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Enhancing Operational Efficiency in Flexographic SMEs through Lean Manufacturing: A Case Study

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Abstract

The flexographic printing sector plays a crucial role in the global, Latin American, and Peruvian economies by efficiently producing packaging, labels, and other printed materials. Previous studies have highlighted the importance of Lean Manufacturing practices, such as SMED and 5S, in improving operational efficiency within SMEs. However, the application of these methodologies specifically in the flexographic sector has been underexplored, creating a gap in the literature. Flexographic SMEs face significant challenges, including high variability in machine setup times, operational errors, and lack of organization in workstations. These issues lead to inefficiencies, prolonged downtimes, and reduced productivity, directly impacting their competitiveness in a demanding market. Addressing these challenges is essential to enhance the sustainability and growth of these enterprises. This research proposed a Lean Manufacturing-based production model tailored for flexographic SMEs, integrating SMED, 5S, and standardized work. The model aimed to optimize production processes, reduce setup and changeover times, and improve overall operational efficiency. Key actions included detailed process analysis, identification and separation of internal and external activities, and implementation of best practices and clear standards. The implementation of the model resulted in significant improvements. Setup times were reduced by 32% in bottleneck problems and 50% in configuration time, leading to a 7% increase in line efficiency. The application of 5S methodology improved workspace organization, reducing unproductive times and enhancing safety. Overall, the model contributed to a 43.24% increase in availability and substantial economic savings of 69,338 USD annually. The academic and socio-economic impact of this research is profound. Academically, it fills the knowledge gap regarding the application of Lean tools in the flexographic sector, providing a framework for future studies. Socio-economically, the improved efficiency and productivity of flexographic SMEs enhance their competitive position, promoting economic growth and sustainability in the sector.
This study calls for further research into the application of Lean methodologies in other sectors and contexts. By exploring new directions and adapting the model to different industries, researchers and practitioners can continue to drive improvements in operational efficiency and economic performance, contributing to the broader goals of sustainable development and industrial excellence.

Keywords
Lean Manufacturing, Flexographic Printing, Operational Efficiency, SME Productivity, Process Optimization.

1. Introduction
Small and medium-sized enterprises (SMEs) in the flexographic sector play a crucial role in the global, Latin American, and Peruvian economies. By specializing in flexographic printing, these companies significantly contribute

to the production of packaging, labels, and other printed materials efficiently and cost-effectively (Maharani & Musfiroh, 2021). Flexography is a versatile printing technique widely used in the packaging and labeling industry, making it a vital sector for the global supply chain (Braglia et al., 2023). In Latin America, flexographic SMEs represent a significant part of the business fabric, generating employment and fostering innovation in the printing field (Ribeiro et al., 2022). In the Peruvian context, these companies not only boost the local economy but also promote competitiveness and quality in the production of printed materials (Horzela & Semrau, 2021).

On the other hand, metalworking SMEs face production challenges, particularly related to deficiencies in machine setup during product changes, operational errors leading to rework, and lack of organization in their workstations (Emekdar et al., 2023). These problems negatively impact the efficiency and profitability of these companies, hindering their ability to compete in an increasingly demanding market (Quiroz-Flores, 2023). Inadequate machine setup can lead to prolonged downtime and lower productivity, directly affecting the ability of metalworking SMEs to meet delivery deadlines and market demands (Ziemba et al., 2020). Additionally, the lack of order and cleanliness in workstations can result in workplace accidents, material loss, and lower quality of final products (Ebrahimi et al., 2021).

Addressing production issues in flexographic industry SMEs is vital for ensuring their long-term sustainability and growth. By implementing Lean Manufacturing practices and tools, such as SMED (Single-Minute Exchange of Dies), companies can optimize their production processes, reduce product changeover times, and improve overall operational efficiency (Runtuk, 2021). The application of Lean methodologies, like SMED, not only enables flexographic SMEs to increase their productivity but also provides the necessary flexibility to quickly adapt to market demands and consistently offer high-quality products (Quiroz-Flores & Vega-Alvites, 2022). Improving production efficiency allows these companies to reduce costs, minimize waste, and enhance their competitive position both locally and internationally (Qayyum et al., 2021).

The existing knowledge gap in the literature on the implementation of Lean Manufacturing tools in flexographic industry SMEs highlights the need for research specifically addressing this topic. The lack of studies and production models based on tools like SMED, 5S, and Standardized Work in the context of flexographic SMEs limits the understanding of how these methodologies can positively impact the efficiency and profitability of these companies (Şahin & Koloğlu, 2022). Therefore, this research aims to fill this knowledge gap by developing a production model that effectively integrates Lean Manufacturing tools into the daily operations of flexographic SMEs, with the goal of improving their performance and competitiveness in the market (Pagliosa et al., 2019).

In summary, SMEs in the flexographic industry play a fundamental role in the global, Latin American, and Peruvian economies, being responsible for the production of essential printed materials for various sectors. Conversely, metalworking SMEs face production challenges due to machine setup deficiencies, operational errors, and lack of organization in their workstations. Addressing these issues in flexographic SMEs is crucial, and the implementation of Lean Manufacturing tools like SMED can be key to improving the efficiency and competitiveness of these companies. This research seeks to close the existing knowledge gap by developing a production model based on Lean Manufacturing for flexographic SMEs, aiming to drive their growth and success in the current market.

2. Literature Review

2.1 Improving OEE in Small and Medium-Sized Enterprises in the Flexographic Sector

Enhancing Overall Equipment Effectiveness (OEE) is crucial for operational efficiency in small and medium-sized enterprises (SMEs) within the flexographic sector. Khodaparasti et al. (2020) discuss the importance of engaging in green procurement for manufacturing SMEs, highlighting the positive outcomes it can bring, including potential improvements in environmental impact and streamlined processes that could boost OEE (Khodaparasti et al., 2020). Sustainable practices have been shown to lead to operational enhancements (Khodaparasti et al., 2020). Additionally, Mendo et al. (2021) demonstrates the economic potential of SMEs and how strategic approaches like the Analytic Hierarchy Process (AHP) can drive growth and efficiency, aiding SMEs in making informed decisions to optimize processes and enhance OEE within the flexographic industry (Mendo et al., 2021).

