ESP IJSHMS
ESP International Journal of Science, Humanities and Management Studies
ISSN: 2583-9756 / Volume 3 Issue 2 April 2025 / Page No: 01-14
Paper Id: IJSHMS-V3I2P101 / Doi: 10.56472/25839756/IJSHMS-V3I2P101

Original Article

Lean-TPM Strategies for Defect Reduction and Productivity Gains: Evidence from a Garment SME Case Study

Brian Jesus Alejandro-Torres[1], Jose Luis Yarma-Rivera[2], Wilson David Calderón-Gonzales[3]
[1,2,3]*Carrera de Ingeniería Industrial, Universidad de Lima, Perú.*

Received Date: 05 February 2025 Revised Date: 01 March 2025 Accepted Date: 02 April 2025

Abstract: *The garment ma nufacturing sector in Peru faced persistent operational inefficiencies despite prior research highlighting the benefits of Lean Manufacturing and TPM principles. Previous studies, however, rarely addressed their combined adaptation for SMEs in developing economies. This research responded to urgent challenges such as production inconsistencies, high defect rates, and equipment neglect. A comprehensive production model was proposed, integrating 5S, standardized work, and autonomous maintenance. The model was validated through a four-month application in a Peruvian garment SME, resulting in a 60.52% reduction in overall defects and a 36.61% improvement in equipment effectiveness. These measurable improvements demonstrated that structured, low-cost interventions could significantly enhance SME competitiveness. Academically, the study contributed by adapting established operational frameworks to small-scale contexts, while socioeconomically, it strengthened SME resilience in volatile markets. Future research is encouraged to validate the model in broader settings and to explore digital enhancements that could further consolidate operational stability and drive sustainable development in the sector.*

Keywords: *Lean Manufacturing, Operational Efficiency, Textile Industry, SMEs, Process Improvement*.

I. INTRODUCTION

The garment manufacturing industry has been important to the world's economic development because it generates employment, innovation, and export revenue, especially in developing countries. This industry is largely made of small and medium-sized enterprises (SMEs), which make up almost 90% of businesses worldwide [1]. In Latin America, SMEs make up almost 99% of total firms, contributing over 60% of formal employment which makes their economic role vital [2]. Within this regional context, Peru is exceptional in that the textile and garment industry is one of the major contributors to the national GDP, and SMEs constitute nearly 95% of businesses in this sector [3]. Even with this prominence, Peruvian garment SMEs encounter significant barriers to effectively scaling their operations because of crippling inefficiencies and outdated production methods that reduce their competitiveness within the region and beyond [4].Garment SMEs face a plethora of problems, however, issues regarding leftover production inefficiencies stemming from a lack of cleanup, poorly maintained equipment, and missing standardization protocols are the most crippling. The cluttered and chaotic environments resulting from inadequate storage for tools and materials waste an excruciatingly large amount of time and increase the probability of making mistakes [5]. Alongside the absence of standardized procedures, which leads to product quality inconsistencies, increasing cycle times, and bottlenecks in training new operators, they face a multitude of problems. Research shows Peruvian textile SMEs are prone to constant shifts in production due to the lack of basic documentation outlining work guidelines and procedures that inevitably lead to subpar sewing standards and product drawbacks [6]. Sewing machine negligence is a commonly noted problem in SMEs, especially when it comes to crucial maintenance tasks like cleaning, lubrication, or machine accessory adjustment. The neglect heavily contributes to the reliability of the production, causing an influx of bears and subpar defect rates [7]. Charged inefficiencies are directly impacted by the operational output and the cumulative hidden costs erode the enterprises financial resilience.

The survival and growth of garment SMEs depend on addressing these production inefficiencies. Organizational and systematic inefficiencies pose serious barriers to bracing the evolving competition which needs high quality, swift delivery, and low cost. It has been documented that organized workplaces and standardized procedures improve production efficiency and product quality [8]. Moreover, the establishment of Autonomous Maintenance programs enables the implementation of proactive maintenance practices resulting in reduced machine downtime and improved production flow consistency [9]. If these garment SMEs persist with arbitrary production layouts, inconsistent methods of production, and maintenance cycles focused on problem resolution, their scale in meeting basic market requirements will always be limited. For economies like Peru, which heavily relies on the strength of their SME sector, the problem is not solely operational optimization but builds toward becoming economically competitive, which makes this issue highly urgent. Supported by deeper analysis, this reasoning begs attention as a precondition for enduring relevance and contribution, especially from the SMEs that drive vital Peruvian economic sectors.

Although these operational problems form the cornerstone for failure, there is a striking lack of attention given in the literature concerning the juxtaposition of Lean Manufacturing and Total Productive Maintenance (TPM) systems customized for garment SMEs. In the same manner, while Lean instruments such as 5S and Standardized Work have received some attention in the world of manufacturing, they are not as widely researched in small garment factories [10]. Also, TPM is considerably effective in large scale industrial contexts, but with little adaptation or application in SMEs, especially in developing countries. Most available literature either exclusively focus on Lean bound initiatives or maintenance exercises devoid of an integrated holistic perspective suitable for garment SMEs and their particularistic limitations and features. This lack of understanding creates an opportunity for capturing the multitiered issues of disorderly workspaces, process inconsistencies, and equipment maintenance reliability to enable enhanced efficiency in low-volume apparel production systems.

This study intends to address the gap in research by creating and testing a production model tailored for garment SMEs, incorporating Lean Manufacturing principles such as 5S and Standardized Work alongside TPM's Autonomous Maintenance. The model attempts to resolve the diagnosed causes of inefficiency in a stepwise manner: first, improving flow as well as waste removal through the organization of work areas (which maximizes utilization) and sharpens productivity on a machine-by-machine basis; second, lowering variability alongside defect levels via the introduction of standard operating procedures; and third, enhancing operational control during periods of low activity by shifting the burden of monitoring unscheduled downgrades on maintenance friendly configurations onto the operators themselves. Unlike prior research efforts, this study distinguishes itself by adopting a holistic perspective and developing an integrated solution that is easily within the reach of small firms in the garment sector, requiring minimal expenditure and undemanding advanced technologies. The research not only adds pragmatic value for the industry but also expands the scholarly discourse on the enhancement of operations in constrained manufacturing systems by validating the model in a Peruvian SME.

II. LITERATURE REVIEW

The materials and techniques section should include enough information to allow all operations to be replicated. If numerous procedures are presented, it may be separated into heading subsections. (Size 10 & Regular)

A. The Application of Lean Manufacturing Approaches in the Fashion Industry

In the manufacturing of fashion goods, Lean Manufacturing is considered one of the most important paradigms for streamlining the processes of production. The application of Lean tools in small and medium enterprises (SME) in the textile industry has been shown to enhance operational efficiency. The approach is rooted in value creation through waste reduction, maximizing customer satisfaction [11]. There are numerous studies that highlight the ways in which Lean Manufacturing permits operational modification by SMEs to cope with challenges of ever-increasing competition. For instance, it is known that the application of Lean Principles of Management (LPM) is important for both productivity and quality control in the fashion industry, thereby increasing the overall effectiveness of these firms [12][13]. One of the studies about the application of the Lean system in garment factories emphasized that the capacity to respond quickly to changes in consumer preferences provides considerable competitive advantage [13].

