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Model to Improve Productivity in Footwear Manufacturing through PM, 5S, SW and SLP

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Abstract

In the Peruvian economy, the footwear industry is a key sector that contributes 0.12% to the national Gross Domestic Product (GDP) annually and generates 67,498 jobs. However, companies in this sector face challenges such as low efficiency in their processes. Therefore, this research aims to develop a model to improve productivity in the production process of a footwear manufacturing company. This study adopts a quantitative and empirical approach, applying observation techniques and data collection related to the production process to identify the main problem and determine its root causes using causal analysis techniques. Based on the literature review, the most suitable engineering tools were selected to contribute to the proposed solution, such as 5S, preventive maintenance (PM), standardized work (SW), and System Layout Planning (SLP). To validate the proposed solution, a pilot test was carried out along with a process simulation using Arena software. Meanwhile, the economic validation was conducted through risk analysis using @Risk software. As a result, productivity improved by 20%, machine availability reached 90%, non-productive times were reduced by 25%, and rework was eliminated. The contribution of this research lies in presenting a proposal that not only addresses the specific problems of a single company but is also replicable in other companies in the sector, reducing the effort required to achieve similar results.

Keywords
productivity, 5S, standard work, preventive maintenance, footwear industry

1. Introduction
The global footwear industry is undergoing significant transformations driven by increasing competition and evolving market demands. This dynamic environment has intensified competition, making operational efficiency and continuous productivity improvement essential for the sustainable development of companies in the sector (Santos and Escurra 2025).

In Peru, this reality is also reflected through specific industry characteristics (Benites et al. 2023). Although the footwear industry represents a modest share of the Gross Domestic Product (GDP), its economic and social impact is significant. According to the National Institute of Statistics and Informatics (INEI), in 2024 the manufacturing sector accounted for 12.7% of the national GDP, and within it, footwear manufacturing contributed S/ 883 million, equivalent to 0.12% of the total (Ministerio de Producción 2025). In addition, this industry generates more than 67,000 jobs and is highly concentrated in small and medium-sized enterprises, many of which operate under informal conditions and with poorly standardized processes (Sociedad de Comercio Exterior del Perú 2022)

Despite its potential, the sector faces structural challenges that limit its growth. Waste in production processes, bottlenecks, poor resource utilization, and external economic disruptions are among the main factors that reduce productivity and hinder its competitiveness and sustainability (Floríian and Floríian 2023).

In response to these challenges, various studies have promoted the adoption of industrial engineering tools such as continuous improvement methodologies and process optimization techniques. However, there is still a significant gap in the development of comprehensive models that integrate tools such as preventive maintenance, workplace organization and cleanliness, plant layout redesign, and task standardization.

This research focuses on a medium-sized Peruvian company specializing in the production of industrial and military safety footwear, located in the district of Ventanilla, Lima. With over 25 years of experience, the organization has demonstrated innovative capacity by incorporating materials such as Kevlar and composite toe caps. However, in recent years, it has faced operational problems that directly impact its productivity and competitiveness. In 2024, the average productivity was 0.30 pairs per man-hour, a figure below the industry standard. Likewise, machine availability reached only 78%, and more than 15,000 minutes were lost due to non-productive time associated with disorganization, unnecessary movements, and rework.

The scope of this study focuses on the cutting, stitching, and assembling stages of the production process, where the most significant bottlenecks and improvement opportunities have been identified. This analysis aims not only to address the specific problems of the evaluated company but also to offer a replicable model that contributes to strengthening the footwear sector in similar contexts.

Research Objectives

Given this situation, the main objective of the study is to develop a production management model aimed at improving productivity through the application of tools such as preventive maintenance, the 5S methodology, Systematic Layout Planning (SLP), and standardized work.

The specific objectives include increasing machine availability, reducing transportation and tool search times, eliminating rework in key operations such as stitching and gluing, and enhancing labor productivity. The structure of this research consists of the following elements: introduction, methodology, results, discussion, and conclusions.

2. Literature Review

This review considers four key tools that have proven to be effective in improving processes within manufacturing companies. They were selected for their ability to reduce nonproductive time, improve organization, prevent failures, and standardize activities, which are fundamental aspects for increasing productivity and operational efficiency.

