# Management Model for Increasing Productivity in Woodworking SME through the Application of 5S, SMED, and Standardization

Israel Grandez-Pella[1]; Ricardo A. Noriega-Leaño[2]; Rafael Chavez-Ugaz[3]; Claudia C. Leon-Chavarri[4]
[1,2,3,4]Universidad de Lima, Perú, *20200946@aloe.ulima.edu.pe, 20201475@aloe.ulima.edu.pe, rchavezu@ulima.edu.pe, cleon@ulima.edu.pe*

***Abstract*– This research addresses the issue of low productivity in a small manufacturing enterprise producing wooden pallets, which is affected by rework, inefficient time usage, and operational disorganization. To tackle this problem, the Lean-based productivity improvement model was designed to apply the tools in a defined sequence: first 5S to organize and clean workstations, then SMED to reduce setup times, and finally standardization to stabilize the improved processes. This sequence allows each tool to complement the previous one, facilitating smoother implementation and more sustainable results. The designed solution reduced pallet assembly time by 20.8%, rework by 43.5%, and line changeover times by 46.6%, as validated through a pilot test. These results demonstrate the effectiveness of the proposed approach in resource-constrained companies and represent a relevant contribution to the integrated use of Lean tools in low-automation production environments.**

***Keywords—5S, SMED, Standardization, Productivity, Pallets.***

## I. Introduction

In the context of supply chains, the pallet industry represents a critical link for ensuring the efficient flow of goods. Pallets are one of the most used returnable transport items, carrying about 80% of all world trade [1]. However, in countries such as Peru, this sector is predominantly composed of small and medium-sized enterprises (SMEs), which face structural constraints including informality, low process standardization, and limited investment in production technologies [2]. These limitations directly impact their productivity and competitiveness in comparison to more technologically advanced markets [2].

Specifically, the company under study, belonging to the pallet manufacturing sector, exhibits critical issues to this industry and to other mass-consumption product sectors such as frequent rework caused by variability in raw materials [3], lengthy setup times [4], and disorganized workstations that hinder flow [2][5]. This situation not only affects costs and delivery times but also undermines the perceived quality by customers, as also reported in [6][7]. Therefore, improving operational productivity is not merely a technical challenge but a necessary condition for business sustainability.

Various experiences in manufacturing environments have demonstrated the effectiveness of Lean tools—such as 5S, SMED, and standardization—in reducing non-productive time and eliminating waste [6][8]. For instance, Briones -Chavez [9] applied a combination of 5s and standardization to improve order picking efficiency and reduce delivery errors, increasing order processing times from 67% to 77%. However, many of these studies focus on medium- or large-scale industries with high levels of automation [6][9][10]. As noted in [6], results in resource-constrained SMEs are often less documented, and there is a lack of models that integrate these tools in a flexible, contextualized, and systematic manner.

This gap highlights the need to develop a new conceptual model that enables the adaptation of Lean tools to low-automation environments, following a logical sequence, with low cost and rapid implementation. Such a model should not only aim for measurable results but also foster the empowerment of operational personnel and the promotion of continuous improvement as an organizational culture. In response to this, the present study proposes and validates a solution to improve productivity in a pallet manufacturing plant through the integrated and sequenced application of 5S, SMED, and standardization.

The approach demonstrates its applicability in real-world contexts, providing quantitative evidence and insights that pave the way for future replication in other small- and medium-sized manufacturing industries with low levels of automation and high variability in raw materials. [2][3][10].

## II. Literature review

### *A. 5S for suboptimal layouts in work areas*

The root cause associated with disorganized workspaces finds an effective solution in the 5S technique. This technique has proven useful in scenarios where poorly designed physical spaces result in idle time, excessive movement, and a lack of visual control. In metallurgical companies, the implementation of 5S alongside standardization and Total Productive Maintenance (TPM) led to a 40.91% reduction in downtime [11]. Similarly, in the food industry, 5S contributed to a 20% decrease in the execution time of complex tasks [12]. In Peruvian SMEs, the benefits are even more pronounced: a 47% reduction in waste and a 33% increase in production in upholstery operations [13]; an increase in productivity to 25.02 kg/second and a reduction in cleaning time [14]; and a 60% improvement in tool accessibility [15]. These results position 5S as a key tool for reconfiguring spaces, optimizing movement, and creating visually standardized work environments, especially in non-automated plants. From the process execution time (PET) perspective, its value lies in minimizing losses due to unnecessary movements and facilitating the execution of repetitive tasks by reducing spatial complexity.

