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Integrating Lean Manufacturing and Ergonomics for Enhancing Operational Efficiency in Peruvian Textile SMEs: A Case Study

Airthon Jhair Julcarima-Perez
Bachelors in Industrial Engineering
Facultad de Ingeniería, Universidad de Lima, Perú
20170776@aloe.ulima.edu.pe

Alvaro Miguel Portal-Huayanca
Bachelors in Industrial Engineering
Facultad de Ingeniería, Universidad de Lima, Perú
20172490@aloe.ulima.edu.pe

Abstract

The Peruvian textile sector faces significant challenges, especially in optimizing operational efficiency in SMEs. These companies are key pillars in the economy, generating employment and contributing to GDP, but they suffer from production inefficiencies caused by inappropriate work designs and unproductive time. These problems limit their competitiveness in the global market and require urgent solutions. The research conducted sought to address these limitations by implementing Lean Manufacturing tools and an ergonomic approach, improving both productivity and working conditions. The findings showed that integrating these methodologies increased production efficiency by 122%, reducing cycle times and improving operational consistency. Also achieved a reduction in batch defects and unscheduled breaks, which strengthened overall performance. The impact of this research is twofold: at academic level, it contributes to the development of models adapted to textile SMEs, and at socio-economic level, it promotes sustainability in a key sector of the Peruvian economy. Further research is needed on the scalability of these solutions in similar industries and to explore integration of digital tools to further optimize processes.

Keywords
Lean Manufacturing, Ergonomics, Textiles SMEs, Operation Efficiency, SLP.

1. Introduction

The small and medium-sized textile industry (SMEs) plays a crucial role in the global economy, especially in regions such as Latin America and Peru. This sector is not only a driver of employment, but also contributes significantly to the gross domestic product (GDP) of these countries. In Latin America, textile SMEs account for approximately 70% of total output in the sector, underlining their importance in generating income and employment (Deepthi & Bansal, 2022). In Peru, the textile industry has historically been a pillar of the economy, with a long tradition dating back to pre-Columbian civilizations. Textile production in Peru not only covers the manufacture of garments, but also the elaboration of high-quality products that are exported to international markets, which highlights the relevance of this sector in foreign trade (Vasconcelos et al., 2022). However, despite their importance, textile SMEs face numerous challenges that limit their growth and competitiveness in an increasingly demanding global market (Shahzad et al., 2020).

One of the most significant problems faced by textile SMEs is the low efficiency of their production lines. This inefficiency can be attributed to several factors, including poor work design and high unproductive times. An inappropriate work design can result in ineffective distribution of tasks, resulting in bottlenecks and extended waiting times (Marzoog et al., 2020). In addition, high unproductive times, which can be caused by machinery failures or interruptions in the workflow, negatively affect the production capacity and thus the profitability of these enterprises (Pastore, 2023). The lack of adequate planning and the absence of methodologies that optimize resource use contribute to many textile SMEs not reaching their maximum operational potential (Adeyemi et al., 2021). The implementation of continuous improvement tools, such as Lean Manufacturing, could be a viable solution to address these problems, allowing companies to reduce waste and improve the overall efficiency of their production processes (Demirtaş et al., 2022).

Resolving these problems is of paramount importance for the SME textile sector, as it impacts not only on the economic viability of companies but also on their ability to compete in a global market. Improved production efficiency can lead to lower costs, which in turn allows companies to offer more competitive prices and improve their market position (Mishra & Singh, 2022). In addition, by optimizing production processes, SMEs can increase their responsiveness to changing consumer demands, which is essential in a rapidly evolving fashion environment (Cao et al., 2022). The implementation of continuous improvement practices not only benefits individual companies, but also contributes to the sustainable development of the sector by promoting waste reduction and efficient use of resources (Lindström et al., 2020). Addressing inefficiency in production lines is therefore a critical step to ensure the long-term sustainability and growth of textile SMEs.

Despite the relevance of these issues, there is a significant gap in literature that specifically addresses the challenges and solutions applicable to textile SMEs in Latin America and Peru. Existing research tends to focus on large companies or contexts that do not reflect the particularities of SMEs (Shahzad et al., 2020). This lack of attention to the specific needs of textile SMEs limits the availability of production models adapted to their realities. The present research aims to fill this knowledge gap by developing a production model that incorporates Lean Manufacturing tools, such as standardized work and an ergonomic approach. These tools not only aim to improve the efficiency of production lines, but also promote a healthier and more productive work environment for employees (Hibino et al., 2019). By integrating these methodologies, it is hoped that textile SMEs will be able to optimize their processes, reduce downtime and ultimately improve their competitiveness in the global market.

In conclusion, the SME textile sector is critical to the economy of Latin America and Peru, facing significant challenges that require urgent attention. Low efficiency in production lines, attributed to poor work design and high unproductive times, represents a considerable obstacle to the growth and sustainability of these enterprises. The importance of addressing these problems is evident, as efficiency improvements not only benefit individual companies but also contribute to the sustainable development of the sector as a whole. Finally, the knowledge gap in the literature on textile SMEs highlights the need for research that develops production models adapted to their needs, using lean manufacturing tools that promote efficiency and occupational health.

2. Literature Review

2.1 Lean Manufacturing in Textile SMEs: A Pathway to Efficiency

The application of Lean Manufacturing (LM) methodologies in small and medium-sized enterprises (SMEs) within the textile sector has garnered significant attention in recent years. Research indicates that the adoption of LM principles can lead to substantial improvements in operational efficiency, waste reduction, and overall productivity. For instance, Inuwa and Usman Inuwa & Usman (2022) highlight that SMEs in Nigeria exhibit a favorable organizational structure that supports the deployment of lean initiatives, although challenges persist. Similarly, Dora et al. Dora et al. (2013) emphasize that while larger firms often dominate the implementation of lean practices, SMEs can also benefit significantly from these methodologies, particularly in enhancing productivity. Furthermore, Robertsone et al. Robertsone et al. (2021) identify demand variability as a critical barrier to lean implementation in the textile industry, suggesting that addressing this issue is essential for successful adoption. The findings from Mohammad and Oduoza Mohammad & Oduoza (2019) further reinforce this notion, indicating that the integration of lean practices in SMEs can lead to improved business management and operational excellence.