A. 5S Methodology

In small and medium-sized enterprises, the implementation of the 5S tool is highly beneficial, as it enables the organization of the production process through order and cleanliness. In a medium-sized company in the footwear sector, its application reduced non-value-adding activities to 8%, thereby improving operational efficiency by minimizing idle time and unnecessary movements (Chinchay-Morales et al. 2022). In addition to promoting organization, this tool also directly contributes to improving process performance. In another women's footwear manufacturing company, a 66% improvement was observed in critical areas that previously caused bottlenecks as a result of its implementation (Ruiz et al. 2021). Finally, various studies highlight that its application generates significant benefits without requiring a large investment (Lira et al. 2021).

B. Systematic Layout Planning

The distribution of workstations in a manufacturing company is a key factor, as inadequate planning that does not consider the relationship between process areas can negatively impact productivity by generating unnecessary movements, idle time, and low operational efficiency. In this regard, a small women's footwear company in the city of Lima improved its competitiveness through the application of the Systematic Layout Planning (SLP) methodology. By redesigning and reorganizing its workstations and the placement of materials, it reduced the manufacturing time per dozen from 996 to 199.2 minutes (Romani et al. 2023). Similarly, another study showed that in a footwear company, the implementation of a new plant layout reduced the distances traveled by materials and operators by 31.80%, resulting in a direct decrease in production times. In one company, a more efficient layout was designed that reduced transport time by 34.01% and costs by 22.92% (Suhardi et al. 2019). These results reflect the impact of a new layout on the efficiency and productivity of the manufacturing process (Ruiz et al. 2021).

C. Preventive Maintenance

Many small and medium-sized companies face difficulties in their production processes due to unexpected machinery failures, which directly impact productivity and delivery times. In a footwear company, a Pareto analysis revealed that maintenance inefficiency accounted for 30.54% of the causes affecting plant performance, with over 200 hours of halted production due to machine failures. This is understandable, as the footwear manufacturing process heavily relies on the continuous use of equipment, and any interruption can create bottlenecks that disrupt the workflow. In some cases, breakdowns forced the complete stoppage of operations for one or two days. After implementing improvements in maintenance management, the company increased its machine availability to 95.85%, compared to the previously recorded 85.69%, reflecting a significant improvement in the reliability of the production system (Ortega et al. 2023). Additionally, in another footwear company, the implementation of a maintenance plan in the sewing area reduced failures in automatic machines from 18 to 5, equivalent to a 72.2% decrease. The analysis identified the main cause as the lack of basic maintenance knowledge among personnel, which led to nonproductive time (Reyes et al. 2018). Finally, it is important to note that preventive maintenance significantly contributes to reducing operating costs, as it helps minimize recurring failures, avoid major repairs, reduce downtime, and optimize the use of spare parts and technical resources. It also enables better work control through the application of proper programs and procedures (Mendoza et al. 2025).

D. Standard Work

Standard Work consists of specific instructions that allow the production process to be carried out efficiently, and its implementation helps reduce unit costs, improve demand fulfillment, and minimize cycle times and unnecessary movements. In a proposal aimed at increasing productivity in a leather footwear company, the implementation of this tool reduced manufacturing time per dozen from 996 to 199.2 minutes, strengthening the company's competitiveness in the sector (Ministerio de Producción 2025). Additionally, in another study, the application of improvements based on standardization reduced rework in the lasting stage from 11.70% to 2.80%, and in the sole stitching area from 29.94% to 10.03%, reflecting significant progress in both process quality and waste reduction (Chinchay-Morales et al. 2022)

3. Methodology

This study proposes a comprehensive productivity improvement model structured into three operational phases and one control stage, specifically designed to optimize processes in a manufacturing company within the footwear sector. The development of the model was based on an empirical and quantitative approach, supported by real data obtained through direct observation, staff interviews, and systematic records of times and activities. Based on this initial diagnosis, the cutting, stitching, and assembling stages were identified as priority areas for intervention. Then, through an analysis using the tool-to-root-cause linkage matrix in Table 1, industrial engineering tools were selected: the 5S methodology, Systematic Layout Planning (SLP), Standard Work (SW), and Preventive Maintenance (PM).

The proposed model is divided into three phases and one control stage. See Figure 1.

