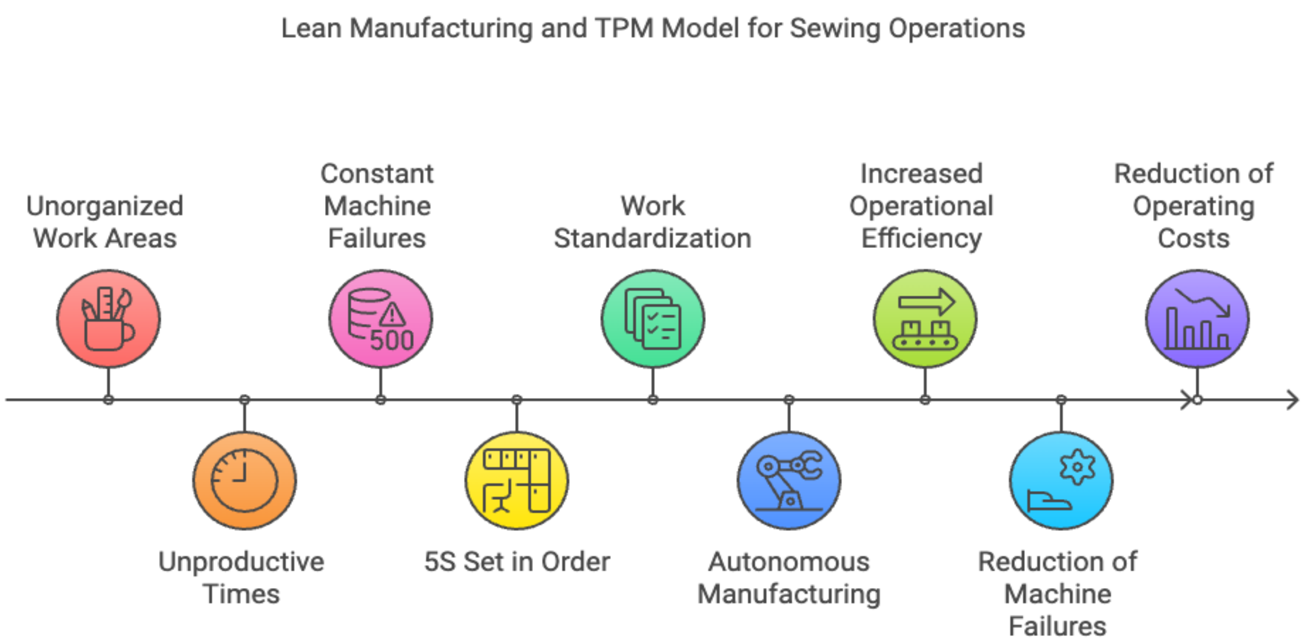

Fig. 1 Proposed model

3.2.3. Work Standardization: Achieving Uniformity and Consistency in Processes

Regarding this model, it seems that both work standardization was essential in reducing process adjustment and lifting the performance level of the nurse who could take care of this issue. It appears that a detailed analysis of each activity accompanied this carried out during the sewing cycle, as well as a definition of the best methods of sewing them and discarding any activities that were a potential waste of time at best. They developed operational manual requirements such as charts and long sentences to help employees better understand and perform the assigned task. In this way, standard times were also established for the various activities to facilitate better management and planning and detect any abnormality in performance. This stage also provided staff training to ensure that every single operator comprehended and was able to execute the stipulated work standards, thereby making the work environment homogeneous and significantly reducing the number of errors made.

3.2.4. Autonomous Maintenance: Determining an Operator's Role

The operator's responsibilities were key in allowing equipment to be functional and preventing machines from stopping. Autonomous maintenance involves sparing the operators some level of equipment care and ownership by assigning them basic cleaning, lubrication and inspections. At the initial stage, emphasis was placed on recognizing the first signs of problems and performing basic activity upkeep. Such conditions eliminated the need to purchase these for downtimes of operation as the life span of machines was increased and the operators' motivation and engagement levels were satisfactory.