Moreover, the literature reveals that the successful implementation of lean practices in textile SMEs is contingent upon understanding specific barriers and facilitators unique to this sector. For example, Agrawal et al. Agrawal et al.

(2017) present a fuzzy logic approach to evaluate leanness in Indian SMEs, demonstrating that tailored strategies are necessary for effective implementation. Yamchello et al. Yamchello et al. (2014) also contribute to this discourse by prioritizing lean practices through a fuzzy environment, underscoring the need for a systematic approach to identify and overcome barriers. Kumar and Vinodh Kumar & Vinodh (2020) expand on this by illustrating how lean principles can be adapted across various manufacturing contexts, including textiles, to achieve waste elimination and value addition. The collective insights from these studies underscore the importance of a nuanced understanding of lean methodologies tailored to the specific challenges faced by textile SMEs.

2.2 Systematic Layout Planning: Optimizing Textile Production

Systematic Layout Planning (SLP) is another methodology that has been effectively applied in the textile industry to enhance production efficiency. Research indicates that SLP can significantly improve workflow and reduce operational bottlenecks. For instance, Huang et al. Huang et al. (2022) demonstrate that SLP can lead to optimized plant layouts in SMEs, thereby facilitating smoother production processes. This is particularly relevant in the textile sector, where space constraints and workflow inefficiencies can hinder productivity. Additionally, Ramadas and Satish Ramadas & Satish (2018) highlight the importance of strategic layout planning in reducing non-fulfillment of orders, a common challenge faced by textile SMEs. Their study emphasizes that a well-structured layout can lead to improved order fulfillment rates and customer satisfaction.

Furthermore, the application of SLP in textile SMEs is supported by empirical evidence from various case studies. For example, Sahoo and Yadav Sankar (2023) provide insights into how SLP can be integrated with lean practices to create a synergistic effect on production efficiency. Their findings indicate that combining these methodologies can lead to enhanced operational performance and reduced lead times. Similarly, Burawat Qureshi et al. (2022) discusses the relationship between effective layout planning and sustainable performance in SMEs, suggesting that a strategic approach to layout can contribute to long-term sustainability in the textile sector. The integration of SLP with lean principles thus emerges as a critical strategy for textile SMEs seeking to optimize their production processes.

2.3 Standardized Work: Ensuring Consistency in Textile Production

The implementation of Standardized Work (SW) methodologies in textile SMEs is crucial for ensuring consistency and quality in production processes. Research indicates that SW can significantly enhance operational efficiency by establishing clear guidelines and procedures. For instance, Lee Nikiforova & Bičevska (2018) emphasizes that standardized work practices can lead to improved productivity and reduced variability in manufacturing processes. This is particularly relevant in the textile industry, where maintaining consistent quality is paramount. Additionally, Campoblanco-Carhuachin et al. Jadhav et al. (2014) highlights the role of SW in reducing non-fulfillment of orders, suggesting that clear standards can streamline production and enhance customer satisfaction.

Moreover, the literature reveals that the successful implementation of SW in textile SMEs is contingent upon effective training and employee engagement. For example, Knol et al. Vega et al. (2020) argue that involving employees in the development of standardized work procedures can lead to greater buy-in and adherence to these practices. This participatory approach not only enhances the effectiveness of SW but also fosters a culture of continuous improvement within the organization. Furthermore, Filho et al. Alefari et al. (2020) provide empirical evidence that the adoption of SW practices can lead to significant performance improvements in Brazilian SMEs, reinforcing the notion that standardized work is a critical component of operational excellence in the textile sector.

2.4 Ergonomic Approaches: Enhancing Worker Well-being in Textile Production

The application of ergonomic principles in textile production is essential for enhancing worker well-being and productivity. Research indicates that ergonomic interventions can lead to reduced physical strain and improved job satisfaction among workers. For instance, Diah et al. diah et al. (2018) highlight the importance of ergonomic design in minimizing repetitive strain injuries, which are prevalent in the textile industry. Their study emphasizes that investing in ergonomic solutions can lead to a healthier workforce and improved productivity. Additionally, Vega et al. Ruiz et al. (2019) discuss the relationship between ergonomic practices and employee performance, suggesting that a focus on worker well-being can yield significant benefits for SMEs.

Moreover, the integration of ergonomic principles with lean manufacturing practices is gaining traction in the textile sector. For example, Alefari et al. Sahoo & Yadav (2018) illustrate how ergonomic interventions can complement lean initiatives by reducing waste associated with worker fatigue and inefficiency. This holistic approach not only enhances operational performance but also fosters a positive workplace culture. Furthermore, the findings from Jadhav et al.

Burawat (2019) indicate that ergonomic considerations should be integral to the design of production processes in textile SMEs, as they can significantly influence overall productivity and employee morale.

3. Methods

3.1 Basis of the Proposed Model

In Figure 1, the production model based on Lean Manufacturing philosophy and Systematic Layout Planning (SLP) is presented. This model aimed to address operational inefficiencies in textile SMEs by integrating method studies, ergonomic approaches, and layout redesign to optimize production processes. The Lean Manufacturing philosophy guided the model's focus on eliminating waste, improving workflow, and enhancing productivity through continuous improvement strategies. SLP principles were employed to redesign the workspace layout, ensuring efficient space utilization and reducing travel times. The ergonomic approach was incorporated to address human factors, such as minimizing physical strain and stoppages due to non-ergonomic conditions, which contributed to unproductive times. The study of methods was used to standardize work processes, ensuring that operational tasks followed a structured and repeatable format. The overarching goal of the model was to increase efficiency by streamlining production activities, reducing unnecessary movement, and improving overall operational flow. By focusing on these key areas, the model aimed to create a more effective and efficient production system, ultimately contributing to higher productivity and standardized work practices in textile SMEs.