Phase 1: Define, Measure, Analyze. This first phase focused on thoroughly understanding the company's production process and identifying the specific causes that limited its performance. To this end, a detailed diagnosis was conducted, combining direct on-site observation, interviews with operational staff, and manual time recordings for each activity. The collected data made it possible to calculate key indicators such as labor productivity, which reached a value of 0.30 pairs per man-hour, revealing low performance compared to expected standards. High levels of nonproductive time, a high frequency of machine failures, and constant rework, particularly in the assembly stage, were also identified. To structure and prioritize this information, two essential tools were applied: the Pareto Diagram, which allowed the visualization of the problems causing the greatest losses in time and resources, and the Problem Tree, which facilitated the identification of root causes. This comprehensive analysis confirmed that the main sources of inefficiency were in the cutting, stitching, and assembling areas, thereby providing the basis for selecting the most appropriate improvement tools to be applied in the following phases

Table 1. Relationship matrix between identified root causes and techniques

	Article			
Causes	**High number of technical failures**	**High total material transfer time**	**High Time Required to Locate Tools**	**Omission in completing the sewing process**
Chinchay-Morales et al. (2022)			5S	SW
Romani et al. (2023)			5S	SW
Ortega et al. (2023) Reyes et al. (2018)	MP			
Ruiz et al. (2021)		SLP		
Proposal	**MP**	**SLP**	**5S**	**SW**

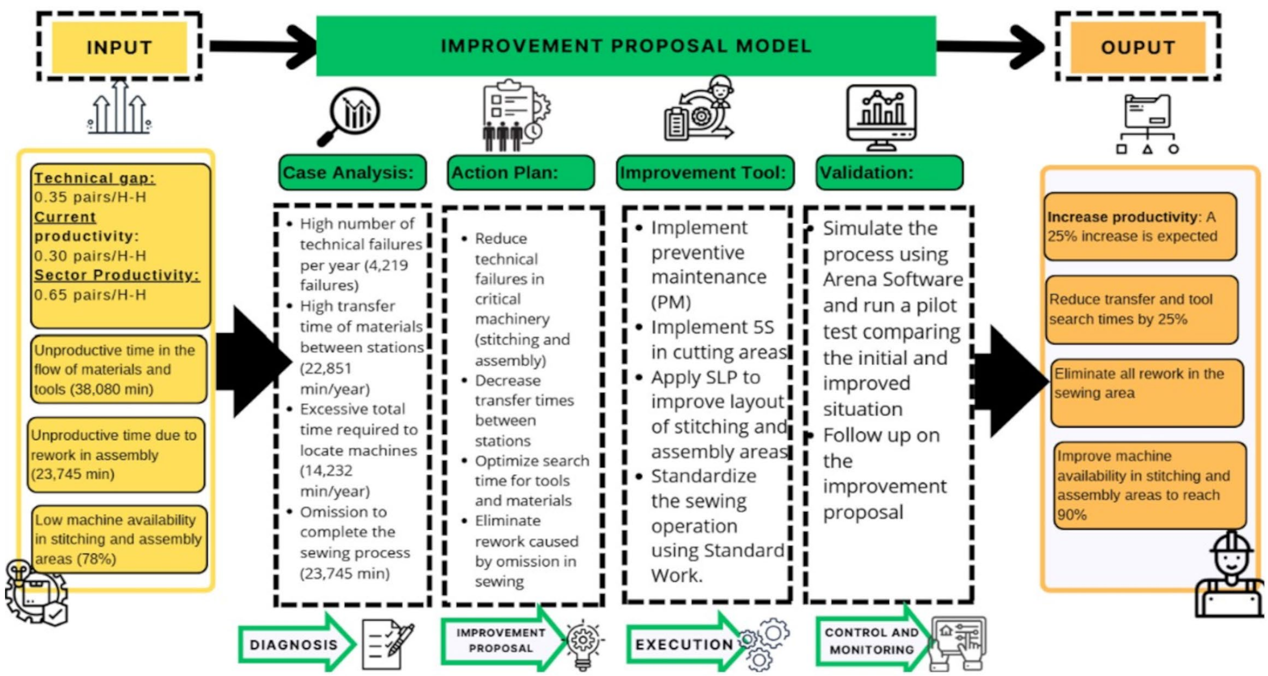


Figure 1. Proposed Model and Solution

Phase 2: Conditioning. To iniate the conditioning phase in the identified critical areas, the necessary conditions for improvement were established through the application of the 5S tool. This methodology is built upon five principles: sort, set in order, shine, standardize, and sustain. The implementation of 5S began with an audit to assess workshop conditions, and a color-coded card system was applied: red for items to be discarded, green for relocation, and yellow for repair. In addition, a comprehensive cleaning plan was developed along with a periodic follow-up plan aimed at maintaining order and preventing the return of poor practices. As a result, nonproductive time caused by the search for tools and materials was reduced.