Research has also found that the application of Lean Manufacturing in the apparel industry helps promote organized and streamlined work processes through reduction of lead times and improvement of material flow [12]. The adoption of Kaizen and 5S champions more sophisticated approaches to systematized continuous improvement which has been greatly advantageous at the production level [14]. Furthermore, it has also been documented that the implementation of Lean affects productivity and strengthens working conditions, workers' health, and well-being [15].

Finally, it is important to mention that SMEs who have adopted Lean Manufacturing practices report enhanced competitiveness as well as a greater alignment to meet the qualitative demands from international clients [12]. While the methodology is originally defined for large scale application, it is also noted that the specific features of SME apparel manufacturers allow for customization which facilitates broader use [11][16].

B. Standardization of Work: Improvements in Efficiency

Its name suggests altogether different aspects, but The Standardized Work method aligns with principles of Lean Manufacturing and focuses on creation of work instructions for every position and attempt to minimize redundancy and variation. This approach has shown tangible results in improving operational efficiency in garment manufacturing SMEs [15]. Previous research suggests that standardization not only increases product consistency but also improves the morale of workers by providing clarity and a defined structure in their daily tasks [14].

In addition, the implementation of Standardized Work aids in the refinement of production steps through the identification and elimination of non-value-adding activities, which greatly enhances cycle times [15][14]. A detailed study on the adoption of this technique in clothing factories reported that standardization leads to reduction of errors and rework, considerably improving the quality of the final product [14]. The benefits of standardized work are not only limited to the production floor but also extend to the training of new hires where the process becomes faster and less susceptible to novice mistakes [15].

It must be noted that for this approach to achieve long term success, it must be accompanied by an organizational commitment. Alongside defining working methods, an effective monitoring system has to be in place for the maintenance of automation, as well as for practice modification loops [14]. With the defined standard, creating a culture of improvement makes it possible for the SMEs to enhance their productive performance and enables their operations to change as per the market demand [15][14].

C. 5S Implementation - Organization And Efficiency

5S is cited as one of the powerful Lean Manufacturing tools, particularly for SMEs. As an element of Lean Manufacturing, 5S centers on efficiency of a workspace, waste elimination, and constant improvement. In the clothing sector, it has been studied that through 5S implementation, industries have managed to not only tidy up the facilities but also improve the hygiene and create a safer working environment to high standards [15]. Furthermore, other Lean tools can be built upon 5S, making it easier to improve the entire system [17].

Using 5S increases not only the efficiency of operations, but also positively contributes to behavioral and organizational culture change in the workplace [14][18]. An orderly and clean working environment contributes to employee commitment and satisfaction, which in turn improves productivity [19]. Moreover, 5S training enables workers to claim ownership and responsibility toward their work environment, which is critical in establishing a continuous improvement cycle [19].

The challenges concerning the application of 5S in the apparel industry are well-known. Senior management must be fully committed and participate actively for the sustainability of the methodology to be ensured [12]. It has already been shown that, without sufficient organizational backing, implementation is likely to become superficial and not meet expected outcomes [20]. Hence, it is advised that SMEs should not use 5S in isolation but rather incorporate it into a broader system in Lean Manufacturing [17].

D. Total Productive Maintenance (TPM): An Ongoing Improvement Strategy

Total Productive Maintenance (TPM) has emerged as one of the vital methods for effectiveness optimization among small and medium enterprises (SMEs) in the textile industry. This approach allows for engaging every employee in working at all levels with machines, with the aim to enhance their performance and minimize downtime [20]. It has been established that the implementation of TPM focuses on the reduction of downtime suffering due to mechanical faults and the inefficient spending during the operation within the fashion industry [12][13]. Research has confirmed that companies adopting TPM experience a significant improvement in their operational efficiency and a reduction in costs associated with corrective maintenance [20]. This has a direct effect on the responsiveness of the market and the quality of the product, which increases the competitiveness of SMEs in a global environment [21]. Implementation of TPM encourages a preventive and proactive culture at the employee level because the workers who operate the machines share the responsibility of equipment upkeep [20].

Despite its benefits, the challenge of implementing TPM lies in the need for an organizational cultural change. To make TPM effective, employees need to be trained on the use, care, and custodianship of the equipment [20][21]. On the other hand, it is necessary to define clear criteria to measure the impact of TPM on productive performance, so that the SMEs can make the required adjustments and informed decisions regarding the management of their resources [20].

E. Autonomous Maintenance: Empowering Employees

As far as Lean Manufacturing is concerned, Autonomous Maintenance allows operators to be proactive with the care and maintenance of the machines that are assigned to them. In the case of SMEs, it has been shown that by empowering employees to be responsible for their own equipment they reduce downtime, raise production quality and improve market competitiveness [22]. This has a positive impact not only on productivity but also on the morale of employees, as they perceive themselves to be active agents in changing their environment [23].

Several studies suggest that the use of Autonomous Maintenance in garment factories may lead to a noticeable increase in operator awareness of machines, leading to early detection of potential failures [12]. The benefits of this practice are limiting production stoppages and increasing safety at work [21]. It helps employees psychologically by eliminating major inconveniences and encouraging a culture of constant self-improvement, where they devise how to optimize production [13].

However, the implementation of Autonomous Maintenance requires a complex training strategy and profound organizational changes. The lack of training on these new approaches and the necessary tools take power away from the workers who are delegated these functions in the exercise, therefore resources must be applied [12]. The resistance to change that some of these workers face can be a challenge, so it requires leadership in support of these initiatives to ensure that Autonomous Maintenance practices are taken up vertically across the organization [15].

III. CONTRIBUTION

The materials and techniques section should include enough information to allow all operations to be replicated. If numerous procedures are presented, it may be separated into heading subsections. (Size 10 & Regular)

A. Proposed Model

Figure 1 shows the production model developed for a small and medium-sized enterprise (SME) in garment manufacturing that leans toward Lean Manufacturing and Total Productive Maintenance (TPM) principles. The model arose strategically considering persistent irregularities for the asymmetric fabric cut, stains on garments, and open seams or loose threads. To mitigate these challenges, the model focused on three synergistic strategies: firstly, the application of the 5S framework to enhance workspace structure and cleanliness; next, minimizisi ng variability in task execution through standardized work; and lastly, enhancing operator engagement in equipment maintenance by promoting autonomous maintenance more actively to improve their technical skills. This model effectively integrated other continuous improvement frameworks aligned with sustaining operational endurance, loss mitigation, high product quality, and the dynamic production system of the company.