2.2 Application of Lean Manufacturing in SMEs in the Flexographic Sector

stress the importance of assessing the lean readiness of manufacturing industries, emphasizing the need for a comprehensive understanding of various aspects such as processes, human resources, and customer relations. By evaluating and enhancing lean readiness, SMEs can effectively implement Lean Manufacturing principles to streamline operations and improve productivity, potentially leading to increased OEE (Al-Najem et al., 2019). Furthermore, Sahoo (2020) explores the assessment of lean implementation within Indian automotive component manufacturing SMEs, indicating ongoing efforts to optimize processes and enhance efficiency, despite room for improvement in many SMEs (Sahoo, 2020).

2.3 SMED Methodology in Production Processes of SMEs in the Flexographic Sector

The Single-Minute Exchange of Die (SMED) methodology is essential for reducing setup times and enhancing operational efficiency in SMEs. Nakasone (2024) conducts a mixed methods assessment of technical and financial assistance to SMEs in Kenya's food sector, highlighting the effectiveness of programs like SMED in streamlining production processes, minimizing downtime, and improving OEE (Nakasone, 2024). Additionally, Van (2023) explores the impact of the formalization process on product innovation results in small and medium-sized private enterprises, emphasizing the role of structured processes like SMED in driving innovation and operational excellence within SMEs (Van, 2023).

2.4 Implementing 5S Methodology in SMEs in the Flexographic Sector

The application of the 5S methodology can significantly impact the operational efficiency of SMEs in the flexographic sector. Zastempowski et al. (2020) discuss the conditions of marketing and organizational innovation in SMEs, highlighting the positive impact of innovative practices like 5S. By incorporating methodologies such as 5S, SMEs can create organized and efficient work environments, leading to improved productivity and quality, essential components for enhancing OEE (Zastempowski et al., 2020). Moreover, Raucci et al. (2020) present a simplified approach to Activity-Based Costing for SMEs, emphasizing the role of advanced technologies in promoting standardized processes and efficiency gains within SME operations (Raucci et al., 2020).

2.5 Standardized Work Methodology in Production Processes of SMEs in the Flexographic Sector

Standardized Work methodology focuses on establishing best practices and standardizing processes to drive consistency and efficiency. Huynh (2021) explores the determinants of SME performance in emerging markets, highlighting how implementing Standardized Work practices can ensure consistency in operations, minimize variability, and enhance overall performance, ultimately contributing to improved OEE within the flexographic sector (Huynh, 2021). Furthermore, Padhil (2024) discusses opportunities for developing safety and health protection systems in SMEs, emphasizing the importance of standardized safety protocols in promoting a conducive work environment that fosters productivity and efficiency (Padhil, 2024).

3. Methods

3.1 Basis of the Proposed Model

Figure 1 illustrates a production model based on Lean Manufacturing philosophy, aimed at increasing the availability of productive resources through the implementation of three key components: SMED, the 5S methodology, and standardized work. The first component, SMED, focused on reducing setup and changeover times, thereby allowing greater flexibility and speed in the production process. The second component, the 5S methodology, emphasized workplace organization and cleanliness, promoting a more efficient and safer environment, which facilitated the identification and elimination of waste. The third component, standardized work, involved the definition and documentation of best operational practices to ensure consistency and quality in repetitive tasks. This integrated approach sought to transform a scenario of low resource availability into one of high availability, thereby improving operational efficiency and responsiveness to market demands. The combination of these Lean tools aimed to optimize production processes, reduce downtime, and elevate standards of quality and productivity within the organization.