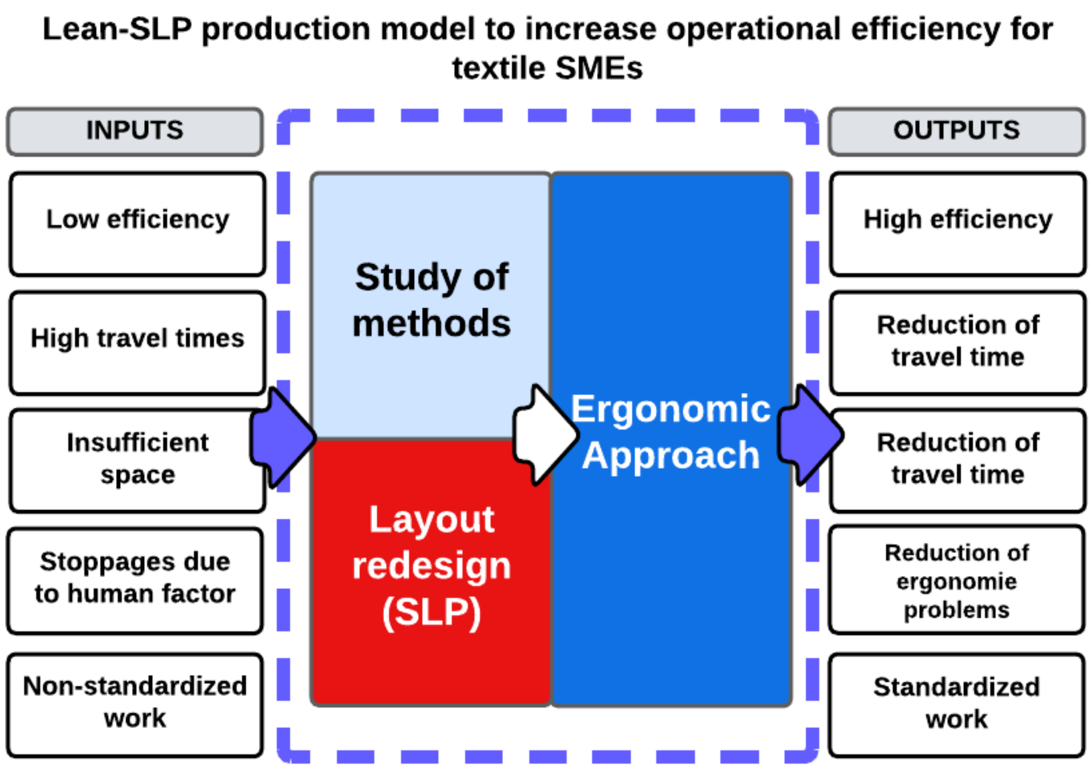

Figure 1. Proposed Model

3.2 Description of the model components

The proposed production model, based on the philosophies of Lean Manufacturing and Systematic Layout Planning (SLP), represents a significant contribution to existing literature, especially in the context of small and medium-sized enterprises (SMEs) textiles. While Lean Manufacturing has been widely recognized for its ability to eliminate waste and improve operational efficiency, and SLP has historically been used to optimize the use of space in industrial facilities, The integration of these approaches with an ergonomic perspective adds an additional layer of value by addressing not only the productive aspects but also the human factors that influence the overall efficiency of the system. In addition, the methodological approach used in this model makes use of studies of traditional methods to standardize work and reduce operational variability, thus complementing lean strategies. This model therefore offers a comprehensive solution that combines process improvement, spatial optimization and human factor management, providing a holistic approach to addressing operational challenges in textile SMEs. The key stages of the model are described below, highlighting their relevance and specific contributions to operational improvement.

C1: Study of Methods

The first component of the model was the study of methods, which aimed to standardize operations and reduce variability in production processes. Based on the lean philosophy, the method study focused on identifying activities that did not generate added value and could be eliminated or improved. According to the principles of Lean Manufacturing, process standardization is fundamental to ensure consistency and repeatability, leading to continuous improvement (Womack & Jones, 2003). This study included a detailed analysis of the operational tasks performed by the workers, evaluating each step of the process to identify opportunities for simplification and elimination of unnecessary activities.

At this stage, a detailed analysis of the time and movements of workers was carried out using traditional techniques such as process diagram and time study (Heizer & Render, 2014). This allowed the identification of bottlenecks and redundancies which were not evident in a superficial review of the process. The study of methods was key to reducing delays and eliminating non-value-adding activities, resulting in greater efficiency on the production line. The use of the method study also allowed a systematic approach to evaluate and adjust the workflow, minimizing variability between operators.

C2: Layout Redesign (SLP)

The redesign of the layout, based on the principles of Systematic Layout Planning (SLP), was the second essential component of the model. The SLP philosophy proposes a structured methodology to optimize space use in production plants, which is particularly critical for textile SMEs facing physical constraints at their facilities. The main objective of this stage was to reduce transfer times and improve material flow within the plant. The layout redesign followed a systematic planning approach in which activities were organized according to their functional relationships, avoiding unnecessary movement and ensuring that resources were efficiently arranged (Muther, 2015).

During the implementation of the layout redesign, key factors such as workflow, workstation layout and accessibility of storage areas were considered. Through an analysis of activity relationship diagram (Muther, 2015), the ideal proximity between different workstations was determined, thus minimizing unnecessary displacements of materials and semi-finished products. This not only helped to reduce transfer times, but also improved the ergonomics of workers who experienced a decrease in the distances they had to cover during their shifts.