*B. SMED to reduce long line changeover time for batch production*

Another critical root cause in production environments is the extended duration of line changeovers, particularly in batch operations. The SMED (Single-Minute Exchange of Die) methodology directly addresses this issue by reorganizing internal and external tasks to minimize setup time. In [4], a 36% reduction was achieved in an automotive company simply by reorganizing the layout and resources. A textile SME after implementing reported a 48% reduction in cutting time in a textile SME after implementing SMED in conjunction with 5S. In a more complex case [16]. Another case reported a reduction in setup time from 18.55 to 8.85 minutes by integrating 5S, SMED, and standardization, validating the synergistic effect of these tools [3]. While demonstrating benefits—a 20% improvement—it is also highlighted that SMED's cost-effectiveness may be limited if high investments are required [17]. From the PET perspective, SMED enhances operational flexibility and eliminates losses due to non-productive time between changes, thereby increasing the availability and effective utilization of key resources.

*C. Non standardized selection and control of raw materials*

High variability in raw materials and the absence of formal control criteria constitute a recurring issue in processes involving heterogeneous inputs. The standardization of procedures addresses this problem by defining sequences, criteria, and best practices applicable in contexts with limited formal control. In the Peruvian textile sector, standardized cutting, quality, and communication processes, increased productivity from 0.38 to 1.155 units/hour and reducing economic losses from $120,865 to $35,692 [18]. Also, other companies achieved a 7% productivity increase by standardizing fabric spreading processes [19], while an improvement in labor-hour efficiency from 74% to 94% and a 5% reduction in painting defects were reported after establishing standards [10]. Within the PET framework, standardization reduces losses caused by defects and rework resulting from operational subjectivity, enabling consistent outcomes even when raw material quality varies.

TABLE I
LINKAGE OF ROOT CAUSES

| Reference | Root causes | | |
|---|---|---|---|
| | Disorganized work areas | Long line changeover times | Inadequate raw material selection |
| [2] | 5S | | Standardization |
| [3] | 5S | SMED | |
| [13] | | SMED | |
| [16] | 5S | SMED | |
| [23] | 5S | | Standardization |
| [24] | 5S | | Standardization |
| Proposed model | 5S | SMED | Standardization |

[a] Tool selection for each root cause

## III. METHODOLOGY

*A. Conceptual model*

The research was developed under the research-action methodology, applying Lean Manufacturing tools in the pallet production process. The proposal was structured in four stages and three components: (i) diagnosis, (ii) model development, (iii) implementation, and (iv) validation of improvements. This approach is consistent with prior applications of Lean in SMEs with limited resources and low automation [2][3][10][14].

During the diagnosis stage, empirical data were collected from the production line through time studies, quality reports, and operator observations. In addition, statistical analysis was conducted to identify the most relevant factors affecting productivity. The results revealed correlations between productivity losses and rework, ineffective hours, and changeover times, with coefficients ranging from 0.67 to 0.79. This is consistent with studies that highlight the importance of quantifying root causes before selecting Lean interventions [14][20].

In the development stage, a solution model was designed with three interventions: (a) application of the 5S methodology in the pallet assembly station, (b) implementation of SMED in the band saw station, and (c) standardization of raw material inspection through technical criteria and checklists. The methodological sequence followed the classical phases of each tool, as documented in prior Lean implementations [2][3][14].