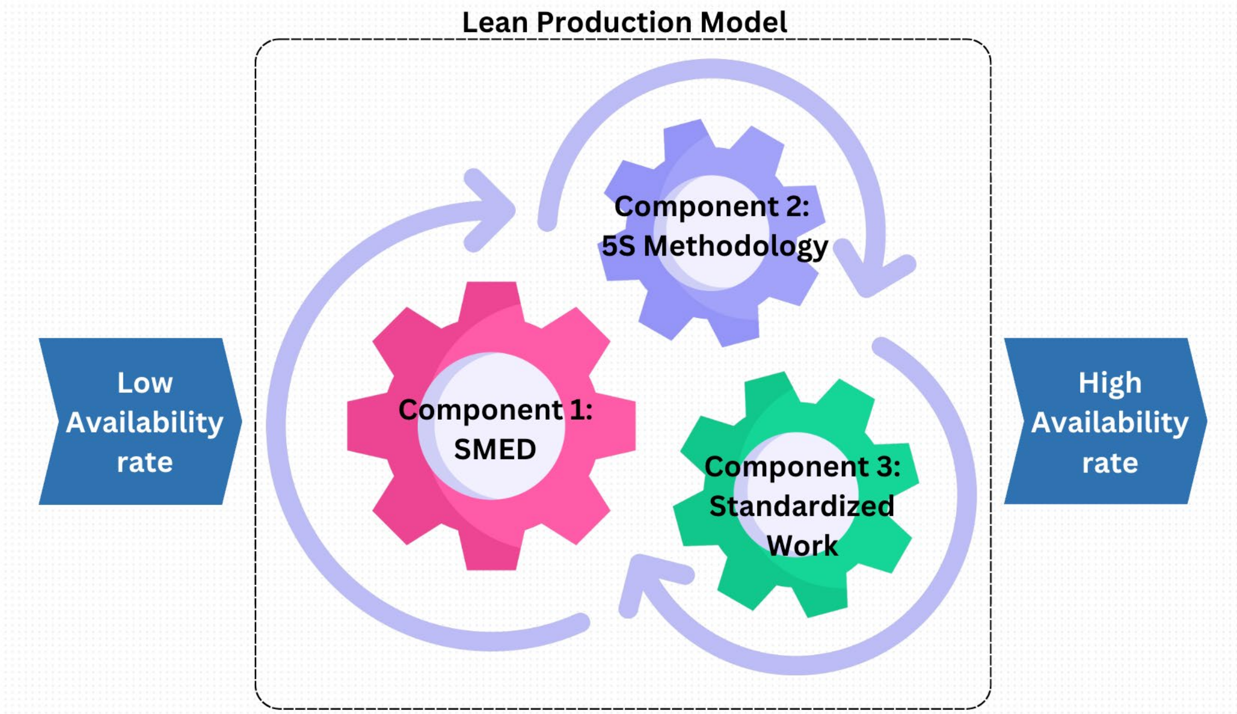

Figure 1. Proposed Model

3.2 Description of the model components

The integration of these three components—SMED, 5S methodology, and standardized work—created a holistic Lean Production Model aimed at addressing the root causes of low production line availability. The implementation of SMED significantly reduced setup times, enhancing machine flexibility and availability. The 5S methodology created a more organized and efficient workplace, reducing waste and facilitating maintenance. Standardized work ensured consistency and quality, reducing variability and errors in production processes. Together, these components transformed the production environment from one with low availability rates to a highly efficient and reliable system. The economic impact of this transformation was substantial, with an estimated annual savings of 69,338 USD, equivalent to 5.4% of sales. This integrated approach not only improved operational efficiency but also enhanced the organization's ability to respond to market demands, thereby providing a competitive advantage. The Lean Production Model, supported by empirical evidence and theoretical frameworks, demonstrated the effectiveness of Lean Manufacturing principles in optimizing production processes and improving overall performance.

Component 1: Single-Minute Exchange of Die (SMED)

The model began with the implementation of SMED, a Lean Manufacturing tool aimed at drastically reducing setup and changeover times to less than ten minutes. This component was crucial as high machine setup times were identified as a major cause of low production line availability, accounting for 53% of the issue. SMED techniques involved analyzing and segregating internal and external setup tasks, streamlining processes, and eliminating non-value-added activities. According to Shingo (1985), SMED facilitated quicker transitions between production runs, thereby enhancing flexibility and responsiveness to market demands. This reduction in setup times not only increased machine availability but also minimized production downtime, leading to significant improvements in operational efficiency and productivity.

Component 2: 5S Methodology

The second component, the 5S methodology, focused on workplace organization and cleanliness. This methodology is composed of five stages: Sort, Set in order, Shine, Standardize, and Sustain. The implementation of 5S aimed at creating a structured and orderly workplace that reduced waste and inefficiencies. It was noted that poor machine settings and regulations contributed to 22% of the problem, with specific issues such as poor cleaning of plates (18%) and deficiencies in color adjustment (27%). By implementing 5S, the organization was able to establish a cleaner and more organized workspace, which facilitated easier maintenance and quicker identification of problems. The literature supports the effectiveness of 5S in improving operational performance and safety standards (Hirano, 1996; Gapp, Fisher, & Kobayashi, 2008). Through systematic cleaning and organizing, the production line experienced fewer disruptions, contributing to higher machine availability and reliability.

Component 3: Standardized Work
The final component was standardized work, which involved the documentation and implementation of the best practices for performing tasks. Standardized work ensured consistency, reduced variability, and maintained quality across production processes. The case study identified issues such as time deficiency in the registry (10%) and process problems (10%) as significant contributors to low machine availability. By establishing standardized procedures, the organization could ensure that tasks were performed uniformly and efficiently, regardless of the operator. Liker (2004) emphasized that standardized work is foundational to continuous improvement and operational excellence in Lean Manufacturing. This component helped in minimizing errors, improving quality, and enhancing overall productivity. Standardized work also facilitated training and development, ensuring that new employees could quickly adapt to established procedures, further reducing downtime and improving production line availability.

3.3 Model Indicators
To evaluate the effectiveness of the proposed production model, a comprehensive set of specific metrics was designed and implemented. These metrics were essential for systematically tracking and managing the outcomes observed during the case study. By closely monitoring these indicators, the research team was able to gather detailed data and insights, ensuring a thorough assessment of the model's impact on production efficiency and overall performance.

Unproductive hours rate: The Unproductive Hours Rate measures the proportion of time during which the production system is not operational compared to the total available hours. This indicator helps identify inefficiencies and downtime in the production process, providing insights for improving overall productivity and reducing unproductive periods.

$$\text{Unproductive hours rate} = \frac{Unproductive\ hours}{Available\ hours} \quad (1)$$

Hours of work change rate: The Hours of Work Change Rate measures the proportion of time spent on changing work tasks relative to the total available hours. This indicator helps identify the efficiency of transition processes within the production system, highlighting opportunities to minimize changeover times and improve overall operational productivity.

$$\text{Hours of work change rate} = \frac{Working\ change\ hours}{Available\ hours} \quad (2)$$

Hours of process failure rate: The Hours of Process Failure Rate measures the proportion of time lost due to process failures relative to the total available hours. This indicator helps identify inefficiencies and reliability issues within the production system, providing insights for targeted improvements to reduce downtime and enhance overall process stability.

$$\text{Hours of process failure rate} = \frac{Process\ failure\ hours}{Available\ hours} \quad (3)$$

Availability Rate: This ratio measures the percentage of time that a production system is operational and available for production, indicating overall efficiency and highlighting downtime impact on productivity.

$$\text{Availability Rate} = \frac{Operating\ time}{Planned\ production\ time} \quad (4)$$

SETUP Time: Measures the average total time required for the execution of SETUP activities on the production line.