3.2.5. Follow-Throughs of the Model: Cross-Cutting Solutions to the Issues Identified

This diagnosis and the different phases outlined in the previous paragraphs are fully carried out to address the basic concerns. First, the 5S method of closing barriers ensured the work allocation's efficacy in the designated areas. Second, effective searching for someone who appears to have spent time but is not working because he cannot locate the required tools and materials was simplified by ensuring every item was endowed with an easily identifiable location. Finally, to alleviate the unforeseen disruptions and enhance the uninterrupted running of the processes, the non-utilization time of the equipment due to repairs was minimized through the integration of autonomous maintenance and preventive maintenance, whereby the equipment was kept operational as much as possible.

3.2.6. Expected Impact of the Model: System Outputs

As expected, the model included re-engineering vital system inputs and achieving the desired results. The expectation was to improve operational efficiency, reduce machine breakdowns, and lower operation costs. On top of that, these changes will increase the efficiency of the processes, competitiveness, and sustainability in the future. Such a fact also made it possible to carry out further steps to implement the improvement tools, which shifted the company's attention towards its efficiency.

3.2.7 Conclusion: A Comprehensive and Sustainable Model

The model that has been constructed could also be described as an integrated and green solution to the operational problems encountered during the seaming operations. It addressed the root causes of the waste by applying Lean Manufacturing and Total Productive Maintenance with the supporting tools of 5S, Work Standardization and Autonomous Maintenance. This method enhanced the efficiency levels of procedures and buffered the possibility of ensuring adaptation to other operational settings, thus improving operational management approaches and making formulating better and more competitive processes within the industry possible.

3.3. Model Indicators

Specifically, specialized metrics were developed to assess the impact of the lean and TPM-based production model for garment manufacturers and SMEs. These metrics were designed to monitor and evaluate performance throughout the case study, providing a solid foundation for analysing critical aspects of the garment manufacturing process within an SME environment. This systematic approach facilitated an in-depth review of key performance indicators. This comprehensive evaluation ensured effective monitoring and supported the continuous improvement of processes within the SME.

Sewing Efficiency: This indicator measures the ratio between actual production and the standard production capacity. It evaluates how effectively the resources are utilized in achieving the planned output, highlighting areas for productivity improvement.

$$E = \frac{\text{Actual Production}}{\text{Standard Production}} \tag{1}$$

Cycle time calculates the average production time per unit by dividing the total production time by the number of units produced. It serves as a key indicator for identifying delays and optimizing workflow.

$$TC = \frac{\text{Production Time}}{\text{Number of units Produced}} \tag{2}$$

Number of Frequent Breakdowns: This indicator summarises breakdowns during the sewing process. It identifies recurring machine failures, providing a basis for maintenance strategies to enhance equipment reliability.

$$Number\ of\ breakdowns = \sum (Breakdowns\ in\ the\ sewing\ process) \tag{3}$$

4. Validation

4.1. Validation Scenario

The validation scenario was carried out in a case study of a Peruvian micro-enterprise in the apparel manufacturing industry. This organization specializes in producing garments for children and adults, focusing on high selling items like jackets and sets. Production depends on overlock and straight stitch. The two identified bottlenecks due to workflow inefficiencies created by poor workspace layouts and lack of work standardization. The enterprise did not have preventive maintenance plans for their machines or for running a cleaning schedule, and hence, many machine breakdowns were the order, increasing the amount of idle time between jobs. The objective of the investigation was focused on addressing these and other issues by introducing Lean Manufacturing tools, especially the methodology of 5S, autonomous maintenance, and work standardization, as well as organizing the operators through training and continuous improvement of processes. This was to increase productivity while decreasing costs while maintaining a clean and well-structured production order.