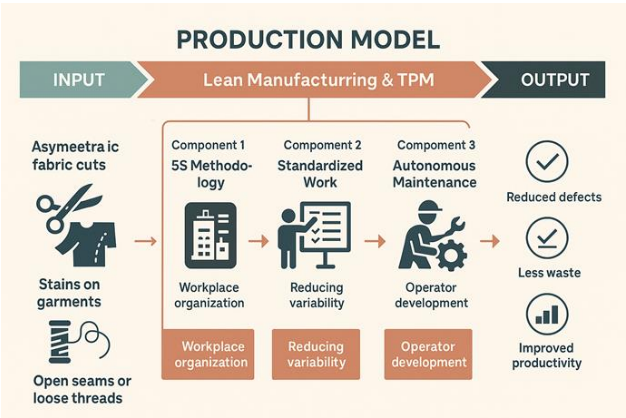


Figure 1 : Proposed Lean-TPM Production Model

B. Model Components

The need for competition in the garment manufacturing industry compels small and medium-sized enterprises (SMEs) to refine their processes for quality, efficiency, and market responsiveness. In this regard, a production model is developed to implement Lean Manufacturing and Total Productive Maintenance (TPM) in synergistic fashion in order to strengthen SME operational performance in garment manufacturing. This synergy focuses on waste elimination in production as well as ager reliability maintenance, two primary elements enabling consistent advancements within smaller manufacturing settings.

The model also aims to mitigate persistent asymmetric fabric cuts, finished goods staining, and sewing open seam or loose-thread defects. Rework, material wastage, and prolonged production times are the result of these quality issues and significantly erodes customer satisfaction and productivity. Lean Manufacturing is addressed through the elimination of activities that do not add value, and maintenance of equipment to optimal working order to avert breakdowns is an approach adopted by TPM. Formulating both strategies into one model approaches the fundamental gaps of inefficiency and defective performance within production systems.

This proposal significantly expands the existing literature, since the integration of Lean and TPM in garment manufacturing SMEs has not been studied extensively. The model implements three main features: using 5S to arrange the workplace, standard operating procedures to reduce variability in the processes, and self [[autonomous]] maintenance where operators take an active role in equipment upkeep.

In conclusion, the model is described with three primary parts: (1) organization of the workplace using the 5S system, (2) work processes/activities standardization, and (3) self-maintenance or autonomous maintenance training. Each step leads incrementally to the goal of transforming a production environment rife with chaos and variability into one that is orderly, consistent, and efficient while delivering outstanding quality. These sections provide other descriptions of these components and how they achieve operational excellence.

a) Component 1: Organization of the Workplace using 5S

The first component focuses on the implementation of the 5S system, a basic Lean Manufacturing tool which aims at creating an orderly, systematic, and a clean workplace. The beginning stage concentrates on getting rid of excess clutter, organizing materials in a logical sequence, and creating a work atmosphere that promotes productivity and quality.

This stage starts with Seiri (Sort) which is grouping items that are necessary and those that are not needed. In this stage, tools, fabrics, accessories and other materials are reviewed and all that do not aid directly in the production process is removed. Decision making toward retaining or getting rid of items is facilitated using clear red tags. Edging and tagging greatly enhances clutter free spaces and decongested workplaces.

In addition to the above, tools and materials are arranged in numerically or chronologically order in termed as step two, Seiton(Set in Order). In this case, Tools and materials are arranged according to their use as ensuring that vital items are placed where they can be reached without any hindrance. Workstations are arranged to allow easy movement and task performance. Labeling and coloring to improve order and to help workers perpetuate the new arrangement even better than under the label of visual management reinforces this addition.

Seiso follows with deep cleaning of tools and their work areas. Maintenance tasks also improve the aesthetics of the workspace. Cleaning assists in proactive maintenance by identifying early signs of equipment wear or malfunction, thus supporting the proactive maintenance culture.

Seiketsu ensures that sorting, organizing, and cleaning are done by formal sustaining procedures. Operating handbooks, checklists, visual aids, and standard procedures ensure uniformity within shifts and between operators. Good practices become ingrained in daily routines.

Shitsuke emphasizes the development of discipline and a mindset where improvement is continuous, aiming for the adoption of a self-sustaining model system. Periodic training sessions, recognition schemes, and feedback from supervisors encourage workers to embrace the 5S principles. Ultimately, 5S becomes an ingrained, organic element of workplace culture. The application of 5S in detail gives the SME in garment manufacturing an environment that is clean and organized, allowing maximization of productivity, minimization of risks, and quality enhancement. Thus, automated workflows can be put in place systematically after the described foundation is established.

b) Component 2: Process Consistency through Standardized Work

As a follow up to maintaining an organized workplace, the second component focuses on the development and implementation of standardized work methods. As highlighted previously, standardization is necessary for reducing variation along all production steps and that all operators undertake identical work steps for work uniformity to achieve uniform product quality.

The complete process starts from analyzing the order of work and processes for the rest of the employees. In the case of sewing and standard making, the operator splits the task into smaller quantifiable parts, which are tracked through time and motion studies, detailed observations. Each task such as fabric cutting, garment assembly, and quality controlling have a range of cycle times and quality metrics for consistently meeting customer expectations and therefore significantly affect product quality and cycle times.

Standardized procedures are created based on the documented minimum yielded results, which capture the devoid step sequence, suggested tools, checkpoints and yield designed cycle times for each operation. Lessons designed reflect the procedures designed through collaboration with the operators so that all stakeholders engage in active and hands on learning for acceptance at all levels.

Subsequently, all workshops will use standard work for operators to aid them with the newly learnt procedures on actual sewing machining. A wide variety of visual resources including process flow plans showing specific work sequences and work instruction posters displaying photographs highlighted techniques which serve both as learning and correction aids.

Monitoring and feedback systems are central to this component. Supervisors monitor adherence to standardized procedures, offer corrective commentary as required, and capture suggestions for improvement. Stagnation does not occur with standardized work; instead, it undergoes continuous examination and revision with respect to practical insights and new avenues for improvement.

The implementation of standardized work results in several critical advantages. There is less variability in processes, which results in more predictable outcomes and higher yield of first pass quality. Workflow becomes more streamlined, resulting in the reduction of delays, re-work, and unnecessary movements. Furthermore, there is increased accuracy in production planning and better resource allocation due to well-defined procedures. Most importantly, with the aid of standardized work, autonomous maintenance tasks can be incorporated easily because unscheduled short maintenance periods can be precisely integrated without hindering the flow of production.

Consistent execution of standardized work allows the SME to develop disciplined operations that sustain improvement and positions the company to achieve consistent excellence in garment production.

c) Component 3: Ensuring Equipment Reliability through Autonomous Maintenance

This third element of the production system proposes the incorporation of autonomous maintenance as one of the foundations of the system. Following the principles of TPM, autonomous maintenance allows for the enhancement of self-care practices at the operator level. This reduces the possibility of equipment failure while also boosting machine reliability in addition to lowering productivity loss due to unanticipated stoppages.

The deployment stage starts with training that is designed to give operators all the required skills and knowledge. The curriculum includes instruction on the operation of the machine, identification of the relevant wear and tear, appropriate cleaning and lubrication, and other actions aimed at failure moderation, as well as basic troubleshooting. Training also includes ensuring that participants competently reclaim control of the situation by correctly and safely executing minor maintenance activities.