(5)

$$\text{Setup time} = \frac{\text{Total setup time}}{Number\ of\ setups}$$

4. Validation
4.1 Initial Diagnosis
In Figure 2, a problem tree illustrates the diagnostic process conducted in the case study to identify the causes and root causes leading to the research problem. The primary issue identified was the low production line availability rate, with a case study rate of 37%, significantly below the standard availability rate of 62%. This performance gap resulted in an economic impact of approximately 69,338 USD per year, accounting for 5.4% of total sales. The first-level causes were categorized into high machine setup times, which contributed to 53% of the issue, and poor machine settings and regulations, responsible for 22%. The remaining 25% were grouped under other unspecified factors. The second level of analysis further identified specific root causes, including high machine preparation times (21%), deficiencies in color adjustment (18%), and time deficiencies in the registry (14%). Additional factors, such as poor cleaning of plates (5%) and changing cushions and decals (6%), also contributed to the low availability rate. This diagnostic approach aimed to systematically uncover the underlying issues impacting the production line's efficiency, guiding the implementation of improvement measures.

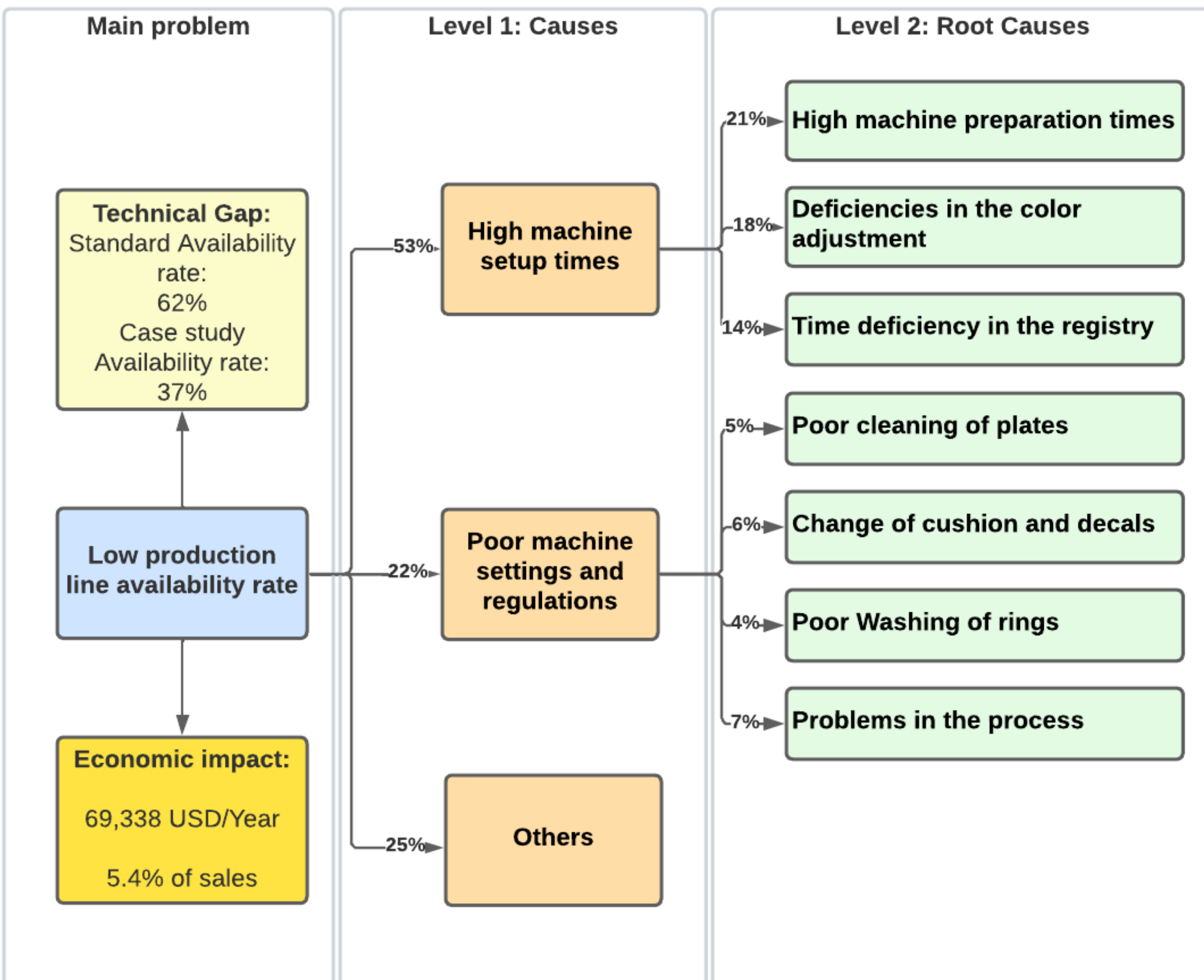

Figure 2. Problem Tree

4.2 Implementation of the model in the case study

Development of SMED in Job Change

During the job change, unproductive times were generated due to the excessive time taken in its execution. The SMED technique aimed to reduce execution time by converting internal activities to external ones. The first stage involved observing and understanding the process, where activities executed during job change were identified and described. This stage specified that the activity encompassed the time from the last printed meter on the machine to the first meter to be printed of the next work order. Activities included receiving and confirming programming, where the programming personnel established production according to needs, priorities, and delivery times coordinated with the commercial area. Supervisors in the printing area validated the information provided to the printing machinists. Next, the printing machinist received the mounted clichés on the required shirts for the next order. This ensured all the shirts in the specified colors were available. The order closing involved filling out the production record by the printing machinist.

In the second stage, internal and external activities were identified and separated. During this phase, the activities of the printing machinist and assistant at the end of the printing work were identified as internal, given that they performed the job change activities and initiated the incoming job. All their activities were categorized as internal, focusing on distinguishing activities that could be externalized.

The third stage involved converting internal activities to external ones. This step aimed to convert as many internal activities as possible into external ones. The preparation of squeegees was converted to an external activity, meaning it would be performed by trained personnel in assembling the squeegee holders while the machine was operating, thus eliminating this task from the job change flow. This activity was previously performed by the printing assistant, adding to their workload and contributing to high turnover rates. Additionally, other activities such as mounting required materials and preparing squeegees were also converted to external activities, further optimizing the process.