The implementation stage was executed through pilot tests in the selected stations. For 5S, the five phases (Seiri, Seiton, Seiso, Seiketsu, Shitsuke) were applied. For SMED, the methodology was implemented in four steps: separation of internal and external tasks, simplification, parallelization, and improvement of adjustments. For standardization, acceptance criteria, tolerances, and technical specifications were formalized, along with operator training and the use of visual checklists. This follows evidence from previous applications where Lean practices were tailored to SMEs and resource-constrained environments [2][3][10].

Finally, in the validation stage, indicators before and after implementation were compared: pallet assembly time, 5S compliance rate, line changeover time, and reprocessing rate. The analysis combined percentage variation, mean and standard deviation, complemented with trend graphs. Although the absence of a control group is recognized as a limitation, this condition is common in action-research and pilot studies within SMEs [10][14].

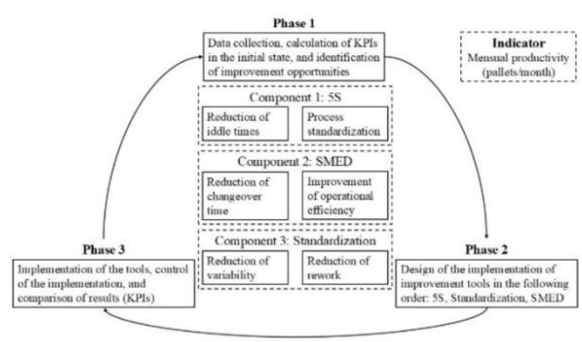


Fig. 1 Conceptual model

*B. Model components*

The proposed solution focuses on improving productivity in pallet manufacturing through the integrated and sequenced application of three Lean tools: 5S, SMED, and standardization. These tools are designed to address the main root causes of inefficiency, including disorganized workstations, excessive changeover times, and rework resulting from poor raw material quality [3][6][20].

- 5S aims to improve order and cleanliness in operational areas, reducing wasted movements and facilitating smoother workflows [3][16].
- SMED targets the reduction of line changeover times, increasing machine availability and production flexibility [13][19].
- Standardization establishes clear criteria and visual controls for raw material selection and quality verification, minimizing rework and variability at the source [2][3].

The proposed solution model is structured into three sequential components preceded by the initial diagnosis where data is collected. Each component is associated with one tool and a root cause.

- Component 1 – The 5S methodology was implemented to optimize the physical organization of workstations. The intervention included the five stages of the system: sorting, set in order, shine, standardize, and sustain, applied to key operational areas of the plant.
- Component 2 – The SMED tool was applied to reduce line changeover times. Actions included the separation of internal and external activities, advance preparation of tools, and simplification of adjustment routines.
- Component 3 – Standardization procedures were established for raw material quality control. Specific technical parameters, inspection formats, and unified acceptance criteria were defined to ensure consistency in material reception.

The effectiveness of the Lean solution will be assessed using key performance indicators (KPIs) such as pallet assembly time, raw material control variability, and line changeover time. Baseline values were established during the diagnosis phase, and these will be compared to results obtained after implementation to quantify improvements. Dashboards and visual management tools will support ongoing monitoring and facilitate data-driven decision-making.

## IV. Validation

TABLE II
EXPERIMENT DESIGN

| Element | Description |
|---|---|
| Independent variable | Implementation of the improvement tools (5S, SMED, Standardization) |
| Dependent variable | Changeover times, assembly times, raw material acceptance rate, number of errors, standard compliance |
| Test group | Specific areas: assembly station, band saw, raw material receiving area |
| Pilot test duration | Approximately 2 weeks per tool |
| Initial measurement | Indicators were measured during the current process (without improvements) |
| Implementation | The designed improvements were applied |
| Final Measurement | Indicators were measured again after implementation |
| Analysis tool | Indicator dashboard, graphical pre-post comparison, percentage variation analysis, absolute improvement |

[a] Summary of the experimental setup and measurement criteria

The experimental design presented in Table II is essential to ensure the methodological rigor of the study and to validate the effects of the proposed improvements. By clearly defining independent and dependent variables, the experiment isolates the impact of the implemented tools on operational performance. The selection of specific test areas allows the interventions to be focused where the problems were most critical, increasing the reliability and relevance of the observed outcomes.