The use of SLP also allowed for an optimization of available space, maximizing its utilization by organizing workstations and storage areas more efficiently. This approach has been proven effective in multiple studies that highlight the importance of good plant design to improve efficiency and reduce operating costs (Kovács et al., 2019).

C3: Ergonomic Approach

The ergonomic approach was another key component of the proposed model. While Lean Manufacturing and SLP focus on waste elimination and space optimization, the integration of an ergonomic perspective ensures that human factors are taken into account, This is essential for the sustainability of any long-term operational improvement (Konz & Johnson, 2015). In the context of textile SMEs, where workers often face demanding physical conditions, an ergonomic approach is crucial to reducing fatigue and health problems related to repetitive work.

During this stage, the working conditions of the operators were evaluated, especially in terms of posture, repetitive tasks and physical load to which they were exposed. The ergonomic analysis included identifying factors that contribute to unscheduled rest or breaks due to physical fatigue, resulting in unproductive times. Adjustments were made to the height of the workstations, improved tool layouts and scheduled ergonomic breaks introduced to ensure that operators had enough time to recover from accumulated fatigue (Konz & Johnson, 2015). This approach not only reduced the number of unscheduled breaks, but also improved workers' overall well-being, resulting in higher productivity.

C4: Integration of Lean Principles

The integration of Lean Manufacturing principles throughout the different stages of the model ensured that each component was aligned with the goal of eliminating waste and increasing efficiency. The lean philosophy, as defined by Womack and Jones (2003), is based on value creation through the elimination of activities that do not contribute to the final result. In this model, lean principles were applied both in the stage of method study and in the redesign of the layout and ergonomic approach, ensuring that the improvements made contributed to the overall efficiency of the system.

One key principle applied was the continuous flow concept, which was ensured by optimizing the layout and standardizing tasks. By improving workflow and reducing moving times, lead times and unnecessary inventory hoardings were reduced. In addition, the reduction of process variability achieved through standardization allowed for more precise control over production times, resulting in improved predictability and consistency of results.

C5: Continuous Improvement and Monitoring
Finally, the model included a continuous improvement and monitoring component, in line with lean kaizen principles, which suggest that there is always room for process optimization (Imai, 1986). Once initial improvements were implemented, a system of constant monitoring was established to assess the effectiveness of interventions and make adjustments as necessary. Performance indicators such as cycle time, transfer times and downtime were regularly monitored to ensure that the implemented improvements had a positive long-term impact.

This approach of continuous improvement ensured that the production system not only achieved the objectives set, but also had the capacity to adapt to changes in demand, production or working conditions. In addition, the active participation of workers in the continuous improvement process fostered a culture of responsibility and empowerment, contributing to the long-term sustainability of the model.

3.3 Model Indicators
To assess the effectiveness of the Lean-SLP production model implemented in textile SMEs, custom metrics were developed to track and evaluate performance throughout the case study. These metrics provided a comprehensive framework for analyzing the critical components of textile operations within the context of SMEs. The structured approach allowed for a thorough review of key indicators such as overproduction level and delivery error rate, providing valuable insight into the operational efficiency and accuracy of the implemented model. This evaluation was crucial to identify areas for improvement and ensure that the management model is adapted to the specific needs and challenges of the textile industry.

Line Efficiency: Refers to the ratio of productive time over the total available time in a production line, considering the number of stations and the cycle time. It reflects how well the line utilizes time for production activities.

$$\text{Line Efficiency} = \left(\frac{\text{Time of Activities}}{\text{Number of Stations} \times \text{Cycle Time}}\right) \times \mathbf{100} \qquad (1)$$

Production Efficiency Index (PEI): Measures the actual production output in relation to the expected production. It is used to assess the overall efficiency of the production system by comparing real versus expected results.

$$\text{Production Efficiency Index} = \left(\frac{\text{Actual Production}}{\text{Expected Production}}\right) \times \mathbf{100} \qquad (2)$$

Percentage of Times Outside Control Limits: Indicates the proportion of measured times that deviate beyond established control limits. This metric reflects the stability of processes and how often they operate outside predefined acceptable ranges.

$$\text{Percentage of Times Outside Control Limits} = \left(\frac{\text{Times Outside Control Limits}}{\text{Number of Measured Times}}\right) \times \mathbf{100} \qquad (3)$$

Space Utilization Compliance Level: Evaluates how well the actual physical space used in production complies with the theoretical space requirements. It is crucial for ensuring that resources are used efficiently within available space constraints.

$$\text{Space Utilization Compliance Level} = \left(\frac{\text{Actual Area Used}}{\text{Theoretical Area}}\right) \times \mathbf{100} \qquad (4)$$

Percentage of Transfer Time: Refers to the portion of the total production time spent on moving products or materials between stations or locations. Lower transfer times indicate better workflow efficiency and less waste in material handling.

$$\text{Percentage of Transfer Time} = \left(\frac{\text{Transfer Time}}{\text{Production Time}}\right) \times \mathbf{100} \tag{5}$$

Percentage of Ergonomic Breaks: Measures the amount of time allocated to ergonomic rest periods for workers, which is essential for reducing fatigue and improving long-term productivity and safety in the workplace.

$$\text{Percentage of Ergonomic Breaks} = \left(\frac{\text{Break Time}}{\text{Production Time}}\right) \times \mathbf{100} \tag{6}$$

4. Validation

4.1 Validation Scenario

The validation scenario was carried out in a case study focusing on a micro-enterprise in the textile sector located in Perú. This company specialized in manufacturing clothing items for medical personnel, including jackets, aprons, and pants, with its flagship product being the polar fleece jacket, representing 75% of total sales. The company employed nine workers, six in operational roles and three in administrative positions. It faced significant challenges in meeting customer orders within the required timeframes, leading to annual losses exceeding 45,000 soles. The main inefficiencies identified were related to work method design, accounting for 78% of the causes of low production efficiency, and musculoskeletal issues and poor plant layout, which contributed to 17% of the problem. The study aimed to address these inefficiencies by implementing a model combining method studies, Systematic Layout Planning (SLP), and ergonomic approaches to increase production efficiency and reduce operational bottlenecks.