The final stage focused on refining the entire process by integrating parallel activities and extracting external activities. This stage detailed the participation of three key personnel involved in the job change process. In the new flow, including the support of job change personnel, waiting times for the printing machinist were eliminated, and certain activities' times were reduced or eliminated. The process was refined with a new flowchart, distributing activities among three labor resources. The new flowchart included support personnel for job changes, which helped in further reducing waiting times and optimizing job changes. This new approach aimed to streamline the process, making it more efficient and less time-consuming.

A detailed time analysis was conducted, leading to significant improvements. Before SMED implementation, the job change process had a high variability in execution times, with intervals typically ranging from 2.2 to 2.8 hours. A scheduled unproductive time of 1.5 hours was considered for job changes. The time study indicated a cycle time of 127.5 minutes on average, based on 20 verification sheets of job changes. The SMED implementation resulted in a reduction of setup time by 32% in bottleneck problems and 50% in configuration time, enhancing line efficiency by 7% compared to the initial state.

By transforming the identified internal activities into external ones and refining the process with a new job change flow, the organization successfully reduced unproductive times and enhanced overall operational efficiency. The approach demonstrated the effectiveness of the SMED technique in minimizing setup times and optimizing the production process.

Figure 3 provides a visual representation of the flow of activities before and after SMED implementation, clearly showing the difference in times and activities. It helps to illustrate how internal and external activities were restructured and how processes were optimized.

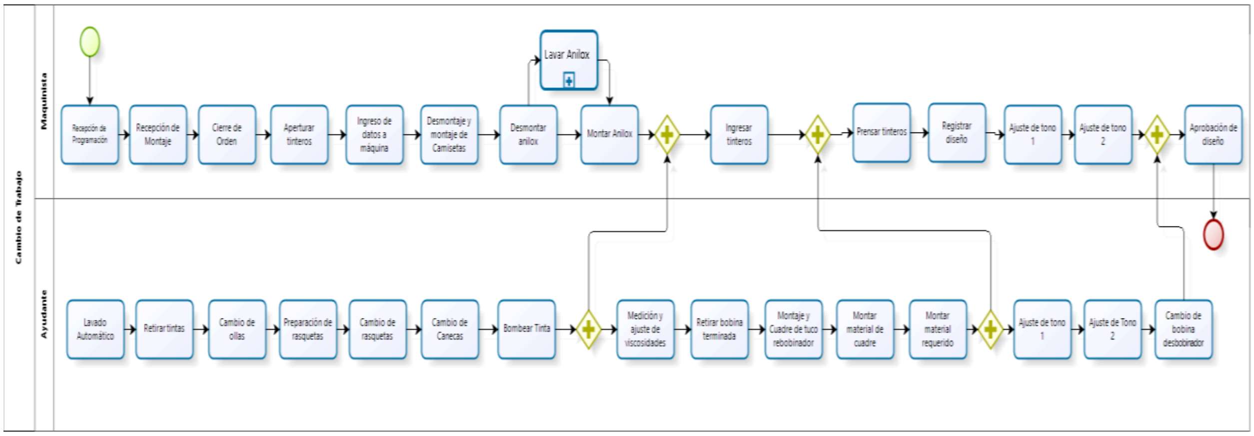

Figure 3. Flow Chart of Change of Job

Figure 4 below details the workflow of the job change process after SMED implementation. It includes the participation of the three labor resources and how the activities were distributed, which is crucial to understand the improvement in efficiency and the reduction of waiting times.

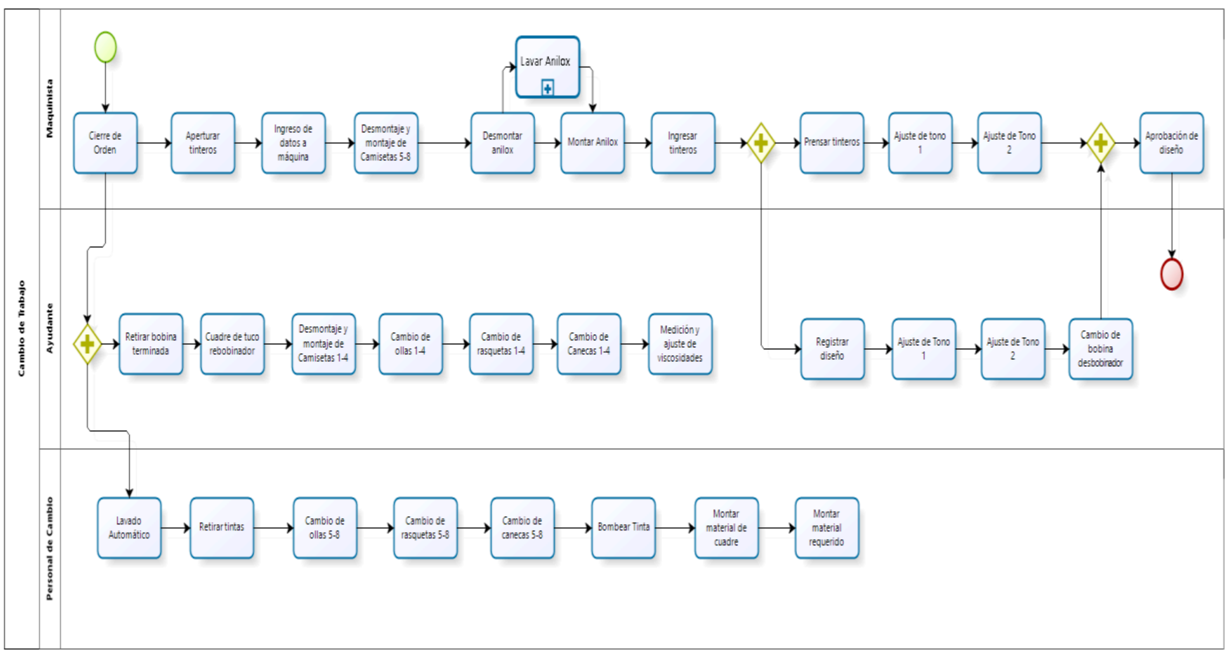

Figure 4. SMED Workflow Change

Development of 5S Implementation

The 5S methodology was implemented with the objective of creating a culture of good practices in order and cleanliness across all areas of the organization. The primary focus was on mitigating causes of unplanned unproductive times in the printing and maintenance areas, both of which were frequently disrupted by disorganization and cleanliness issues. The support and commitment of management and all employees were crucial to the success of this implementation.