Operators are expected to perform certain tasks related to their machines. These include wiping off dust, lint, and other extraneous materials from the machine, performing set routines for the lubrication of rotational parts, checking for signs of wear for key components either through visual inspection or rotation, and notifying relevant authority of any defects, irregularity or anomaly that ought to be acted upon. Checklists are given to operators for sign off which ensures that checklists are active and no critical tasks are ignored.

The maintenance demands are integrated into production workflows by scheduling short cycles for cleaning and inspections. This aids in developing an environment where maintenance is not forgotten and equipment support is considered a responsibility that is part of production practices.

Support from leadership is imperative for the success of self-managed maintenance functions. Supervisors complete maintenance and inspection audits and offer remedial or positive recognition depending on the observed performance. Through the use of equipment boards or other visual aids, the present conditions of equipment can be communicated to everyone, thereby enhancing control over machinery.

Self-administered equipment care has significant consequences. Operators are able to manage other equipment problems, and in the event that they escalate, machine breakdowns can be avoided. A direct result of this is enhanced equipment availability. Enhanced precision and stability during the operation of machines also improves maintained machines, enhancing product quality. This also increases operator participation as they take pride in tools which fosters reliability for production.

Additionally, the creation of autonomous maintenance integrates strongly with the previous components. An orderly and clean workplace (Component 1) supports easier inspection of equipment, while SOPs (Component 2) enable maintenance tasks to be seamlessly integrated into daily routines. All of these factors contribute towards proactive focus and improvement, fostering excellence.

The suggested model of production for a garment manufacturing SME illustrates the remarkable opportunity of applying Lean Manufacturing and TPM principles within a small industrial setting. The incorporation of 5S workplace organization and maintenance into standard work processes transforms the production system from chaotic, high-variability, and failure ridden to orderly, dependable, and consistent.

The model addresses inefficiencies and defects promptly and, therefore, improves product quality, process stability, and productivity. The product scope is bolstered with advanced operational measures, but so are organizational change efforts - with culture focus, where the employees learn to embrace responsibility and take pride in their craftsmanship. Tasks are not simply accomplished, but rather the functionality and beauty of the entire production system is maintained and enhanced by workers.

This method provides a complete solution to be used by other small and medium sized enterprises (SMEs) within the textile industry who wish to improve their operational efficiency and competitive market position. It provides an example of how organizations with few resources can implement and adjust best practices from manufacturing paradigms when supported by an overarching, unified theory that is customized to their circumstances.

Essentially, the proposed model takes care of the operational problems of the SME in focus, while constructing the organization's enduring growth and excellence parameters from the ground-up.

C. Model Indicators

The effectiveness of the production model based on Lean Manufacturing and Total Productive Maintenance (TPM) principles was evaluated through performance indicators specifically designed for garment manufacturing SMEs. These indicators were developed to monitor the reduction of defective product rates and assess key aspects of process efficiency and operational reliability. The systematic evaluation provided a structured understanding of the improvements achieved, ensuring accurate monitoring and continuous support for quality enhancement efforts. This approach enabled a consistent measurement framework aligned with the objectives of minimizing defects and fostering sustainable production practices within the sector.

a) Defective Products

This indicator measures the percentage of garments that fail to meet quality standards due to any type of defect detected during production or final inspection.

$$\text{Defective Products (\%)} = \left(\frac{\text{Number of Defective Products}}{\text{Total Products Produced}}\right) \times 100$$

b) Defective Products due to Asymmetric Cuts

This indicator identifies the proportion of garments rejected because of inaccurate or uneven fabric cuts that compromise the final product's appearance or fit.

$$\text{Defective Products due to Asymmetric Cuts (\%)} = \left(\frac{\text{Defects from Asymmetric Cuts}}{\text{Total Products Produced}}\right) \times 100$$

c) Defective Products due to Stains

This measures the percentage of garments that are discarded due to the presence of stains, which affect both the aesthetics and acceptability of the final product.

$$\text{Defective Products due to Stains (\%)} = \left(\frac{\text{Defects from Stains}}{\text{Total Products Produced}}\right) \times 100$$

d) 5S Compliance

This indicator assesses the degree to which the 5S methodology has been properly implemented and sustained across the production environment to ensure workplace organization.

$$\text{5S Compliance (\%)} = \left(\frac{\text{Number of 5S Criteria Met}}{\text{Total 5S Criteria Evaluated}}\right) \times 100$$

e) Defective Products due to Open Seams or Loose Threads

This indicator tracks the percentage of garments classified as defective because of sewing flaws, including open seams or threads not properly secured.

$$\text{Defective Products due to Open Seams or Loose Threads (\%)} = \left(\frac{\text{Defects from Open Seams or Loose Threads}}{\text{Total Products Produced}}\right) \times 100$$

f) Overall Equipment Effectiveness (OEE)

OEE measures how effectively manufacturing equipment is utilized, considering availability, performance, and quality rates to determine the true productive capacity.

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

IV. VALIDATION

A. Validation Scenario

The validation scenario took place in a case study involving a micro and small enterprise (MYPE) dedicated to the textile and garment sector. The company, located in Lima, Peru, had more than ten years of experience in the market and operated primarily within a major commercial hub. It employed a small workforce distributed across production and administrative roles, reflecting a typical organizational structure for its size. The business specialized in the manufacturing of basic clothing items and served a diversified client portfolio, including corporate and retail sectors. Despite its growth aspirations, the case study faced persistent challenges related to product quality, mainly due to inconsistencies in cutting and sewing processes. These operational shortcomings hindered its ability to fully meet customer expectations and limited its competitiveness within the industry. Understanding this context was fundamental to framing the need for structured process improvements aimed at supporting the company's long-term development.

B. Initial Diagnosis

The diagnostic assessment conducted in the case study identified a significant gap in product quality, with a defective rate reaching 12.74%, compared to a sector benchmark of 4.13%, resulting in a technical gap of 8.61%. The analysis revealed that 52.06% of the defects originated from failures in the sewing process, 42.02% from failures in the cutting process, and 5.92% from other causes. Among the main findings, asymmetric cuts accounted for 34.36% of defective products, the presence of stains for 28.38%, and open seams or loose threads for 23.68%. Additionally, minor causes such as torn fabric explained 7.66% of the total defects. The study also highlighted that the economic impact of defective products amounted to PEN 116,960, equivalent to 9.55% of the company's annual revenue, emphasizing the need for targeted improvements in production processes.

C. Validation Design

The validation of the proposed production model, based on Lean Manufacturing and Total Productive Maintenance (TPM) tools, was carried out through a pilot application in an SME dedicated to the manufacturing of basic garments. The process lasted four months and focused on reducing the level of defective products by improving operational practices. The implementation of the model followed a structured plan involving three main strategies: organizing the work environment through the 5S methodology, standardizing production activities to minimize variability, and promoting autonomous maintenance to ensure equipment reliability. The validation was conducted using a data-driven approach, enabling a comprehensive evaluation of the results achieved.