Phase 3: Improvement. In this phase, three industrial engineering tools were applied in an integrated manner, aimed at eliminating the root causes identified in the diagnosis. The first intervention involved the application of Systematic Layout Planning (SLP), a tool focused on redesigning the plant layout to optimize material flows and reduce unnecessary movements, which in the initial situation accounted for 22,851 minutes of lost time per year. Through the analysis of relationships between activities and distances, a new layout was proposed to minimize time and inefficient movements. Subsequently, Standard Work (SW) was implemented. This tool enabled the standardization of operational processes based on the new layout design. Through standardization, rework caused by omissions or incorrect sequences in production was eliminated. Previously, these issues led to 23,745 minutes of annual losses, affecting delivery times and the efficient use of resources. Finally, Preventive Maintenance (PM) was incorporated as a strategic tool to improve machine availability, which previously stood at only 78%. A systematic plan was established for the inspection, adjustment, and scheduled maintenance of critical equipment, with the goal of achieving availability above 90%, thereby significantly reducing the 726,000 minutes of annual downtime that affected production continuity.

Phase 4: Control. The control phase was a key component of the model, aimed at ensuring the sustainability and permanence of the improvements achieved in the production process. To this end, a monitoring system was established based on key performance indicators, allowing continuous evaluation of the achieved results. The selected indicators were labor productivity, machine availability, transportation time, nonproductive time, and the percentage of rework, all of which were directly linked to the objectives of the intervention. See Table 2.

Table 2. Key Performance Indicators

Indicator	**Formula**
Produced pairs	Total pairs produced
Operational Availability (%)	(Actual operating time/ Total scheduled time) *100
Pairs reprocessed	∑ Pairs reprocessed
Average transfer time (min/doz)	Total transfer time / Total dozens produced
Average search time per event	∑ Search time / number of events

To quantitatively validate the impact of the improvements and anticipate the future behavior of the system, the Arena simulation software was used. This tool facilitated the creation of a representative model of the optimized process. The simulation enabled an objective comparison between the initial scenario with the improved one, revealing significant progress in each of the analyzed indicators. To complement this analysis, a comparative results table was developed, clearly reflecting the positive effect of the implemented interventions.

This control system not only enabled the verification of the effectiveness of the implemented actions but also provided a solid foundation for the early detection of deviations or new improvement opportunities. By ensuring the continuity of results over time, this phase contributed to the consolidation of a culture of continuous improvement within the organization. Furthermore, the proposed model proved to be a viable and adaptable strategy for other micro and small footwear companies facing technological limitations, enabling them to improve their productivity and competitiveness through the integrated application of Lean Manufacturing tools.

Validation

A. Initial Diagnosis

To validate the functional effectiveness of the proposal, an initial diagnosis was conducted focusing on identifying the main deficiencies affecting the productivity of a microenterprise dedicated to the manufacturing of safety footwear. Through direct observation, analysis of historical records, and staff interviews, high levels of nonproductive time, frequent rework, unnecessary movements, and low machine availability were detected. To structure these findings, a Problem Tree was developed, which clearly illustrated the root causes and guided the selection of the most appropriate improvement tools. See Figure 2.

B. Selection method of validation

To validate the effectiveness of the proposal without interrupting actual operations or compromising resources, simulation using Arena software was selected as the most appropriate validation method. This choice responded to the need for a controlled, flexible, and low-risk environment that would allow for a quantitative evaluation of the "As-Is" and "To-Be" scenarios. The simulation enabled a detailed comparison of the key performance indicators defined for the study, highlighting the real impact of the proposal on system outcomes.