The initial step involved presenting the 5S tool to all employees in the printing and maintenance areas to raise awareness about the benefits of maintaining a clean and organized workspace. This awareness aimed to eliminate unproductive times and ensure safety for all workers. Group information sessions were held to involve everyone and convey the advantages of the tool.

The second step involved forming 5S working groups to ensure the comprehensive development of the tool. These groups were led by the production manager with the support of a Lean advisor. The groups included disseminators, facilitators, and auditors. Each group had specific responsibilities: disseminators conducted daily five-minute talks, facilitators handled requests and requirements for improving order and space, and auditors performed initial and post-implementation audits.

In the third step, the areas were segmented to designate specific initial working zones, with the future goal of encompassing 100% of the organization to achieve a complete culture of order and cleanliness. The work initially focused on sector 2 (printing area) and sector 4 (maintenance area). Responsible personnel were appointed for each sector to lead actions aimed at improving each selected area.

The next step involved developing a baseline of the current situation in the printing and maintenance areas to obtain quantifiable values that could be improved through the 5S implementation. A questionnaire was used to establish this baseline, and subsequent evaluations after implementation would utilize the same questionnaire.

The actual implementation of the 5S tool began with SEIRI (Sort), which focused on categorizing objects, utensils, materials, and tools to determine their necessity in their respective areas. Items were either discarded or relocated based on this evaluation. The execution of SEIRI utilized red identification tags to classify items and determine the required action based on the evaluation.

Following SEIRI, the next stages included SEITON (Set in Order), SEISO (Shine), SEIKETSU (Standardize), and SHITSUKE (Sustain), each aimed at further embedding order and cleanliness into the workplace culture. The results from these implementations were evaluated through the same questionnaire used in the initial assessment.

The implementation of 5S showed significant improvements. Initially, the areas were rated poorly, with a score of 40%, indicating a "bad" rating. Post-implementation, the score improved to over 80%, reflecting a "good" rating. Quantitative data showed a substantial reduction in unplanned unproductive times, search times for tools, and free space for maintenance tasks. The personnel developed a culture of order and cleanliness through standardization and discipline instilled by the 5S tool.

Specifically, in the printing area, the implementation of 5S led to measurable improvements. The accumulated times for changing anilox rolls in the P8 printer were analyzed before and after implementation. In May, during the initial phase, 38 anilox changes took a total of 827 minutes, averaging 21.76 minutes per change. By June, after full implementation, 40 anilox changes took 673 minutes, averaging 16.83 minutes per change. These results demonstrated a streamlined and standardized anilox change process, eliminating the need to repeat the operation due to dirt or deterioration of the anilox.

Overall, the 5S implementation demonstrated its effectiveness in improving organizational order and cleanliness, reducing unplanned unproductive times, and fostering a culture of continuous improvement and safety within the workplace. This comprehensive approach to workplace organization was crucial for achieving the desired operational efficiency and effectiveness.

In Figure 5, a comparative audit of the 5S implementation, before and after, is shown. The graph reveals significant improvements across all dimensions of the 5S (Sort, Set in Order, Shine, Standardize, Sustain), highlighting the effectiveness of the methodology in achieving the set objectives for order and cleanliness.

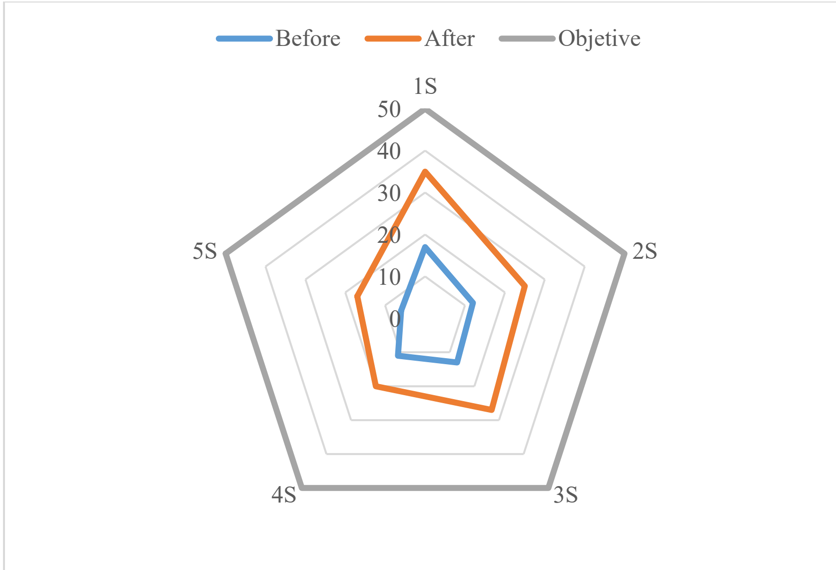

Figure 5. Audit 5S Initial vs Final

Development of Work Standardization
Work standardization was developed following a detailed analysis of secondary causes related to the printing process. It was concluded that the primary cause of production problems was high variability in the preparation of machine components and parts. Key elements included the manufacture and change of CUSHION, mounting of clichés, mounting and regulation of anilox rollers, and the preparation of ink chambers. Incoming materials for the printing process were always inspected; however, in many cases, polymer plates that did not maintain uniform height between bands were reused, requiring customized solutions and increasing variability in task execution times. The work standardization aimed to reduce this variability by establishing optimal practices for each operation, defining precise standards, and optimal execution times.