4.2. Initial Diagnosis

The diagnosis carried out during the case study established that the level of efficiency of the sewing process operating at a current level of 73.91% is considerably far from the target industry value of 83.08%. This problem caused a maximum economic factor of 45,056.77 PEN, 3.59% of the total annual sales expected in 2023. Among the identified parameters, the delay in the sewing process was the problem that constituted 74.91% of the total delay, and this was caused by time spent looking for lost tools caused by a disorderly working environment (17.45%) and lack of proper ways to do the task (57.46%). Also, the breakdown of machines accounted for 16.72% of factors due to lack of proper maintenance, including cleaning, lubricating and changing necessary parts in 100% of the cases analysed.

Other causes, such as rework, which was responsible for 8.36%, made this the primary cause of inefficiency in the process; thus, there are some potential areas for tactical and strategic changes. This provided a quantitative and qualitative description of the problem, detailing the factors that should be addressed in the future to ensure efficiency and generate more revenue.

4.3. Validation Design

A pilot validation method was employed to validate the proposed model, which integrates Lean Manufacturing and Total Productive Maintenance (TPM) tools. Its implementation lasted four months in the case study, encompassing all the proposed techniques. These included the 5S methodology, autonomous maintenance, and work standardization. Each of these tools is detailed below. The study aimed to put a model into practice to target the unreliability of the sewing operations of a garment producing Peruvian micro-enterprise. This model combined principles of recognition of TPM maintenance with Lean Manufacturing techniques to ensure total killing of any possible losses that might hinder production. The approach dealt with major concerns related to lean operations: lack of procedure standardization, chaos in the working environment, and poor internal care of equipment. By extensively using Lean techniques, the model sought to improve operational practices and create conditions for improvement in all organisational management areas.

4.3.1. Key Diagnosis – Issues that Need Solution

The process commenced with a thorough audit of the 5S methodology to evaluate the starting state of the workplace. These problems included littered tables and desks, nonpermanent structures for tools, and various means for carrying out the same task. These outcomes demonstrated the necessity for a programmatic approach to implement change in the processes being performed and enhancing the basis for positive new cycles.

4.3.2. 5S Commission Setting Up: Management and Management

A dedicated 5S commission was developed, specifically promoting the Lean approach. Most of the tasks assigned to this team involved arranging activities, controlling activities, and seeing that all practices employed were consistent with the design objectives in the model. In addition, the committee's responsibilities included conducting training, implementing procedures, and working as a team to improve processes.

4.3.3. First "S": Sorting out What is Not Needed

The goal of the sorting phase was to remove all unwarranted objects within the workplace, which would reduce wasted space. Tools and materials were assessed for their state, relevance to production processes, and safety. Non-necessary items needed to be accessible, and functional equipment was either thrown away or dispossessed in another area. This phase helped to declutter the workspace and provided readiness for the following stages.

Fig. 2 Seiri's current situation

Fig. 3 Implementation of seiri

Fig. 4 Seiton's current situation

Fig. 5 Implementation of Seiton

4.3.4. Second "S": Setting out the Workplace

The second phase concentrated on reducing excessive movements by reorganizing the materials and tools used to reach out for them. The station's work was modified according to ergonomics, usage frequency, and visualization. Appropriate labelling and storage spaces also made it easier and faster for the operators to find what they needed. This arrangement greatly facilitated business processes, minimizing time wastage.

4.3.5. Third "S": Cleaning and Autonomous Maintenance

It was essential to keep a dimension tidy and independently clean within scope to prolong the machines' lifecycle, so this phase centered on upkeep. Thus, operators were identified to self-perform daily clean-up activities and other self-operational tasks such as lubrication and routine check-ups. This created a scenario where the employees took care of their machines, which reduced unplanned downtimes and increased machine availability.