C. Research Methodology

The defined unit of analysis was the number of footwear pairs produced, as it objectively and directly represents the behavior of the production system. The population consisted of all footwear pairs manufactured on production line S06 during the year 2024, totaling 128,138 units. A representative sample size of 384 pairs was determined using a statistical approach for finite populations, ensuring the validity and reliability of the results.

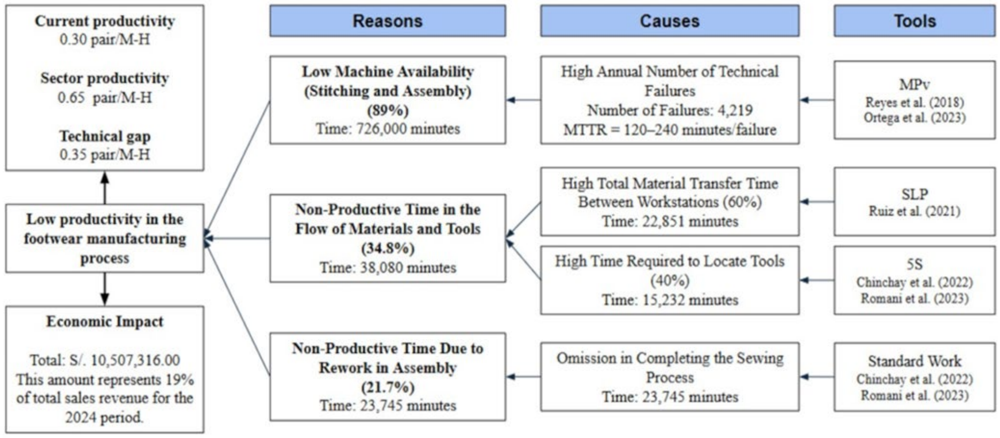


Figure 2. Linkage Between Improvement Tools and Root Causes

A non-probability convenience sampling method was applied, selecting complete and representative records of the production process under normal conditions. Only valid data from the model were included, excluding incomplete, defective records or those belonging to other production lines. The functional model was built using Arena software, replicating the main operations of the footwear production process; See in Figure 3. The key system resources were identified and modeled, with specific attributes assigned to the entities. In addition, statistical distributions were applied to each operation using the Input Analyzer, ensuring an accurate simulation of the real system behavior.