To address these issues, a five-stage action research methodology cycle was implemented. The first stage was diagnosis, where the current state of CUSHION change was analyzed. Time-taking records, change of parts records, associated problems records, and videos of the complete work were used. This analysis allowed the identification of the main variables contributing to the variability in execution times. Quantitative data obtained during this stage were crucial for planning corrective actions.

In the second stage, called Action Planning, the 5W and 2H tool was used to guide the planning. This tool allowed defining what actions to take, when and where to carry them out, who would be responsible for their execution, why they were necessary, how they would be carried out, and how much they would cost. In this phase, a detailed plan was developed, including specific activities and the resources needed to implement the proposed changes.

The third stage, Action Taking, involved executing the planned activities. It focused on implementing the identified best practices for CUSHION change, improving these practices, and defining clear standards. During this stage, tests and adjustments were made to ensure that the proposed changes resulted in a significant reduction in the variability of operation times. Data collected during this phase showed a notable improvement in process efficiency.

The fourth stage was evaluation, where the results of the implemented actions were analyzed. New execution times were compared with pre-implementation times, showing a 23% reduction in the average time for CUSHION changes. This reduction translated into a significant improvement in productivity and a decrease in downtime in the printing process. Data collected in this stage demonstrated the effectiveness of work standardization in reducing variability and improving operational efficiency.

Finally, the fifth stage was learning. In this phase, the lessons learned during the standardization process were documented. Key lessons included the importance of work time standardization based on detailed studies, the identification of critical activities, and continuous process improvement. Additionally, the importance of graphical visualization of workstations and transfer times for better understanding by collaborators was highlighted. Documenting these lessons allowed consolidating the acquired knowledge and establishing a solid foundation for future improvements.

In summary, the development of work standardization in the printing process focused on reducing variability in operation times by implementing optimal practices and defining clear standards. The five stages of the action research cycle allowed identifying and addressing the main causes of production problems, resulting in a significant improvement in operational efficiency and a 23% reduction in the average time for CUSHION changes.

Figure 6 shows a detailed representation of the work change time model, highlighting improvements and reductions in operating times following the implementation of standardization.

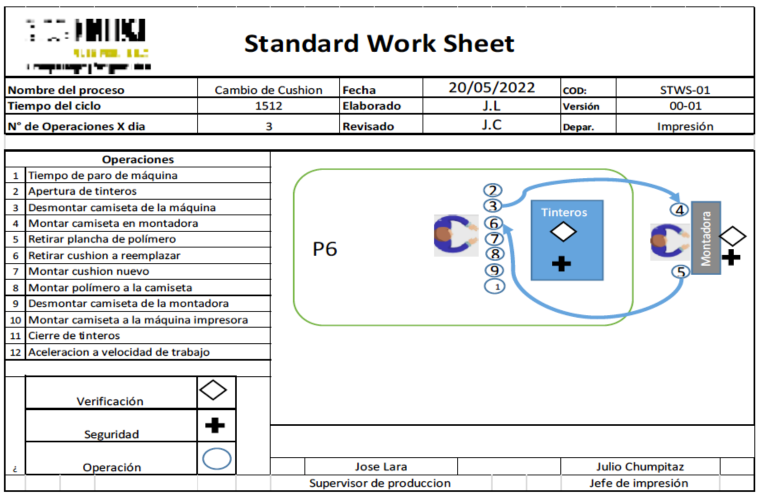

Figure 6. Job Change Time Model

5. Results

Table 1 shows the results of the validation of the proposed model, conducted through a six-month pilot. There was a 28.57% decrease in unproductive hours and a significant reduction of 45.45% in work change hours. Process failure hours decreased by 14.29%. Availability increased from 37% to 53%, representing an improvement of 43.24%. These results demonstrated the effectiveness of the model in enhancing the efficiency and availability of the production process.

Table 1. Results of validation of the proposed model

Indicator	As-Is	To-Be	Results	Variation (%)
% Unproductive hours	63%	30%	45%	-28.57%
% Hours of work change	33%	15%	18%	-45.45%
% Hours of process failure	14%	10%	12%	-14.29%
% Availability	37%	65%	53%	43.24%
Setup time (hrs)	2765	1400	1510	-45.39%

6. Conclusions

The main findings of the study indicate that the implementation of the Lean Manufacturing-based production model, consisting of SMED, the 5S methodology, and standardized work, resulted in significant improvements in the operational efficiency of SMEs in the flexographic sector. The application of SMED reduced setup times by 32% in bottleneck problems and by 50% in overall setup time, increasing line efficiency by 7%. The 5S methodology improved workspace organization, reducing unproductive times and enhancing safety, which led to a 28.57% decrease in unproductive hours. Work standardization allowed for greater consistency and quality in production processes, reducing variability and errors by 14.29%. Together, these improvements led to a 43.24% increase in production line availability and an estimated annual economic savings of 69,338 USD.

The importance of this research lies in its contribution to the efficiency and competitiveness of SMEs in the flexographic sector, a crucial area for the global and local economy. The implementation of Lean practices not only optimizes production processes but also fosters a safer and more organized work environment, which is essential for employee well-being and the long-term sustainability of companies. By addressing common issues such as high variability in setup times and lack of organization, this research provides practical and effective solutions that can be adopted by other companies in the sector.

This study makes significant contributions to the field of industrial engineering. First, it fills a gap in the literature regarding the application of Lean Manufacturing tools in the flexographic sector, offering a comprehensive production model that can be replicated and adapted in different industrial contexts. Second, the study demonstrates the effectiveness of integrating SMED, 5S, and standardized work in improving operational efficiency and reducing costs, providing a solid foundation for future research. Furthermore, the proposed model highlights the importance of a systematic, data-driven approach to implementing improvements in production processes.

In final observations, it is suggested that future studies could explore the application of this model in other industrial sectors to validate its effectiveness and adaptability. Further research on the long-term impact of Lean practices on the sustainability and growth of SMEs is also recommended. The incorporation of emerging technologies, such as digitalization and artificial intelligence, could complement Lean methodologies, providing new opportunities for process optimization and data-driven decision-making. These studies could offer valuable insights into how companies can remain competitive in an increasingly dynamic and demanding business environment.