4.2 Initial Diagnosis

In Figure 2, the problem tree outlines the diagnostic conducted in the case study to identify the root causes behind low efficiency in garment manufacturing. The efficiency rate of the case study was 31%, significantly below the industry standard of 60%, resulting in an annual economic impact of 45,619 PEN, or 36% of the company's revenue. The analysis revealed two primary causes at Level 1: inefficient work design (78.42%) and high unproductive times (17.20%). These factors contributed to inefficiencies in the production process. At Level 2, the root causes of inefficient work design were identified as the sequence of differentiated activities (61.20%), non-standard production times (17.22%), excessive movement due to inadequate workstation layout (5.45%), and high material transfer times (3.86%). Additionally, the root causes of high unproductive times included rest stops due to non-economic conditions (7.89%) and other minor reasons (4.38%). The goal of this diagnostic approach was to quantify the factors leading to inefficiency, enabling a clear understanding of how operational design and time management issues affected overall productivity, and providing the foundation for targeted interventions to improve efficiency in garment manufacturing processes.

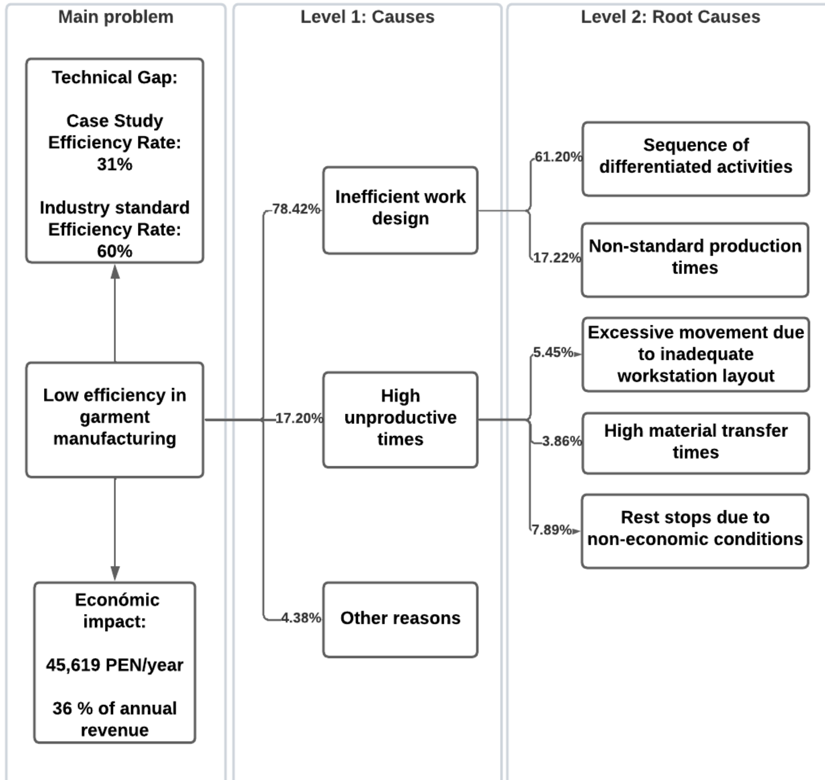

Figure 2. Problem Tree

4.3 Implementation of the model in the case study

The detailed solution design implemented in the case study sought to address critical inefficiencies in the production process of a textile micro-enterprise, which faced significant challenges in meeting customer demand, maintaining production efficiency, and reducing operational costs. The enterprise, located in Perú, specialized in manufacturing clothing for medical personnel. Despite the company's steady product demand, inefficiencies in workflow, poor ergonomic conditions, and an unoptimized plant layout contributed to delays, excessive production times, and high defect rates. These issues directly impacted the company's profitability, leading to losses of over 45,619 soles annually due to unmet customer orders and operational inefficiencies.

The solution was designed to integrate Lean Manufacturing principles, Systematic Layout Planning (SLP), and ergonomic improvements to create a comprehensive model that not only increased production efficiency but also enhanced the well-being of the workers. By focusing on eliminating waste, optimizing the plant layout, and improving working conditions, the solution aimed to streamline production activities and reduce non-productive times. The approach ensured that improvements were not only technical but also addressed human factors that could affect long-term sustainability. Each component of the solution played a key role in creating a more efficient, productive, and worker-friendly environment, contributing to the company's overall competitiveness in the local market.

Improvement of Method Proposal: The proposed solution began with an exhaustive analysis of the operational processes in the case study, focusing on identifying non-value-adding activities and eliminating inefficiencies. Through the application of time and motion studies and Activity Diagrams (DAP), key bottlenecks were identified, such as excess handling time and unnecessary transportation between workstations. The average processing time for specific tasks was reduced by 35% after redistributing tasks and sequencing operations more logically. The method standardization process included the creation of standardized work instructions for each operator, ensuring a uniform approach to every task and reducing variability in performance. Before implementation, task performance times ranged widely, with some tasks taking up to 45% longer than average. After standardization, this variation was minimized to a difference of less than 10%. Furthermore, these improvements contributed to a 21% reduction in overall production lead time, allowing the company to better meet customer delivery deadlines. The reorganization of tasks also led to a 22% increase in labor productivity, as operators could complete tasks faster and with fewer interruptions. The overall reduction in non-productive activities, such as waiting for materials or excessive movements, contributed directly to a more streamlined production process.