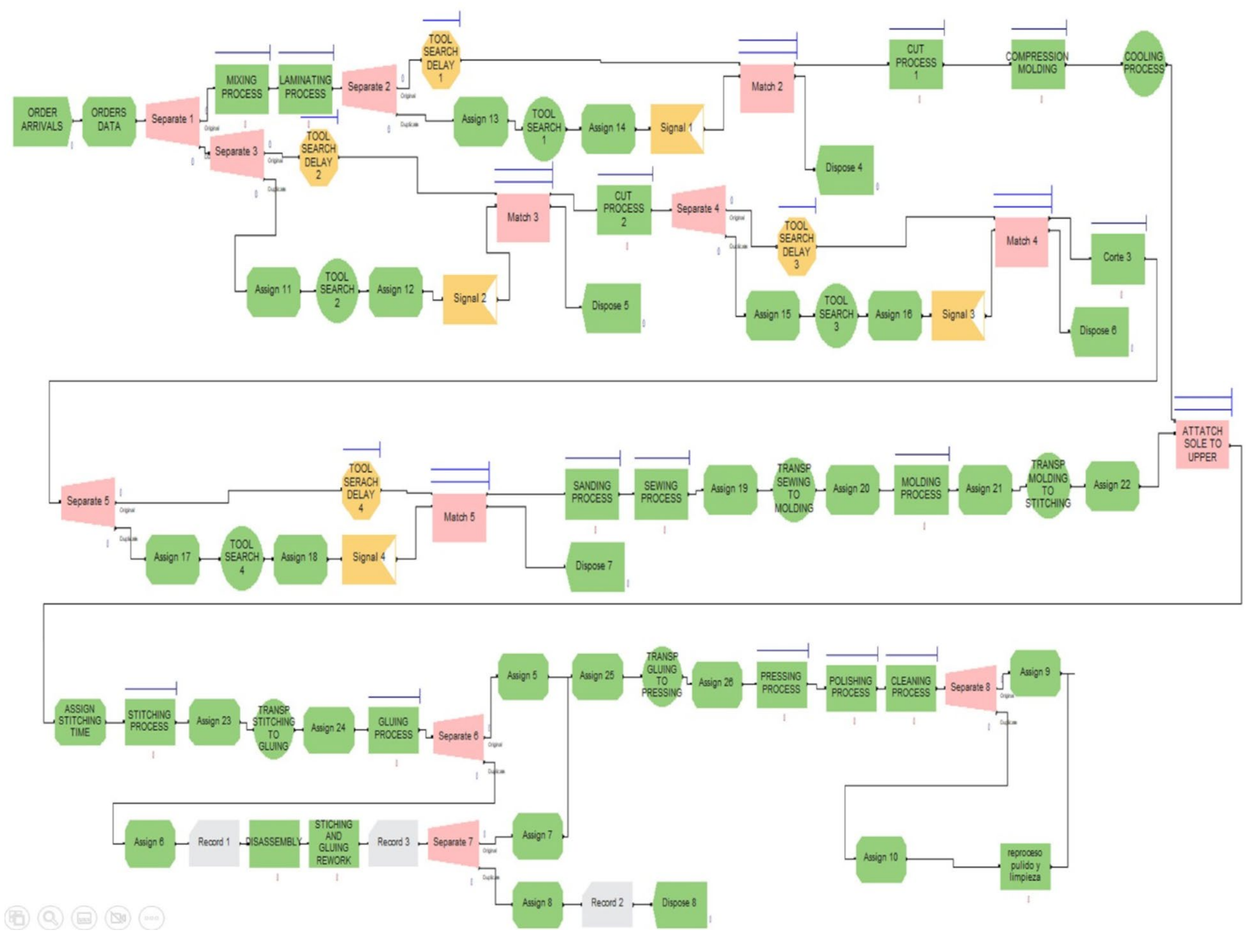


Figure 3. Proposed model simulated

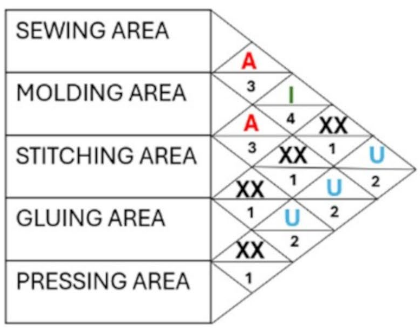
D. Improvement Proposal and Validation

The improvement proposal focused on the integration of four key tools that, together, made it possible to optimize the production process and reduce the deficiencies identified during the diagnosis. First, the 5S tool was simulated by reducing nonproductive time associated with the search for tools, implementing a control system with attributes and variables that reflected the improvement in workflow. Next, Systematic Layout Planning (SLP) was applied to redesign the plant layout, which allowed for the optimization of movements between processes. See Figure 4 and 5.

The new transport times were adjusted in the model to reflect this improvement in operational efficiency, in Figure 5. Subsequently, the Standard Work tool was represented through logical control that ensured the correct sequential execution of operations, preventing omissions and eliminating the rework observed in the initial diagnosis. Finally, Preventive Maintenance was incorporated by scheduling two exclusive hours per week for equipment inspection and adjustment, thereby ensuring greater machine availability without affecting production capacity. Each of these tools was precisely modeled within the simulated environment, making it possible to demonstrate their positive impact on productivity, the reduction of nonproductive time, the decrease in rework, and the improvement in the availability of plant resources.

E. Master Validation Plan

The Master Validation Plan was structured in three stages: construction of the "As-Is" and "To-Be" models, execution of the simulations, and comparison of the results obtained. This approach ensured the validity, reliability, and applicability of the proposal, guaranteeing its feasibility for sustainable and replicable improvement without affecting the company's actual operations.