Establishing baseline (initial) and post-intervention (final) measurements makes it possible to quantify the improvements and attribute them directly to the applied changes. Additionally, the use of both graphical and numerical analysis tools strengthens the evaluation by enabling a comprehensive understanding of the results, both in terms of statistical significance and practical impact. Overall, this structured approach ensures that the conclusions drawn are supported by systematic observation and objective evidence.

*A. Implementation of 5S*

The pallet assembly station was selected as the site for the 5S pilot test. The unit of analysis was defined as the assembly time per pallet. An initial time study was conducted to determine the sample size representative of the actual conditions at the assembly station. The required sample size was determined using the following equation:

$$n = \frac{Z^2 \times \sigma^2}{E^2}$$

Z= value of the standard normal distribution at the desired confidence level (95%)

σ= standard deviation

E= margin error

The sample size was determined to be n = 42 observations.

Additionally, a baseline audit of the station was carried out to assess its level of compliance with 5S criteria. The audit score was 10 out of 25, equivalent to a 40% 5S compliance rate. From that audit, it was noticed that the station was underperforming in the areas of order, standardization and sustainment.

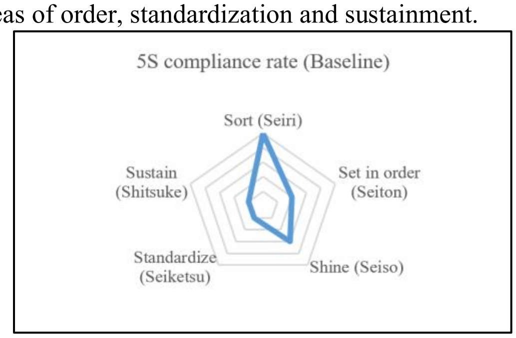


Fig. 2 Baseline audit results

Following the initial analysis, the average pallet assembly time was determined to be 132.52 seconds, with a standard deviation of 6.57 seconds. This indicated a relatively uniform process, though with clear opportunities for improvement. Based on these findings, a training program was launched for the operational staff, focused on the 5S methodology, with the goal of facilitating its future implementation at the workstation. Informative brochures and visual materials were used to enhance understanding of the principles of order, cleanliness, and standardization embedded in this methodology.

Upon completion of the theoretical training phase, physical improvements were carried out at the station in accordance with the five stages of the 5S system. The first stage involved sorting the existing items by identifying essential tools and materials and separating those with no added value to the process. While no unnecessary materials were found, a lack of defined locations for each tool was observed, negatively affecting efficiency.

In the second stage, the necessary items were organized carefully by assigning specific locations based on their frequency of use. Clear signage was installed, and dedicated spaces were marked for slats and blocks. Additionally, an unused cabinet was repurposed to store boxes of nails and the pneumatic nail gun.

The third stage, focused on cleaning, included the implementation of a daily cleaning schedule and the incorporation of periodic visual inspections. This ensures the cleanliness of the area and the proper maintenance of tools, thereby contributing to quality standards.

Next, standardized procedures for order and cleanliness were developed for the assembly area, following engineering guidelines. The objective was to systematize tasks, prevent regressions, and ensure the sustainability of improvements under the 5S framework.

Finally, ongoing staff training is promoted to reinforce habits of order and discipline. In parallel, a system of continuous visual audits supported by checklists was developed to allow for quick and objective evaluations of compliance with established standards, thereby consolidating a culture of continuous improvement.

Fig. 3 Initial scenario vs final scenario comparison

Upon completion of the initial 5S implementation at the workstation, an audit was conducted to assess its performance based on compliance with the 5S principles. The results revealed a clear improvement in the areas of standardization (Seiketsu) and discipline (Shitsuke). Unlike the initial state of the station, the workstation now has an established cleaning program and defined standards for order and cleanliness, ensuring optimal conditions for pallet assembly operations. Improvements were also achieved in the areas of organization (Seiton) and cleanliness (Seiso).