Figure 3 illustrates the standardization of working methods for the production of garments, specifically focusing on the process for making polar and regular jackets. The left side shows a detailed operations diagram (DOP), outlining each step in the production process, from cutting fabric to final assembly and quality inspection. This diagram provides a clear sequence of activities, identifying key tasks and decision points, ensuring that all workers follow a consistent approach to garment production. On the right side, the final product outcomes for both a polar jacket and a regular jacket are displayed, providing visual confirmation of the expected results. The standardization aims to reduce variability in production, improve consistency, and increase overall efficiency. By implementing these standardized procedures, the company ensures that garments are produced to meet quality standards while optimizing production time and minimizing errors. The visual guides also help workers clearly understand the expectations for the finished products.

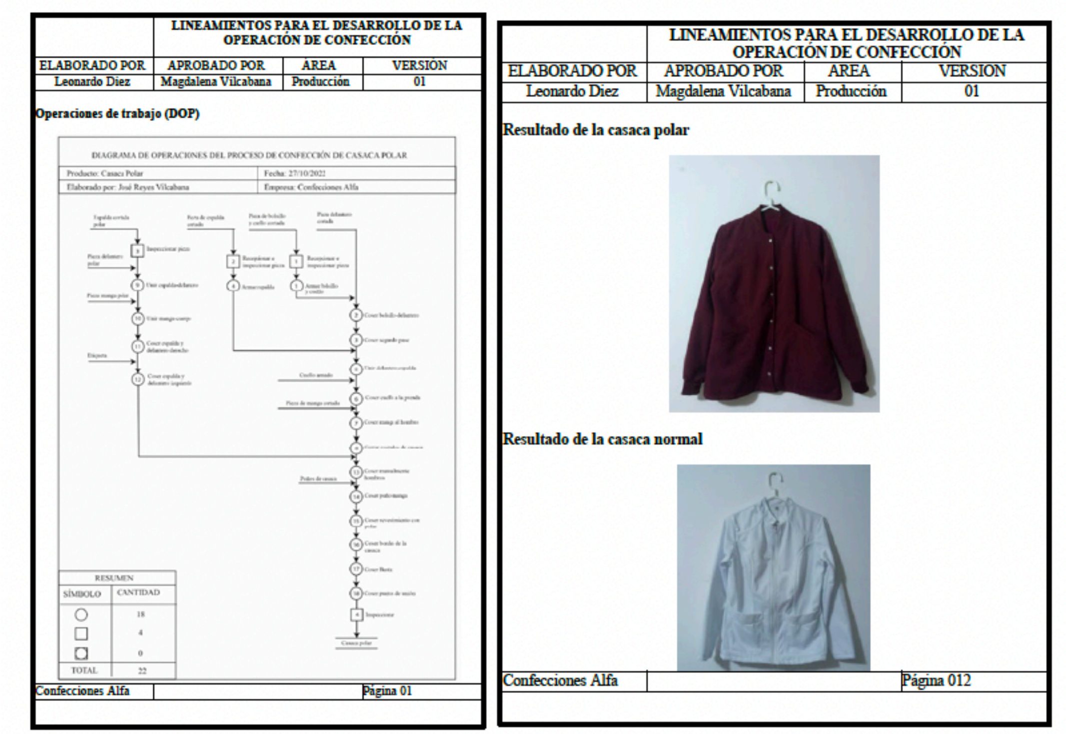

Figure 3. the standardization of working methods for the production of garments

Plant Layout Redesign: A systematic layout planning (SLP) approach was applied to optimize the physical arrangement of the production area. Prior to the redesign, the layout exhibited inefficiencies due to the poor positioning of workstations, which caused operators to walk long distances between stations. For example, the average distance traveled by an operator between sewing and cutting stations was over 25 meters, contributing to a 12% increase in production time due to unnecessary movement. After applying the SLP methodology, workstations were rearranged to ensure a smoother workflow and shorter distances between sequential tasks. The new layout reduced the average walking distance to less than 10 meters, translating into a 58% reduction in travel time. Additionally, the workspace allocation was restructured to comply with ergonomic and operational standards, achieving an 85% space utilization compliance rate, compared to 60% before the redesign. The improved layout also allowed for better material flow, reducing idle time between processes by 14%. As a result of these changes, the overall efficiency of material handling improved, with a 28% reduction in the time required to move raw materials and finished products throughout the facility. Furthermore, the new layout allowed the company to free up 15 square meters of previously underutilized space, which could now be used for additional storage or future production expansion.

Figure 4 presents the proposed layout for the production area of the case study, designed to optimize workflow, reduce unnecessary movements, and improve overall efficiency. The layout shows distinct sections, including areas for material storage (Section I), cutting (Section C), sewing (Sections E, F, and G), and finishing (Section H). The arrows indicate the streamlined movement of materials through the production process, starting from the entry of raw materials (Area A) and proceeding through various workstations with minimal backtracking. Key improvements include the relocation of workstations to reduce travel distances between tasks, especially between the cutting and sewing sections. The optimized layout also enhances space utilization, with storage areas (L and M) strategically positioned near the production flow to ensure easy access to materials. Furthermore, ergonomic considerations are evident in the arrangement of workstations, allowing operators to work more comfortably while minimizing physical strain. This new layout is expected to significantly decrease production lead times and enhance the overall productivity of the facility.