In addition, routine cleaning practices lower the immediate sources of dirt and something even more so contamination, thus enhancing the reliability of workings more so in operations. Table 2 outlines an autonomous maintenance plan comprising three stages: cleaning and inspection, removal of FS and LDA, and lubrication. It details specific steps and associated activities like cleaning, identifying oil leaks, and performing lubrication checks alongside their frequencies, ranging from daily to monthly. The plan ensures optimal equipment functionality. Table 3 describes the autonomous maintenance plan for the overlock machine, encompassing stages of cleaning and inspection, removal of FS and LDA, and lubrication. It details steps such as cleaning surfaces, identifying anomalies, and ensuring proper lubrication. Activities include daily, weekly, and annual tasks, ensuring operational reliability and longevity.

Fig. 6 Seiso's current situation

Fig. 7 Implementation of Seiso

Table 2. Autonomous maintenance plan

Stage	Steps	Activities	Frequency
Cleaning And Inspection	Remove dirt	Remove the needle, presser foot, and needle plate	Daily
		Clean the tools and machine head	Daily
	Identify anomalies	Identify oil leaks	Daily
Removal Of Fs and Lda	Eliminate FS and LDA	Keep the work area clean and organized during the workday	Daily
		Perform cleaning at the end of the workday	Daily
	Review tasks	Review tasks for FS and LDA	Daily
Lubrication	High-frequency lubrication	Perform oil changes as per the manual	Monthly
	Check lubricant level	Ensure the marker is between HIGH and LOW	Daily
	Avoid leaks or contamination	Inspect the oil sight glass	Daily
	Visual control	Use the oil marker for verification	Daily

Table 3. Autonomous maintenance plan of the overlock machine

Stage	Steps	Activities	Frequency
Cleaning And Inspection	Remove dirt	Clean the external surface of the machine and the operation table	Daily
		Clean lint from the feed teeth	Daily
	Identify anomalies	Identify oil leaks	Daily
		Check if electrical components are loose or in their correct position	Weekly
		Inspect wear on the transmission belt	Annually
Removal Of Fs and Lda	Eliminate FS and LDA	Perform internal and external cleaning of the presser foot	Weekly
		Keep the operation panel clean	Weekly
		Perform cleaning at the end of the workday	Daily
	Review tasks	Review tasks for FS and LDA	Weekly
Lubrication	High-frequency lubrication	Perform oil changes as per the manual	Quarterly
	Check lubricant level	Ensure the oil level lies between the upper and lower marks on the sight gauge	Daily
	Avoid leaks or contamination	Inspect the oil sight glass	Daily
	Visual control	Use the oil marker for verification	Daily