The garment production model was piloted in a small clothing manufacturing firm in a bid to lower the defect rate which had been diagnosed earlier. The Proposal was designed using Lean Manufacturing integrated with Total Productive Maintenance (TPM) to enhance and facilitate process optimization, waste elimination, and equipment reliability. The construction of the model design was built around the root cause and directly keyed on its causative factors which were organized into three major areas: the 5S approach to workplace organization, reduction of variability through standardization of production steps, and the addition of autonomous maintenance to improve machine availability. Every intervention was thoroughly validated against the quantitative results that were collected as a demonstration of the resolved problem's efficacy.

a) Component 1: Organization of the Workplace Using the 5S Methodology

In the case study, the production areas particularly the sewing section was filled with outdated materials, broken tools, and other supplies which showed a high degree of disorder and indiscipline that ought to be put in check. The first cumulative 5S compliance audit reported an initial level of 64% which indicates a failure to ensure adequate standards of cleanliness, organization, and material control, and maintenance of work areas. These shortcomings had a grave impact on the productivity of processes and further added to the very high rate of defects in garments that were primarily related to fabric soiling and manipulation of the garments.

To remedy these gaps, a staged approach employing the 5S approach was done, beginning with the systematic implementation of each of its five components. A rigorous sorting process was carried out for all equipment, tools, and materials. Items that were not needed for daily use were purged, which resulted in about an 18% reduction in the number of stored materials. This step not only eliminated a significant amount of clutter but also reduced valuable space, error, and contamination sources. Following this, the remainder was reorganized in terms of order. This included setting marked areas for items depending on how frequently they were used and their relevance to ongoing operations. There was an improvement of approximately 22% in the amount of time taken by operators to locate tools and materials because of this reordering, allowing for smoother operations.

The Seiso stage implemented a standardized cleaning procedure which included daily, and weekly cleaning routines allocated to specific workstations. The most significant cleaning practices focused on preventing the accumulation of dirt, lint, and fabric debris which was already identified as a contributory factor to defects such as staining. Accordingly, the average time spent per workstation cleaning was reduced by 17% allowing operators to concentrate on production activities while still maintaining a clean workspace. During the Seiketsu phase, procedures and checklists granulated sorting, order, and cleaning activity control to ensure consistency of these activities. The use of color-coded labels and proper design of lay out and posters entrenched these practices for all shifts to foster operational consistency and improved stability.

In the Shitsuke phase, a focus on building an organizational culture that encourages self-discipline, and self-control was developed amongst staff. Enforcement compliance to 5S standards is through regular internal audits, feedback sessions, and recognition of outstanding employees. As organizational training reinforced that the order in the workstation directly impacts the quality and effectiveness of products and services provided, a stronger culture began to emerge. Showable change was increased employee engagement in maintaining personal workspaces to protect the sustained changes.

The 5S compliance level passed 95% after four months of implementation, which signifies a relative gain of 48.44% from the baseline. Environmental defect contamination was reduced because of the workplace cleanup; defective product stains alone decreased by 24.07%. Additionally, these improvements, along with the improved efficiency from the reduced search and cleaning time, provided a strong platform for the subsequent phases of the model, particularly for the standardization of work methods and the implementation of self-sustaining maintenance activities. The straightforward and consistent application of the 5S methodology proved that basic organizational changes could have dramatic impacts on operational and quality metrics in a small garment manufacturing facility.

Figure 2 illustrates the condition of the company's production areas before the implementation of the 5S methodology. The images show notable disorganization across workstations, with tools and materials scattered without defined locations, hindering operational efficiency. Fabric pieces and finished products were accumulated without order, increasing the risk of contamination and damage. In addition, the visible presence of waste materials and poorly maintained equipment reflected the absence of systematic cleaning routines. The lack of visual controls and standardized procedures negatively impacted the workspace, contributing to delays, errors, and a higher rate of defective products. This initial situation highlighted the urgent need for structured organizational improvements to support the production process.

Figure 2 : Company status before 5S implementation

Figure 3 depicts the condition of the company's production areas after the implementation of the 5S methodology. The images reveal significant improvements in workplace organization, with tools, fabrics, and materials systematically arranged and clearly labeled. Workstations appear clean, free of unnecessary items, and structured to facilitate efficient operations. Fabrics are neatly folded and categorized, reducing search time and preventing material damage. The sewing area reflects the application of visual management techniques, ensuring easy identification of tools and enhancing operational flow. Overall, the environment conveys a disciplined, orderly workspace aligned with the principles of Lean Manufacturing and sustained through daily 5S practices.

b) Component 2: Standardization of Work Activities to Minimize Variability

During the diagnosis phase of the case study, it was evident that there was a high level of variability in the production process, especially in cutting and sewing. Employees worked using their own informal criteria because there were no placed work regulations and instructions. Such practices, which led to asymmetric cuts, which alone comprised 34.36% of the total defective products, created inconsistencies that induced multi-defects. Moreover, the absence of definitive procedures compounded the inefficiencies in production by lengthening the time taken to process a garment.

In response, the company developed and implemented a comprehensive standardization program. In every critical task, especially for cutting, sewing, and quality control, standardized work instructions pertaining to their specific area of responsibility were written. These cuts were developed around the best practices which were gleaned during the internal analyses and archived into a document that was easy to understand, clear, concise, and visual. All products were accompanied by Technical Data Sheets which delineated precise measurements, types of stitches, seam allowances, and other quality standards to be achieved at each stage of the production. In addition, operators were trained using new appliances and materials under new guided instructions that were practiced across all shifts so that everyone on all shifts had the same understanding on standard operating procedures.

Figure 3 : Company status after 5S implementation

c) Component 2: Standardization of Work Activities to Minimize Variability

During the diagnosis phase of the case study, it was evident that there was a high level of variability in the production process, especially in cutting and sewing. Employees worked using their own informal criteria because there were no placed work regulations and instructions. Such practices, which led to asymmetric cuts, which alone comprised 34.36% of the total defective products, created inconsistencies that induced multi-defects. Moreover, the absence of definitive procedures compounded the inefficiencies in production by lengthening the time taken to process a garment.

In response, the company developed and implemented a comprehensive standardization program. In every critical task, especially for cutting, sewing, and quality control, standardized work instructions pertaining to their specific area of responsibility were written. These cuts were developed around the best practices which were gleaned during the internal analyses and archived into a document that was easy to understand, clear, concise, and visual. All products were accompanied by Technical Data Sheets which delineated precise measurements, types of stitches, seam allowances, and other quality standards to be achieved at each stage of the production. In addition, operators were trained using new appliances and materials under new guided instructions that were practiced across all shifts so that everyone on all shifts had the same understanding on standard operating procedures.

The adoption of standardized work practices not only brought stability to operational activities but also resulted in marked improvements in the quality of the product. After four months, the percentage of defective products caused by asymmetric cuts dropped from 34.36% to 23.10%, which is a relative improvement of 32.76%. Simultaneously, average cycle time for garment production was reduced by 12%, further increasing productivity. Supervisory audits showed a compliance with the standardized instructions of 90%, which indicates that the new methods were indeed adopted by the members of the workforce. Standardized work also made it possible to detect deviations and nonconformities at an earlier stage, thus facilitating prompt corrective actions that stemmed the spread of defects.