Following the completion of the initial implementation, an audit was conducted which revealed clear improvements in standardization (Seiketsu) and discipline (Shitsuke), as the workstation was now equipped with defined cleaning and order programs and standards. Progress was also observed in the areas of organization (Seiton) and cleanliness (Seiso).

Following the completion of the initial implementation, an audit was conducted which revealed clear improvements in standardization (Seiketsu) and discipline (Shitsuke), as the workstation was now equipped with defined cleaning and order programs and standards. Progress was also observed in the areas of organization (Seiton) and cleanliness (Seiso). After the implementation, the audit score was 20.5 out of 25, equivalent to an 82% 5S compliance rate.

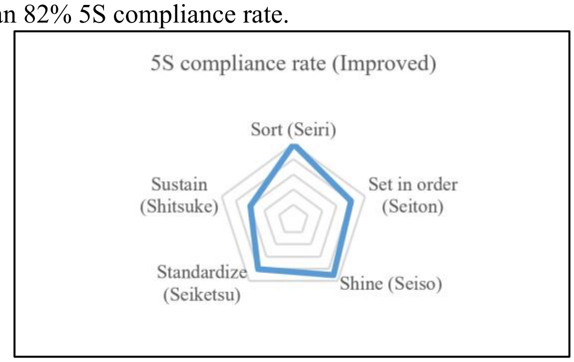


Fig 4. Post-implementation audit results

Subsequently, the time study was repeated using the same sample size (42 observations). The new average assembly time was 104.93 seconds per pallet, with a standard deviation of 12.73 seconds. The 95% confidence interval for the mean assembly time was [100.6; 108.9] seconds, as determined through a paired t-test. This reflected a reduction in assembly time, but also an increase in time variability.

### B. *Implementation of SMED*

For the implementation of the SMED pilot test, the unit of analysis selected was the line changeover time at the band saw cutting station. Prior to the initial time study, the activities involved in the changeover process were analyzed in collaboration with the operators. To obtain the required sample size, the same equation used in the implementation of 5S was applied, obtaining a sample size of $n = 6$ changeover times.

TABLE III
CHANGEOVER ACTIVITIES DESCRIPTION

| Order | Activity | Description | Type | Average time (sec) |
|---|---|---|---|---|
| 1 | Blade change | Stop machine to replace and align blade. | Internal | 592 |
| 2 | Work area cleaning | Remove waste around machine. | Internal | 902 |

| 3 | Tool transport | Move tools from storage. | External | 9.5 |
|---|---|---|---|---|
| 4 | Saw blade replacement | Replace and align saw blade. | Internal | 594 |
| 5 | Guide adjustment | Adjust guides to match cut type. | Internal | 61 |
| 6 | Setup and test cut | Set parameters to ensure the cut quality | Internal | 31 |

[c] Average time was measured using an initial sample

The SMED methodology was then implemented in four stages.

*1) Differentiation between internal and external setup*

Six activities were identified, of which only one was initially classified as external. After analysis, it was concluded that cleaning could be transferred to an external phase, thus reducing machine downtime.

*2) Reduction of internal setup time trough process improvements*

Internal operations (e.g., blade changes, guide adjustments, parameter setup) were optimized by assigning specific roles, eliminating unnecessary steps, and introducing standard formats per model. This reduced manual calculations and repetitive checks.

*3) Reduction of internal setup time trough equipment modifications*

The work area was reorganized to position essential tools near the machine. Predefined guide positions and quick-adjust stops were installed, and the blade tensioning system was redesigned to allow tool-free changes. These modifications reduced reliance on operator skills.

*4) Toward zero setup*

The improvements enabled progress toward minimal or zero setup. Automated mechanisms were integrated for parameter adjustments, and the equipment was adapted to handle different models within the same family without complex reconfiguration. This enabled continuous flow and increased operational flexibility.

After implementation, staff training was conducted to ensure proper adoption of the new procedures. Following a one-week adaptation period, an audit was performed to measure the updated changeover times.