Fig. 8 Seiketsu's current situation

Fig. 9 Implementation of Seiketsu

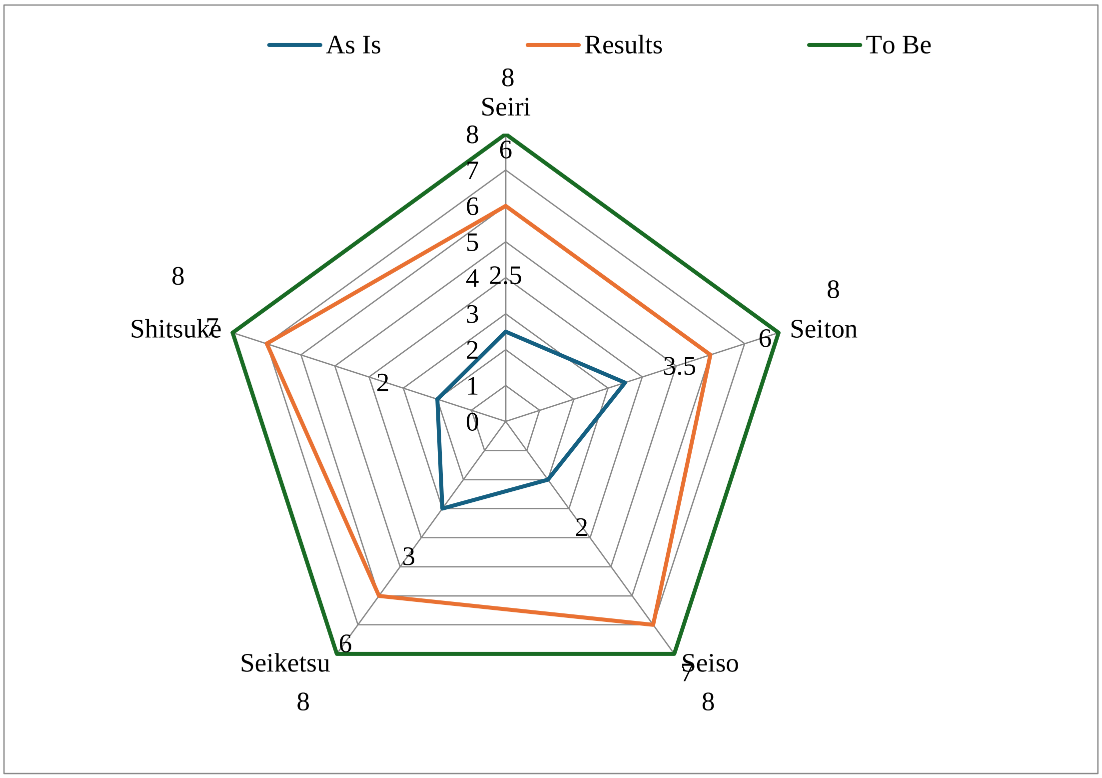

Fig. 3 Initial and final audit of the 5S methodology

4.3.6. Fourth "S": Standardizing Processes

This concept was important in the activities intended to counter check and control all the production activities. Detailed What, How and Why was done? Moreover, What do we expect next time? All these were documented stepwise as standard operational procedures. Maps and checklists were deployed to ensure operators adhered to the prescribed methods. As a result of eliminating repetitive movements and activities, the model improved efficiency and reduced the variability of the sewing operations.

4.3.7. The Fifth S: Sustaining Improvements

The last phase targeted ensuring the benefits realized by implementing the first four S's. Regular audits and follow-ups were conducted to ensure that staff complied with the management systems and recommended areas for further improvement.

The committee appointed also maintained the drive as it was actively involved in the processes and enhancing systems within the organization. This phase ensured its perpetuity and reconfirmed its relevance in the organisation's daily practices and processes.

4.3.8. Systemic Application of Lean and TPM Models

In what appeared to be organizational improvement efforts a step further, the organization did not stop at the 5S methodology; total productive maintenance practices also came into play. Autonomous maintenance schedules were drawn up, and each operator on a shift was required to perform hourly checks and preventive and corrective actions, including scheduled and ad-hoc maintenance. Such an approach has alleviated machine downtimes due to breakdowns and aided operators' comprehension of the machines' operational capabilities and potential. Maintenance plans were tailored for easy access to the specific needs of the fabrics and seam overlocks to offer the necessary treatment that reduced degradations and greatly elevated productivity.

4.3.9. Focus on Outcomes

Implementing this multi-faceted approach produced concrete results for the case study. Improving efficiency and establishing substantial maintenance and organizational policies enabled the company to significantly reduce cycle time, enhance machine availability, and increase the reliability of the processes. This holistic approach stressed the importance of integrating Lean and TPM principles in solving problems and achieving continuous improvement in the context of the garment industry's challenges.

4.4. Results

Table 1 highlights key results in applying the lean and TPM production model in the case study. Sewing efficiency improved from the initial value of 73.91% to 82.58%, approaching the proposed target, thanks to the standardization of working methods and the application of the 5S methodology. Cycle time for straight and overlock seam operations shows significant reductions, with an average time decreased from 16 minutes to 13.52 minutes for overseam and from 15.92 minutes to 13.38 minutes for the straight seam. This represents a reduction of almost 16% in the total cycle time. In addition, the number of breakdowns decreased due to the implementation of autonomous maintenance, achieving a reduction of more than 54% for both types of seams. This improvement allowed for fewer interruptions and increased availability of sewing machines. These results demonstrate the effectiveness of the proposed production model in addressing initial challenges and increasing the operational efficiency of the case study.