As stated above, the practices for standard work development and implementation were critical in reducing the process variability to improve more product defect for better quality, as well as in establishing a more controlled and predictable environment for production. These findings validated the operational advantage of institutionalizing the organization’s operational know-how to sustain the performance and productivity improvements.

Figure 4 shows the company's work documentation practices before the implementation of standardized procedures. The images reveal the use of handwritten sketches and informal notes without clear specifications, formats, or consistent measurements. This lack of formal documentation increased variability in production processes and made it difficult to ensure product quality and repeatability. The absence of standardized technical sheets contributed to inconsistencies in garment dimensions and sewing techniques, leading to a higher defect rate. This situation emphasized the urgent need to establish formal work standards to support consistency and operational efficiency.

Figure 5 shows the company's situation after the implementation of work standardization. The image presents a detailed technical sheet for garment manufacturing, including clear measurement diagrams and a precise size chart for different specifications. Each measurement point is properly identified and described, ensuring consistency throughout the cutting and sewing processes. The adoption of this formal documentation significantly reduced process variability and enhanced product quality and repeatability. This standardization represented a major improvement in process control and operational quality assurance within the company.

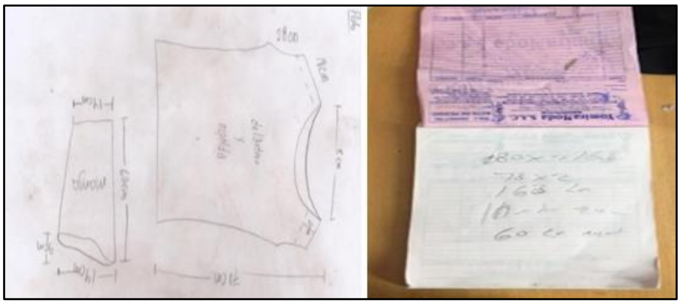
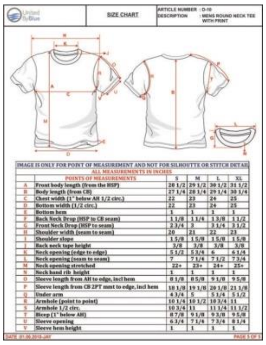


Figure 4 : Company's Situation Before Work Standardization

d) Component 3: Strengthening Equipment Reliability through Autonomous Maintenance

The first round of the case study highlighted maintenance practices in the selected company to be largely reactive in nature when dealing with equipment. The machines were used up to the point of failure which led to unplanned downtimes, production holdups, and increased defective product seaming and stitching failures like open seams and loose threads (defect rate of 23.68%). The value of Overall Equipment Effectiveness (OEE) or Efficiency of Resources Utilized had an alarming figure close to 65.88% which is below par when compared with other industries.



SIZE CHART

ARTICLE NUMBER : D-10
DESCRIPTION : MENS ROUND NECK TEE WITH PRINT

IMAGE IS ONLY FOR POINT OF MEASUREMENT AND NOT FOR SILHOUTTE OR STITCH DETAIL

ALL MEASUREMENTS IN INCHES

	POINTS OF MEASUREMENTS	S	M	L	XL
A	Front body length (from the HSP)	28 1/2	29 1/2	30 1/2	31 1/2
B	Body length (from CB)	27 1/4	28 1/4	29 1/4	30 1/4
C	Chest width (1" below AH 1/2 circ.)	22	23	24	25
D	Bottom width (1/2 circ.)	22	23	24	25
E	Bottom hem	1	1	1	1
F	Back Neck Drop (HSP to CB seam)	1 1/8	1 1/4	1 3/8	1 1/2
G	Front Neck Drop (HSP to seam)	2 3/4	3	3 1/4	3 1/2
H	Shoulder width (seam to seam)	20	21	22	23
I	Shoulder slope	1 5/8	1 5/8	1 5/8	1 5/8
J	Back neck tape height	3/8	3/8	3/8	3/8
K	Neck opening (edge to edge)	5 1/2	5 3/4	6	6 1/4
L	Neck opening (seam to seam)	7	7 1/4	7 1/2	7 3/4
M	Neck opening stretched	22+	23+	24+	25+
N	Neck band rib height	1	1	1	1
O	Sleeve length from AH to edge, incl hem	8 1/8	8 5/8	9 1/8	9 5/8
P	Sleeve length from CB 2PT mmt to edge, incl hem	18 1/8	19 1/8	20 1/8	21 1/8
Q	Under arm	4 3/4	5	5 1/4	5 1/2
R	Armhole (point to point)	10 1/4	10 1/2	10 3/4	11
S	Armhole 1/2 circ.	10 3/4	11	11 1/4	11 1/2
T	Bicep (1" below AH)	8 7/8	9 1/8	9 3/8	9 5/8
U	Sleeve opening	6 3/4	7 1/4	7 3/4	8 1/4
V	Sleeve hem height	1	1	1	1

Figure 5 : Company's situation after work standardization

Given these problems, the self-managed maintenance system was developed that allowed operators handle the basic maintenance tasks of their machines. The program began with training sessions that targeted machine operation, cleaning machine parts, lubrication, and the ability to identify wearing parts on machines. Accompanying manuals was placed at each workstation to serve as reminders for daily and weekly maintenance checklists. Maintenance recommends regular maintenance activities, essential cleaning, limb removal, and anomaly discovery.

The systematic introduction of autonomous maintenance resulted in notable enhancements in equipment dependability and operational flow. After four months, the OEE value increased from 65.88% to 90%, marking a relative improvement of 36.59%. Specifically, the OEE availability component improved by 18% and quality performance also improved by 12%, which directly increased production stability and decreased defects. The proportion of defective items attributable to open seams and loose threads was reduced from 23.68% to 15.64%, a decline of 33.96%.

At the same time, alongside the technical improvements, the fostering of autonomous maintenance created a remarkable cultural change within the company. Operators exhibited enhanced responsibility in relation to their workstations and actively participated in the maintenance of their machines' performance. Dependable maintenance became part of daily workflow routines, decreasing the need for maintenance by outside providers and bolstering the company's ability to reliably achieve operational targets.

In any case, the achievements of autonomous maintenance have greatly improved equipment reliability while also strengthening the elements of continuous improvement, employee initiative, and self-governance as stipulated by the production system grounded on Lean Manufacturing and TPM.

Figure 6 shows the company's situation before the implementation of Autonomous Maintenance practices. The image illustrates an informal list of machine failures and basic corrective actions, manually recorded by operators without a structured or standardized format. This improvised documentation reflects the absence of preventive maintenance routines and a reactive approach to equipment management. The lack of systematic inspections and early detection of abnormalities led to frequent machine failures and unplanned downtime, negatively impacting production flow and product quality. This initial situation underscored the urgent need to introduce Autonomous Maintenance to promote equipment reliability and operational stability.