Activity	Symbol
SEWING AREA	1
MOLDING AREA	2
STITCHING AREA	3
GLUING AREA	4
PRESSING AREA	5

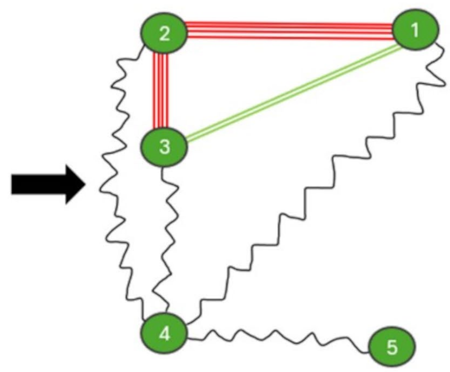


Figure 4. Activity Relationship Chart for the Stitching and Assembling Areas

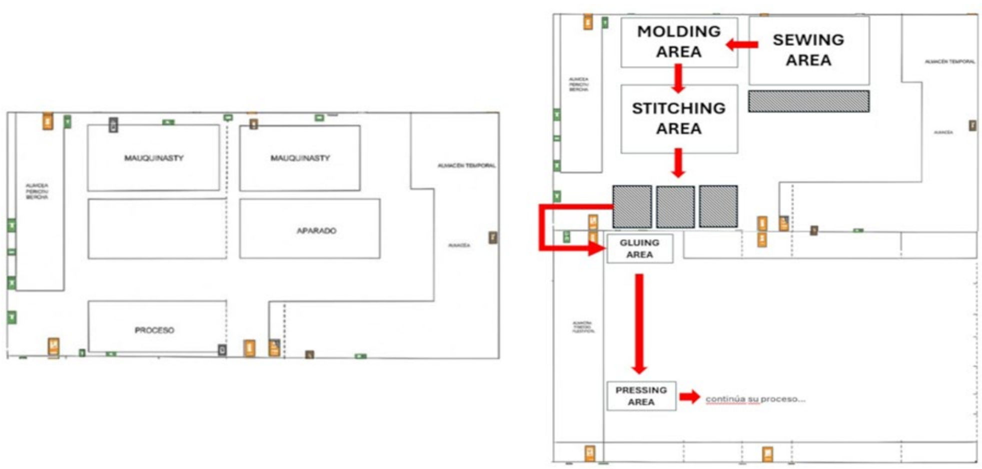


Figure 5. Current layout vs Proposed improved layout

4. Results and Discussion

To statistically validate the improvement proposal, Arena software was used, applying an approach based on the Central Limit Theorem. Initially, 30 replications of the model were executed, which allowed for the calculation of the first confidence intervals using the Half-Width (ho) value provided by Arena. Based on this value, the corresponding statistical formula was applied to determine the optimal number of required replications. This procedure was repeated three additional times, recalculating the Half-Width and the sample size in each iteration until reaching a final total of 162 replications. This value ensured the desired statistical precision and the reliability of the results obtained.

In the current scenario, 162 annual replications of the model without improvements were simulated. The main performance indicators were exported to Output Analyzer, where 95% confidence intervals were constructed. The baseline model showed low productivity, high transport and search times, and a high incidence of rework. These results reflected deficiencies in the system's efficiency and control, as shown in the results.

In contrast, the improved scenario incorporated industrial engineering tools such as Preventive Maintenance (PM), 5S, Systematic Layout Planning (SLP), and Standard Work. The 162 replications of the improved model demonstrated a significant increase in productivity, the complete elimination of rework, and a substantial reduction in transport and search times. The specific results are detailed in Table 3.

The comparison between both scenarios, based on 95% confidence intervals, statistically confirmed the effectiveness of the improvement proposal. For all evaluated indicators, the intervals of the improved model did not overlap with those of the current model, validating a real improvement in system performance. These findings demonstrate not only an increase in efficiency and quality but also the stability and sustainability of the newly implemented model.

Table 3. Results of the AS-IS vs TO-BE Scenarios

Variable	As Is	To Be
Productivity (total pairs produced)	211197	253437
Machine availability	78%	90%
Reworked pairs	5425	0
Transfer times	22851	17138
Time required to search for tools	15232	11424

The main objective of this research was to increase the productivity of a medium-sized safety footwear company through the implementation of a production management model based on industrial engineering tools. To achieve this, the workstations in the stitching and assembly areas were reorganized, a preventive maintenance plan was developed, the 5S methodology was implemented, and work procedures were standardized. As a result, productivity increased by 20%, machine availability reached 90%, non-value-added activities were reduced by 25%, and rework was eliminated. These findings demonstrate the effectiveness of integrating multiple industrial engineering tools to address operational inefficiencies in a comprehensive manner rather than treating them as isolated problems.