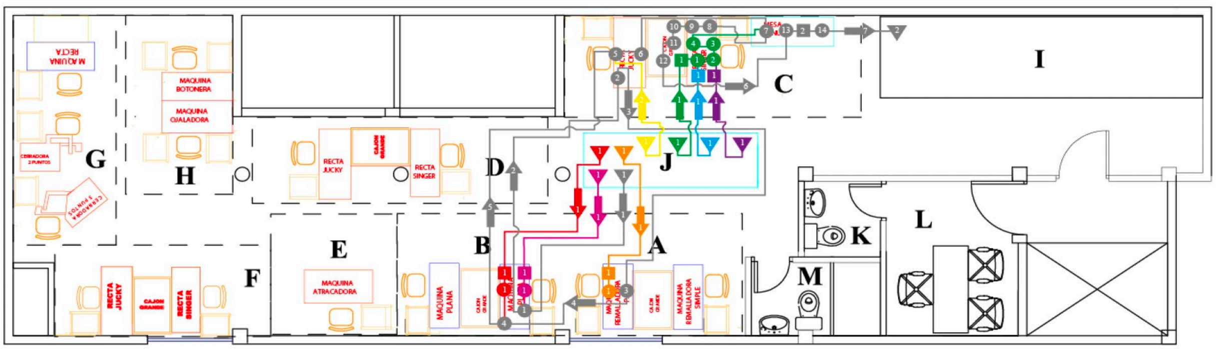

Figure 4. Proposal Layout

Ergonomic Approach: The ergonomic component of the solution was crucial to ensuring sustainable improvements in worker productivity and health. An ergonomic assessment of the operators' workstations was carried out using tools such as RULA (Rapid Upper Limb Assessment) and REBA (Rapid Entire Body Assessment). These assessments revealed that 60% of the workstations posed a high risk for musculoskeletal disorders due to poor posture and repetitive movements. As part of the solution, workstations were redesigned to improve operator posture, reduce repetitive strain, and minimize awkward body positions. Adjustable chairs and tables were introduced, allowing operators to modify their workspaces to suit their individual needs, thus reducing physical strain. Additionally, tools and materials were repositioned to be within easy reach, cutting down on unnecessary bending and stretching. As a result of these ergonomic interventions, the risk level for musculoskeletal disorders dropped by 40%, according to post-intervention RULA and REBA scores. Operators also reported a significant decrease in physical discomfort, with 75% of them indicating improved comfort during their shifts. The reduction in discomfort directly contributed to a decrease in non-scheduled rest breaks, which dropped by 16%. This improvement in ergonomic conditions not only enhanced operator well-being but also led to a 12% increase in continuous production time, as operators were able to work for longer periods without needing breaks due to physical fatigue. Moreover, the implementation of scheduled ergonomic breaks, designed to allow operators to rest and recover without affecting production, further improved overall worker satisfaction and productivity.

Figure 5 displays the proposal for an ergonomic worktable designed to improve operator comfort and reduce physical strain during production tasks. The exploded view shows the different components of the table, including the tabletop (Element 1), table base (Element 2), support frame (Element 3), and fastening hardware (Element 4). The table has been designed with adjustable features, allowing operators to modify the height to suit their ergonomic needs, promoting better posture and minimizing the risk of musculoskeletal issues. The robust structure of the table ensures stability while in use, and the inclusion of ergonomic adjustments aligns with best practices for reducing operator fatigue during long shifts. This design was developed specifically to address the ergonomic concerns identified in the production process, ensuring that the workspace is not only efficient but also conducive to maintaining worker health and productivity over time.

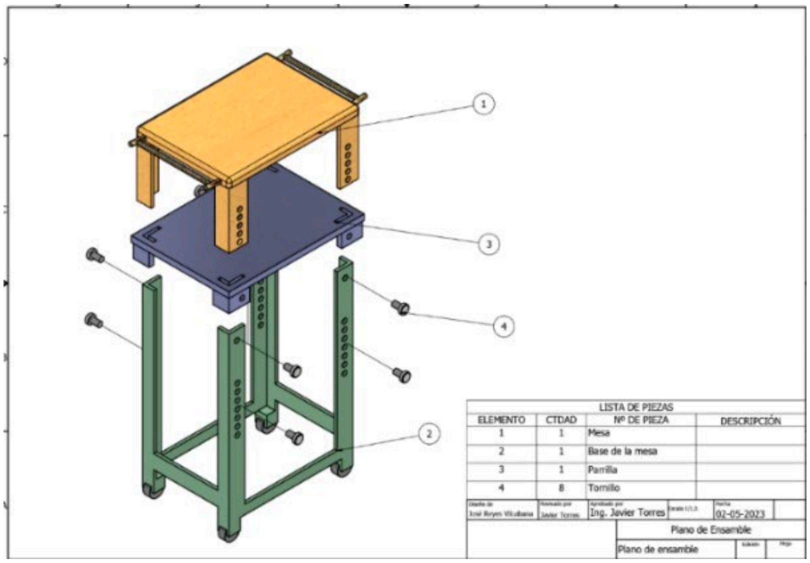

Figure 5. Proposal for an ergonomic worktable manual

Figure 5 illustrates the detailed plan for the ergonomic table, showing the dimensions and structure of its components. The top-left section provides a top-down view of the table, indicating the exact width and length measurements, while the side views display the height and depth of the table legs and support structures. Precise measurements are provided for key elements such as the table surface, leg spacing, and the adjustable height slots that allow the table to be customized to suit the operator's needs. The design emphasizes adjustability and durability, with clear specifications for each component, ensuring stability and ergonomic flexibility. This detailed plan serves as a guide for constructing the ergonomic table, focusing on reducing operator fatigue by allowing height adjustments and promoting better posture during work tasks. The careful attention to measurements ensures that the table will meet both ergonomic standards and the functional requirements of the production environment.