The result was a significant reduction in total changeover time to 1,169.2 seconds, with a standard deviation of 74.09 seconds, demonstrating improvements in both efficiency and process stability. A paired t-test was conducted, yielding a 95% confidence interval for the mean changeover time of [1,091.44; 1,246.96] seconds.

## C. *Implementation of Standardization*

For the standardization phase, the selected station was the quality control station at the beginning of the production process. The unit of analysis chosen was a single wooden slat (raw material), on which the effectiveness and consistency of the selection process would be measured.

Based on historical data, an average probability of 17% (p) was established for encountering a slat that does not meet quality standards and requires reprocessing or removal. Furthermore, records indicated that, on average, 82.92% of the raw material received is approved during the selection process, with a standard deviation of 3.60 slats per batch. To determine the required sample size, the following formula was applied:

$$n = \frac{Z^2 \times p \times (1-p)}{E^2}$$

The sample size required was n = 217 slats.

To initiate the implementation of the pilot test, the required quality criteria for slats to be deemed suitable for the production process were defined and documented.

TABLE IV
QUALITY CRITERIA

| Criterion | Description |
|---|---|
| Dimensions | Thickness: 3.5 in., Length: 80 in., Width: 4 in. Permissible tolerance: ±1 in. |
| Surface defects | Reject slats with visible cracks, chipped or broken edges, mold stains, and/or contaminant residues. |
| Moisture | Reject slats with moisture content outside the acceptable range (12–18%). |
| Color and appearance | Avoid slats with significant stains or intense discoloration. |

[d] Summary of the experimental setup and measurement criteria

Based on the established criteria, a document was developed outlining the step-by-step procedure and the tools required to properly carry out raw material selection.

- Determination of sampling quantities: The operators responsible for verifying the conformity of the raw material first assess the total number of wooden boards or pieces delivered by the supplier. From there, the sample size is determined using the inspection level and the total lot size.
- Measurement of boards or pieces: Once the sample size is determined, each selected board or piece is measured according to supplier specifications, allowing a tolerance of ±1 inch. The measurements include length, width, and thickness.
- Crack inspection: In general, no more than two cracks per board are permitted, and these should not exceed 20% of the board's total length. Deep cracks are not acceptable under any circumstances. This task is performed through visual inspection.
- Knot detection: Knots are evaluated based on size, quantity, and firmness. A board with knots is acceptable only if none exceeds 2 centimeters in diameter, and the total number does not exceed three. Additionally, knots located on the edges of the boards are not allowed. This task is also performed through visual inspection.
- Moisture level: Measuring moisture content provides insight into the potential presence of mold or fungi. According to ISPM 15, which governs pallets for export, wood should not exceed 22% moisture content. However, rejection of a lot for exceeding this threshold may be conditional, as moisture can often be reduced through proper storage. In contrast, the presence of mold

or fungi warrants immediate rejection. This task is conducted using a digital hygrometer.

The key to this standardization effort was to ensure the procedure did not remain merely as a document. Personnel received training, practical tests were conducted, and adjustments were made according to real working conditions. The goal was for each operator not only to understand the standard but also to contribute improvements based on their day-to-day experience. Additionally, a checklist and visual aids were implemented at the station to support compliance with the standardized procedure.

In the final scenario, the acceptance rate of raw material decreased slightly to 80.42%, while the raw material selection process was significantly standardized, as evidenced by a substantial reduction in standard deviation to 0.64 slats per batch. The confidence interval for the standard deviation was calculated using the chi-square distribution, resulting in a 95% confidence interval of [0.42; 1.15] seconds.

## V. Results

The integrated implementation of 5S, SMED, and standardization led to notable improvements in productivity, quality, and process efficiency. Assembly time was reduced by 20.8%, reprocessing by 43.5%, and changeover time by 46.6%. While some variability increased temporarily, overall consistency and performance improved significantly. Table I presents the key results before and after implementation.