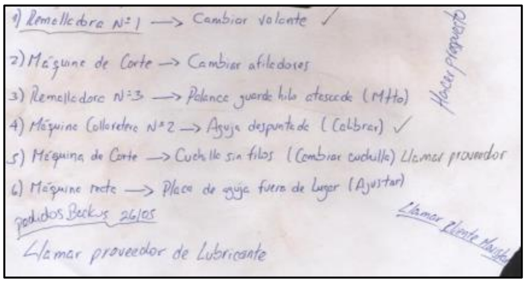


Figure 6 : Company's Situation Before Autonomous Maintenance

Figure 7 shows the company's situation after the implementation of Autonomous Maintenance practices. The image highlights the adoption of structured formats for maintenance management, including lubrication records and preventive inspection sheets placed at workstations. These documents enable operators to systematically perform routine maintenance activities and document completed interventions. The introduction of these visual controls strengthened operational discipline, reduced the occurrence of unexpected equipment failures, and supported the continuity of production processes. This evolution reflected a clear transition toward a preventive and organized approach to equipment management.

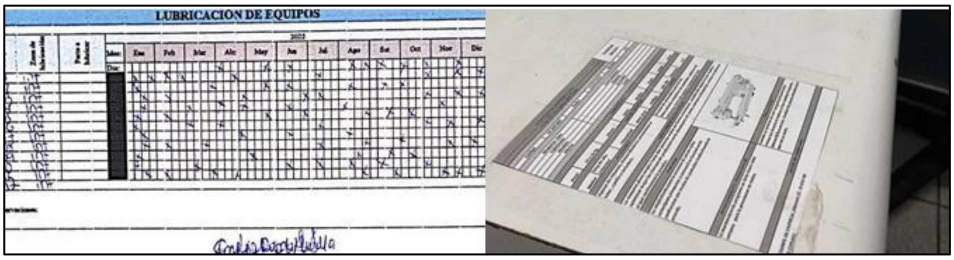


Figure 7 : Company's situation after Autonomous Maintenance

D. Results

Table 1 presents a summary of the results obtained after validating the production model based on Lean and TPM tools. A significant reduction in the percentage of defective products was observed, decreasing from 12.74% to 4.13%, representing a variation of -60.52%. Regarding specific defects, products with asymmetric cuts decreased by 24.04%, while defects caused by the presence of stains reduced by 24.07%. Similarly, the percentage of open seams and loose threads declined by 24.07%. In parallel, a substantial improvement was noted in the 5S compliance level, which reached 95%, and in the OEE level, which increased to 90%. These results confirmed the effectiveness of the proposed model in reducing quality defects and enhancing operational efficiency in the evaluated garment manufacturing SME.

Table 1 : Indicators After Model Implementation

Objective	Indicator (%)	As-Is	To-Be	Results	Variation (%)
Reduce defective products	% Defective products	12.74 %	4.13%	5.03%	-60.52%
Reduce asymmetric cuts	% Defective products due to asymmetric cuts	34.36 %	23.10 %	26.10 %	-24.04%
Reduce presence of stains on garments	% Defective products due to presence of stains	28.38 %	19.08 %	21.55 %	-24.07%
	% 5S Compliance	64.00 %	95.00 %	95%	48.44%
Reduce open seams and loose threads	% 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%

V. DISCUSSION

The validation results of the proposed model aligned with previous literature concerning the impact on defect mitigation and operational efficiency improvement within a textile manufacturing SME. To begin with, the application of 5S yielded a reduction of 24.07% in staining defects as spill over as Randhawa and Ahuja [14] challenged that there is an influence of an organized workplace on product quality. In addition, the standardization of production techniques brought about a reduction of 24.04% in asymmetric cut defects, supporting Rahman et al. [15] who argued that standardized work in garments leads to productivity because it removes unnecessary variability in work steps. Furthermore, implementation of autonomous maintenance raised the OEE by 65.88% up to 90%, supporting the evidence from Wickramasinghe and Perera's [8] findings that autonomous maintenance enhances equipment utilization and maintenance reliability, processes that reportedly stabilize production in the textile industry. These results affirm that the combination of Lean Manufacturing and TPM with the aim on SMEs in developing countries can improve their operational performance.

Despite the improvements highlighted in this study, it still lacks in a number of areas. The case study validation was done in a singular, small sized garment manufacturing company located in Lima, Peru, which limits the extrapolation of results to different industrial settings. Furthermore, the duration allocated for execution and evaluation spanned only four months. While this time frame makes room for primary improvements to be noted, it does not make certain the perpetual retention of these results. Another drawback is stemming from the reliance on the operational and managerial staff's will, as in the absence of sustained commitment, the engagement could undo the improvements attained. The monitoring of the company's index indicators, which form the basis of internal self-auditing processes, do not involve the external auditing bodies, which raises concerns regarding the neutrality of the outcomes.

Practical considerations stemming from this study are valuable for the operations management of small- and medium-sized enterprises in the textile industr y. Integrating 5S, standardized work, and autonomous maintenance systems offers a simple and inexpensive model to improve product quality, optimize resource allocation, and enhance business competitiveness. Moreover, the model helps to improve an organization's culture by instilling a sense of ownership and fostering operational responsibility towards continuous improvement at all levels of the organizational hierarchy. The proposed model provides companies that lack sophisticated technologies and financial means with a proactive approach that is highly customizable, enabling them to directly reduce waste, boost productivity, and improve customer satisfaction. This illustrates that meticulously planned, momentous changes will yield profound and long-term improvements in production efficiency.

These results suggest that future studies may seek to validate the model with other companies of larger scope, or from different subsectors of the textile industry, in order to further strengthen evidence for the model's versatility. Also, increasing the evaluation period to twelve months or more would be beneficial in determining the sustainability of the improvements gained in the medium to long term. Another interesting area of research could be the inclusion of inexpensive devices like IoT for the strengthening of autonomous maintenance and improving precision of data collection IoT devices. In addition, other research could be done on the effect of the model on other aspects not addressed in this study, such as employee's job satisfaction and the impact on the environment resulting from more efficient production processes.

VI. CONCLUSION

The model significantly enhances the operational performance of textile SMEs with the implementation of an integrated Lean-TPM model. The case company achieved notable improvements in defect rates, equipment reliability, organizational discipline, and enhanced self-discipline on the shop floor due to the application of 5S, standardized work, and autonomous maintenance. More precisely, the model improved structure within a production environment, reduced consistency and variability of processes, strengthened preventive maintenance practices, and further increased overall quality and efficiency improvements. It is quite evident how these changes successfully improved the quality and efficiency performance indicators; however, it is even more important to understand how a systematic comprehensive solution is necessary when tackling persistent problems in small garment manufacturing.

The lack of research integrating Lean Manufacturing concepts with Total Productive Maintenance in developing economy contexts showcases the gaps this research intends to address emphasizing the relevance of the study. Bestowing the model on a small Peruvian firm gives the research great value not only for enhancing productivity but also for deepening The firm's competitiveness in volatile markets. These findings underscore the importance of established operational frameworks emerging from developed nations needing fines to function effectively in diverse industrial and regional contexts.

The study impacts the industrial engineering field by showing that even the most basic enterprises can combine Lean and TPM for remarkable operational improvements. It also adds more academic value by arguing how some complex production issues can be solved with planned actions. Additionally, the model's validation within actual operational settings reinforces the practicality of the study and provides guidance for its application, thus highlighted the disparity between theory and practice.