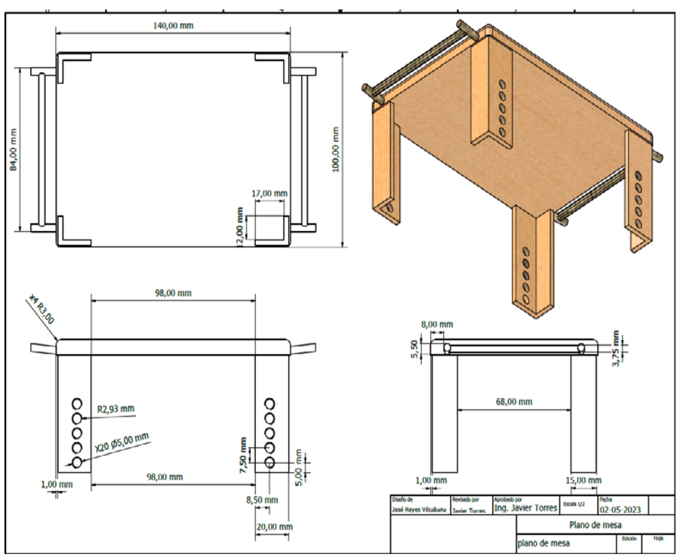

Figure 6. Plan of the ergonomic table

Production Efficiency Improvement: The culmination of the method improvements, layout redesign, and ergonomic adjustments resulted in significant gains in production efficiency (Figure 6). Prior to the intervention, the company's production efficiency was measured at 31%, far below industry standards. After the detailed solution design was implemented, production efficiency increased to 69%, representing a 122% improvement. This efficiency gain was primarily driven by the reduction in cycle time, which decreased from an average of 6.5 minutes per garment to 3.8 minutes. Additionally, the number of defective products produced per batch was reduced by 18%, as the standardized methods and improved workflow minimized errors and rework. The company also experienced a 26% increase in throughput, allowing it to produce more garments in less time, which enabled it to fulfill customer orders more promptly and reduce order backlogs. The overall improvement in production efficiency contributed to a 10% reduction in operational costs, as fewer resources were wasted on rework and downtime, and labor productivity increased. The success of the detailed solution design underscored the effectiveness of integrating Lean Manufacturing principles, ergonomic improvements, and systematic layout planning in addressing the operational challenges faced by the case study.

5. Results

In Table 1, the key results of the Lean-SLP production model validation for textile SMEs are shown. Line efficiency increased by 122.58%, significantly improving production processes, while production efficiency rose by 26.87%. The theoretical space compliance level decreased by 36.21%, suggesting reduced space utilization contributed to overall efficiency gains. Additionally, out-of-time out-of-control times improved by 94.67%, indicating fewer deviations. Travel times and ergonomic rest rates decreased by 67.10% and 66.64%, respectively, enhancing workflow and productivity. These results demonstrate that the proposed model effectively addressed the operational challenges, optimizing both production and space utilization.

Table 1. Results of validation of the proposed model

Indicator	Unit	As-Is	To-Be	Results	Variation (%)
Efficiency of the line	%	31%	64%	69%	122.58%
Production efficiency rate	%	67%	88%	85%	26.87%
Theoretical space compliance level	%	58%	35%	37%	-36.21%
Rate of out-of-time out-of-control times	%	75%	146%	146%	94.67%
Rate of travel times	%	10%	3%	3.29%	-67.10%
Rate of ergonomic rest	%	14%	3%	4.67%	-66.64%

6. Conclusions

The main findings of this research highlight the significant improvements achieved through the implementation of Lean Manufacturing, Systematic Layout Planning (SLP), and ergonomic principles in the textile SME. The study demonstrated that the integration of these methodologies led to a 122% increase in production efficiency, reducing the average production time per garment from 6.5 minutes to 3.8 minutes. Additionally, labor productivity improved by 22%, and defects per batch were reduced by 18%. The ergonomic interventions also contributed to a 16% decrease in unscheduled rest breaks, enhancing continuous production time and reducing the risk of musculoskeletal disorders by 40%. These measurable results underscore the effectiveness of the comprehensive model applied to address operational inefficiencies in the case study.

The importance of this research lies in its direct impact on a crucial segment of the Peruvian economy: textile SMEs. Given the high demand for medical clothing and the increasing competition in the market, addressing inefficiencies in production was essential for the company's survival and growth. The integration of Lean Manufacturing and ergonomic approaches not only improved production efficiency but also promoted a healthier and more productive work environment. The research underscores the value of adopting systematic methodologies to optimize operations in a sector that has traditionally been challenged by resource limitations and suboptimal working conditions. By addressing these critical areas, the study contributes to both operational excellence and worker well-being.

This research contributes significantly to the field of industrial engineering by providing a practical framework for the application of Lean Manufacturing, SLP, and ergonomic principles in small-scale textile manufacturing. The integration of these methodologies offers a novel approach to improving both production efficiency and worker health in environments where resources are limited, and processes are often inefficient. The study's findings also contribute to the broader body of knowledge by demonstrating that even small-scale operations can benefit from sophisticated process improvement techniques, thereby reinforcing the relevance of Lean and ergonomic principles across different industries and company sizes. The research provides a clear blueprint for similar companies facing operational inefficiencies and emphasizes the importance of continuous improvement and worker-centric approaches in industrial settings.

The research's final observations suggest that while the implemented solutions significantly improved operational efficiency, there are still areas that warrant further investigation. For instance, the long-term sustainability of the ergonomic improvements should be monitored, particularly as production volumes increase. Future studies could explore the integration of digital tools, such as Industry 4.0 technologies, to further optimize production processes and enhance real-time monitoring of both efficiency and worker health. Moreover, the scalability of the proposed solutions in larger textile operations should be studied to evaluate their effectiveness across different company sizes. The findings from this study provide a solid foundation for future research aimed at refining and expanding the application of Lean and ergonomic principles in diverse manufacturing environments..

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Biographies

Airthon Jhair Julcarima-Perez has a degree in industrial engineering and has a strong background in supply chain management and logistics. He has been a leader in the supply chain and procurement industries, and a well-recognized leader in his field. He is currently in the purchasing department of a Peruvian company specializing in personnel transportation and vehicle rentals, where his responsibilities include speeding up acquisitions, engaging in strategic conversations with suppliers, and ensuring the efficient use of resources to achieve the company's objectives.

Alvaro Miguel Portal-Huayanca has a degree in industrial engineering with expertise in retail, energy and sales, and experience in commercial processes and data management. He currently works as Key Account Manager in a Peruvian company specialized in the distribution and marketing of healthy products to the retail and digital channel, seeking to improve its presence in the domestic market.