Table 3. Results of the pilot

Indicators	As-Is	To-Be	Results	Variation (%)
Sewing Efficiency	73.91%	84%	82.58%	11.73%
Cycle Time Sewing Overlock	16	14	13.52	-15.50%
Cycle Time Sewing Straight	15.92	14	13.38	-15.95%
Number of Frequent Breakdowns - Sewing Overlock	37	19	17	-54.05%
Number of Frequent Breakdowns - Sewing Straight	11	6	5	-54.55%

5. Discussion

The use of Lean Manufacturing and Total Productive Maintenance (TPM) in a Peruvian textile microenterprise signifies a notable enhancement in process optimization for SMEs within the industry. Enhancements such as an 11.73% rise in sewing efficiency, a 16% decrease in cycle durations, and a 54% reduction in recurrent machinery failures underscore the capacity of these technologies to tackle prevalent industry issues, such as insufficient standardization and inadequate maintenance. In contrast to earlier research on large corporations, including the studies by Potjanajaruwit [10], Johnson, and Schaltegger [11], which highlight Lean's efficacy in minimizing operational expenses and improving sustainability, this case underscores its relevance in SMEs, a sector frequently overlooked in academic discourse. The lack of longitudinal studies constrains the comprehension of enduring benefits.

5.1. Study Limitations

This study is constrained by its concentration on a singular microenterprise, limiting its findings' applicability to other SMEs in diverse environments. Moreover, data gathering may be biased due to dependence on internal diagnostics and the absence of external validation.

The four-month implementation period may be inadequate to assess long-term effects, including permanent alterations in company culture or employee departure rates.

5.2. Recommendations for SMEs Based on Results

Commence with approaches like 5S and autonomous maintenance, as they yield scalable, short-term advantages. Highlight the enhancement of operator competencies to provide autonomous maintenance and standardization of tasks. Identify essential metrics, like sewing efficiency and cycle time, to systematically assess outcomes and modify techniques as needed.

5.3. Future Works

Analyse the enduring impacts of Lean-TPM integration on SMEs' financial and operational viability. Assess the influence of these approaches on analogous industries in developing nations. To enhance production efficiency, investigate integrating Lean methodologies with emerging technologies, including the Internet of Things (IoT). This methodology can improve comprehension of the transformative impacts of Lean and TPM, while simultaneously addressing existing gaps in the literature and assisting SMEs in pursuing enhanced competitiveness and sustainability.

6. Conclusion

The authors of the research claimed that the implementation of lean production and TPM as a production system has had a positive impact on operational performance when applied in a Peruvian textile microenterprise. Some highlights included improved sewing efficiency by 11.73%, reduced cycle times by 16%, and reduced machine failure occurrences by 54%. These improvements were achieved using key tools such as the 5S methodology, Standardized Work, and Autonomous Maintenance, which helped streamline processes and eliminate waste. The research asserts the need to incorporate continuous improvement approaches to the problems often experienced by Small and Medium Enterprises (SMEs). With such efforts as workplace organisation improvement and facility and equipment maintenance, the researchers noted that such efforts created increased productivity and improved working environment, guaranteeing the firm's continued growth. This paper expands the knowledge of the industrial engineering field by providing an applicable model that incorporates lean and maintenance practices to the issues observed in the textile industry. It also provides a reference for other SMEs in an identical situation and emphasizes the need to integrate traditional practices with application-oriented ones.It has been presented above that this model and its evolution need to be further investigated. As highlighted in the text, expanded future work might investigate how other lean tools, such as value-added analysis or kaizen, may deliver results. This perspective gives researchers and practitioners another aspect to consider concerning the model's flexibility and expansion, which can strengthen the competitiveness of firms in the manufacturing industry.

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