The results presented here may provide insights into new areas of work. Expanding the model's application to include medium-sized enterprises or other manufacturing sectors could serve as additional corroborating evidence. Other verifiable suggestions include the application of digital monitoring and maintenance technologies, such as inexpensive IoT devices. Examining the practical and sustainability dimensions of the model's implications could also introduce further social and environmental considerations.

V. REFERENCES

[1] N. F. Ramos Benancio, M. E. Suarez Mandujano y T. Chanca Henry, "Impact on waste reduction when applying Lean Manufacturing tools in SMEs: Systematic Literature Review," en 4th LACCEI International Multiconference on Entrepreneurship, Innovation and Regional Development - LEIRD 2024, Virtual Edition, 2–4 diciembre 2024, doi: 10.18687/LEIRD2024.1.1.626.

[2] E. M. Ventura Hernández, M. A. Nolasco-Mamani, D. Hernández Celis, J. Monrroy Aime y E. J. Guardia Huamani, "Production costs and their effect on the profitability of the SMEs in Latin America," F1000Research, vol. 13, p. 836, Jul. 2024, doi: 10.12688/f1000research.143777.1.

[3] Ministry of Production of Peru (PRODUCE), "Annual Economic Report of Textile and Apparel Sector," 2022, [Online]. Available: https://www.gob.pe/produce.

[4] C. Elias Sarhuana, D. Vasquez Hernandez, M. Collao-Diaz, J. Quiroz-Flores, and A. Flores-Perez, "Lean Manufacturing Production Model to Increase Productivity under the DMAIC Approach in Peruvian SMEs Garment Manufacturers," in Proc. WCSE 2022 Spring, 2022, pp. 331–338, doi: 10.18178/wcse.2022.04.040.

[5] F. Penagos Guzman and M. García Solarte, "The mediation of dynamic capabilities between management skills and SME performance," PLOS ONE, vol. 19, no. 10, p. e0312172, 2024, doi: 10.1371/journal.pone.0312172.

[6] J. R. Romero-Parra, F. G. Tataje-Sanchez, and R. N. Meza-Ortiz, "Application of 5S and Standardized Work to Improve Labor Productivity: Case of Textile SME," in Proc. 22nd LACCEI Int. Multi-Conf., 2024, doi: 10.18687/LACCEI2024.1.1.453.

[7] I. Herrera-Barreda, "Enhancing Operational Efficiency in Textile SMEs: Integrating Lean Manufacturing and Total Productive Maintenance," in Proc. 5th Asia Pacific Conf. IEOM, 2024, doi: 10.46254/AP05.20240101.

[8] G. L. D. Wickramasinghe and M. P. A. Perera, "Total Productive Maintenance, Affective Commitment and Employee Retention in Apparel Production," Merits, vol. 2, no. 4, pp. 304–313, 2022, doi: 10.3390/merits2040021.

[9] Y. Kose, S. Muftuoglu, E. Çevikcan, and M. Durmuşoğlu, "Axiomatic Design for Lean Autonomous Maintenance System: An Application from Textile Industry," International Journal of Lean Six Sigma, vol. 14, no. 3, pp. 555–587, 2022, doi: 10.1108/IJLSS-01-2022-0020.

[10] V. Sarasi, I. Primiana, B. Harsanto, and Y. Satyakti, "Sustainable Supply Chain of Indonesia's Textile and Apparel Industry: Opportunities and Challenges," Research Journal of Textile and Apparel, vol. 27, no. 1, pp. 95–117, 2023, doi: 10.1108/RJTA-08-2022-0091.

[11] I. Hoque, "Buyer-assisted lean intervention in supplier firms: a supplier development approach", Journal of Manufacturing Technology Management, vol. 33, no. 1, p. 146-168, 2021. https://doi.org/10.1108/jmtm-11-2020-0445

[12] A. Hamja, M. Maalouf, & P. Hasle, "Assessing the effects of lean on occupational health and safety in the ready-made garment industry", Work, vol. 64, no. 2, p. 385-395, 2019. https://doi.org/10.3233/wor-192982

[13] A. Hamja, M. Maalouf, & P. Hasle, "The effect of lean on occupational health and safety and productivity in the garment industry – a literature review", Production & Manufacturing Research, vol. 7, no. 1, p. 316-334, 2019. https://doi.org/10.1080/21693277.2019.1620652

[14] J. Randhawa and I. Ahuja, "Evaluating impact of 5s implementation on business performance", International Journal of Productivity and Performance Management, vol. 66, no. 7, p. 948-978, 2017. https://doi.org/10.1108/ijppm-08-2016-0154

[15] S. Rahman, A. Baten, M. Hoque, & M. Mahmud, "Impact of lean manufacturing on productivity and layout design in sewing section of a garment industry", International Journal of Industrial Management, vol. 17, no. 3, p. 152-161, 2023. https://doi.org/10.15282/ijim.17.3.2023.8955

[16] J. Sun, S. Li, C. Xu, & J. Liu, "Simulation analysis and optimization of garment manufacturing process based on em-plant software", Journal of Computational Methods in Sciences and Engineering, vol. 21, no. 6, p. 1727-1738, 2021. https://doi.org/10.3233/jcm-215401

[17] J. Randhawa and I. Ahuja, "5s – a quality improvement tool for sustainable performance: literature review and directions", International Journal of Quality & Reliability Management, vol. 34, no. 3, p. 334-361, 2017. https://doi.org/10.1108/ijqrm-03-2015-0045

[18] J. Randhawa and I. Ahuja, "Examining the role of 5s practices as a facilitator of business excellence in manufacturing organizations", Measuring Business Excellence, vol. 21, no. 2, p. 191-206, 2017. https://doi.org/10.1108/mbe-09-2016-0047

[19] O. Monnanyana and K. Gupta, "A case study on implementation of 5s in a manufacturing plant to improve operational effectiveness", Matec Web of Conferences, vol. 346, p. 03109, 2021. https://doi.org/10.1051/matecconf/202134603109

[20] C. Costa, L. Ferreira, J. Sá, & F. Silva, "Implementation of 5s methodology in a metalworking company",, p. 001-012, 2018. https://doi.org/10.2507/daaam.scibook.2018.01

[21] A. Singh and I. Ahuja, "Review of 5s methodology and its contributions towards manufacturing performance", International Journal of Process Management and Benchmarking, vol. 5, no. 4, p. 408, 2015. https://doi.org/10.1504/ijpmb.2015.072320

[22] A. Lora-Soto, C. Morales-Silva, J. Llontop-Jesus, & N. Mamani, "Process improvement proposal for the reduction of machine setup time in a copper transformation company using lean manufacturing tools",, p. 585-591, 2020. https://doi.org/10.1007/978-3-030-55307-4_89

[23] J. Runtuk, "Set up time reduction using single minute exchange of dies (smed) and 5s: a case study", Jie Scientific Journal on Research and Application of Industrial System, vol. 6, no. 2, p. 162, 2021. https://doi.org/10.33021/jie.v6i2.3384