Romani et al. (2023) implemented 5S, Systematic Layout Planning (SLP), and Standard Work in a medium-sized footwear company. Their approach reduced search time by 34.7 minutes per dozen and transportation time by 19.7 minutes per dozen, resulting in a 9.83% increase in productivity and a 19.79% increase in annual production. Similar improvements were observed in the present study; however, the results were slightly more favorable. Annual production increased by 20%, transportation time was reduced to 9.6 minutes per dozen, and tool search time decreased to approximately 3 seconds. These differences may be explained by the simultaneous implementation of layout redesign, workplace organization, preventive maintenance, and work standardization, which addressed multiple sources of productivity loss at the same time. From a practical perspective, these findings suggest that productivity improvements in footwear manufacturing are more effective when operational, maintenance, and organizational practices are integrated into a single improvement strategy rather than implemented separately.

The implementation of preventive maintenance also proved effective in improving machine availability. Ortega et al. (2023) reported an increase in machine availability from 85.69% to 95.85%, representing a relative improvement of 11.86%. In the present study, machine availability increased from 78% to 90%, corresponding to a relative improvement of 15.38%. Although the final availability level remained lower than that reported by Ortega et al. (2023), the greater relative improvement reflects the less favorable initial conditions of the company under study. This comparison highlights the importance of considering baseline performance when evaluating the effectiveness of maintenance initiatives. In real manufacturing environments, preventive maintenance not only reduces unexpected downtime but also enhances production planning reliability and improves the utilization of available resources. However, its long-term success depends on management commitment, proper scheduling of maintenance activities, and continuous monitoring of equipment performance.

The reduction of rework is a key indicator of improvements in both process efficiency and product quality. Chinchay-Morales et al. (2022) reported that the implementation of standardization tools reduced rework from 11.70% to 2.80% in the lasting stage and from 29.94% to 10.03% in the sole stitching area. These results demonstrate the ability of standardized procedures to improve process control and reduce variability in manufacturing operations. In contrast, the present study achieved the complete elimination of rework, reducing the number of reprocessed pairs from 5,424 per year to zero. This outcome was achieved through the standardization of tasks, the improvement of work methods, personnel training, and stricter control of critical operations. Compared with previous studies, these findings suggest that combining Standard Work with training and operational supervision can generate greater quality improvements than standardization alone. From an industrial perspective, eliminating rework not only improves productivity but also reduces material waste, labor costs, and delivery delays, thereby contributing to higher operational efficiency and increased customer satisfaction.

6. Conclusions

The implementation of the proposed management model, which integrates Preventive Maintenance, 5S, System Layout Planning (SLP), and Standard Work (SW), resulted in a 20% increase in productivity. This improvement confirms the effectiveness of the approach in enhancing operational efficiency in SMEs within the footwear sector by applying low-cost, high-impact tools. To ensure the continuity and success of the results, it is recommended to establish a system of continuous monitoring and feedback, as well as to conduct periodic staff training to ensure that the tools are applied effectively and adapted to the company's evolving needs.

The improvement in machine availability, which increased from 78% to 90%, highlights the importance of adopting systematic preventive maintenance to reduce downtime and ensure operational continuity, especially in companies with limited resources.

The layout redesign through SLP, combined with the implementation of 5S, led to a reduction of more than 25% in nonproductive time, optimizing material flow and minimizing unnecessary movements. This reorganization highlights the impact of a well-planned workspace on improving efficiency.

The standardization of processes using Standard Work eliminated rework in the stitching and gluing stages, contributing to greater consistency in production and improved quality of the final product.

The proposed model offers a viable and scalable solution for other SMEs in the sector, with implications for improving competitiveness without requiring major investments. Furthermore, it opens new lines of research on the integration of emerging technologies, such as automation and predictive analytics, to further enhance operational efficiency in the future.

Finally, this study paves the way for future research that could explore the integration of emerging technologies such as real-time monitoring systems, process optimization algorithms, and partial task automation into continuous improvement models. The convergence between continuous improvement principles and technological innovations represents a promising line of research with the potential to further transform the manufacturing sector, not only in terms of efficiency but also in terms of sustainability and adaptability to an increasingly competitive and dynamic global market.

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