TABLE V
RESULTS

| Tool | Indicator | Values | | | Improvement (%) | Progress toward goal (%) |
|---|---|---|---|---|---|---|
| | | As-Is | To-Be | Goal | | As-Is |
| 5S | Assembly time per pallet (sec) | 132.52 | 104.93 | 100 | 20.8 | 132.52 |
| | Standard deviation (sec) | 6.57 | 12.73 | 3 | -93.8 | 6.57 |
| | Productivity in assembly station (pallets/man-hour) | 27.23 | 34.79 | 40 | 27.8 | 27.23 |
| | 5S compliance rate (%) | 40 | 82 | 100 | 105.0 | 40 |
| Standardization | Standard compliance rate (%) | 82.92 | 80.42 | - | - | 82.92 |
| | Standard deviation of non-compliance rate (slats) | 3.60 | 0.64 | 0.5 | 82.2 | 3.60 |
| | Reprocesses (slats/lots) | 2.00 | 1.13 | 1 | 43.5 | 2.00 |
| | Average reprocessing time (sec) | 88.71 | 89.86 | - | - | 88.71 |
| SMED | Line changeover time (sec) | 2190 | 1169.20 | 1100 | 46.6 | 2190 |
| | Standard deviation (sec) | 80.63 | 74.09 | 60 | 8.1 | 80.63 |
| | Belt changeover time (sec) | 591.83 | 540.20 | 520 | 8.7 | 591.83 |
| | Work area cleaning time (sec) | 902.33 | 827.40 | 800 | 8.3 | 902.33 |
| | Saw blade replacement time (sec) | 594.33 | 544.50 | 500 | 8.4 | 594.33 |

[e] Results obtained from the pilot test. As-is: initial scenario, To-be: post-implementation

## VI. Conclusions

The sequential and integrated implementation of the Lean tools 5S, SMED, and standardization in a pallet manufacturing plant allowed the validation of their positive impact on key productivity indicators. In the assembly stage, pallet processing time was reduced by 20.8%, rework decreased by 43.5%, and line changeover time dropped by 46.6%. These improvements translated into a 22% increase in overall productivity, rising from 10.3445 to 12.62028 pallets per man-hour. These results demonstrate that the proposed model is not only effective in low-automation environments but also viable in contexts with limited resources.

Additionally, standardization not only reduced the reprocessing rate but also generated a measurable economic benefit. Before the intervention, approximately 7,200 boards were reprocessed per month, compared to 3,800 boards after standardization, representing a reduction of 3,400 defective boards. Considering an average unit cost of 3.60 PEN per board, this improvement translates into an estimated savings of 12,240 PEN per month (≈146,880 PEN annually), reinforcing the practical value of Lean tools in SMEs operating with limited resources.

A major contribution of this study is the validation of the tool sequence: 5S → Standardization → SMED. This order proved essential: 5S created the organizational foundation by improving cleanliness and order, Standardization stabilized criteria for raw material selection and operational consistency, and SMED optimized time usage during frequent line changeovers. The sequential logic was critical for ensuring that each improvement stage was built on a stable operational baseline.

Unlike most Lean models that assume high automation or formalized processes [6][10], this study validated a structured, yet flexible methodology tailored to SMEs operating in informal and low-tech settings. While it reinforces previous findings about Lean's role in waste reduction and performance improvement [3][14], it adds new evidence by focusing on under documented constraints such as informality and limited data availability [2][20].

Based on these findings, the following recommendations are proposed:

- Start model implementation in manual workstations with high variability, as these areas showed the most significant impact from the applied tools [10].

- Incorporate visual procedures and dashboards to facilitate local monitoring and operator ownership, especially in contexts lacking digital infrastructure [9].
- Prioritize raw material selection processes, where standardization significantly reduced rework and established the basis for effective quality control [20].
- Embed continuous feedback loops to sustain improvements and reinforce a Lean culture over time.

As future work, it would be valuable to test the model in other operations within the same sector or in SMEs from similar industries to evaluate scalability. Additionally, conducting a longitudinal follow-up of results would help assess the sustainability of the improvements achieved.

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