References

Al-Najem, M., Garza-Reyes, J., & ElMelegy, A., Measuring the lean readiness of kuwaiti manufacturing industries. International Journal of Business Performance Management, 20(1), 70, 2019. https://doi.org/10.1504/ijbpm.2019.096467

Braglia, M., Paco, F., Frosolini, M., & Marrazzini, L., Quick changeover design: a new lean methodology to support the design of machines in terms of rapid changeover capability. Journal of Manufacturing Technology Management, 34(9), 84-114, 2023. https://doi.org/10.1108/jmtm-12-2022-0430

Ebrahimi, A., Khakpour, R., & Saghiri, S., Sustainable setup stream mapping (3sm): a systematic approach to lean sustainable manufacturing. Production Planning & Control, 34(4), 311-329, 2021. https://doi.org/10.1080/09537287.2021.1916637

Emekdar, E., Açikgöz-Tufan, H., Şahin, U., Bahadır, S., Tuluk, B., & Şimşek, A., Process improvement and efficiency analysis using the single-minute exchange of dies method applied to the set-up and operation of screen-printing machines. Coloration Technology, 139(2), 209-218, 2023. https://doi.org/10.1111/cote.12676

Gapp, R., Fisher, R., & Kobayashi, K., Implementing 5S within a Japanese context: An integrated management system. Management Decision, 46(4), 565-579, 2008. https://doi.org/10.1108/00251740810865067

Hirano, H., 5 Pillars of the Visual Workplace: The Sourcebook for 5S Implementation. Productivity Press, 1996.

Horzela, A. and Semrau, J., Using tools to improve logistics and production processes in a selected construction company. European Research Studies Journal, XXIV(Special Issue 1), 1211-1232, 2021. https://doi.org/10.35808/ersj/2100

Huynh, T., Determinants of the performance of small and medium-sized enterprises in emerging markets. International Journal of Productivity and Performance Management, 71(8), 3160-3178, 2021. https://doi.org/10.1108/ijppm-08-2020-0440

Khodaparasti, R., Garabollagh, H., & Mohammadpour, R., Engagement in green procurement: antecedents and outcomes on manufacturing small and medium-sized enterprises from iran. WWW Amfiteatrueconomic Ro, 22(53), 102, 2020. https://doi.org/10.24818/ea/2020/53/102

Liker, J. K., The Toyota Way: 14 Management Principles from the World's Greatest Manufacturer. McGraw-Hill, 2004.

Maharani, D. and Musfiroh, I., Review: penerapan metode single-minute exchange of dies sebagai upaya peningkatan produktivitas kerja di industri farmasi. Majalah Farmasetika, 6(3), 287, 2021. https://doi.org/10.24198/mfarmasetika.v6i3.34884

Mendo, A., Niode, I., Hasim, R., & Daud, V., Economic potential by msmes at coastal area: evidence of bone balango regency in indonesia. Dinasti International Journal of Education Management and Social Science, 3(1), 23-34, 2021. https://doi.org/10.31933/dijemss.v3i1.1013

Nakasone, E., A mixed methods assessment of technical and financial assistance to small- and medium-sized enterprises in kenya's food sector. Applied Economic Perspectives and Policy, 46(2), 435-455, 2024. https://doi.org/10.1002/aepp.13426

Padhil, A., Opportunities for the development of safety and health protection systems in the small and medium enterprise (smes) sector. International Journal of Safety and Security Engineering, 14(2), 623-632, 2024. https://doi.org/10.18280/ijsse.140228

Pagliosa, M., Tortorella, G., & Ferreira, J., Industry 4.0 and lean manufacturing. Journal of Manufacturing Technology Management, 32(3), 543-569, 2019. https://doi.org/10.1108/jmtm-12-2018-0446

Qayyum, B., Zuki, N., Nelfiyanti, N., & Yusrizal, Y., Smed simulation in optimising the operating output of tandem press line in the automotive industry using witness software. International Journal of Automotive and Mechanical Engineering, 18(3), 8895-8906, 2021. https://doi.org/10.15282/ijame.18.3.2021.05.0682

Quiroz-Flores, J., Production management model under the lean approach to reduce the waste rate in the manufacturing process of smes in the cercamic sector, 2023. https://doi.org/10.18687/laccei2023.1.1.197

Quiroz-Flores, J. and Vega-Alvites, M., Review lean manufacturing model of production management under the preventive maintenance approach to improve efficiency in plastics industry smes: a case study. The South African Journal of Industrial Engineering, 32(2), 2022. https://doi.org/10.7166/33-2-2711

Raucci, D., Lepore, D., & Sabatiello, R., Activity-based pricing in small and medium-sized restaurants. evidence from the italian context. International Journal of Culture Tourism and Hospitality Research, 14(4), 565-577, 2020. https://doi.org/10.1108/ijcthr-02-2020-0046

Ribeiro, M., Santos, A., Amorim, G., Oliveira, C., Braga, R., & Netto, R., Analysis of the implementation of the single minute exchange of die methodology in an agroindustry through action research. Machines, 10(5), 287, 2022. https://doi.org/10.3390/machines10050287

Runtuk, J., Set up time reduction using single minute exchange of dies (smed) and 5s: a case study. Jie Scientific Journal on Research and Application of Industrial System, 6(2), 162, 2021. https://doi.org/10.33021/jie.v6i2.3384

Şahin, R. and Koloğlu, A., A case study on reducing setup time using smed on a turning line. Gazi University Journal of Science, 35(1), 60-71, 2022. https://doi.org/10.35378/gujs.735969

Sahoo, S., Assessing lean implementation and benefits within indian automotive component manufacturing smes. Benchmarking an International Journal, 27(3), 1042-1084, 2020. https://doi.org/10.1108/bij-07-2019-0299

Shingo, S., A Revolution in Manufacturing: The SMED System. Productivity Press, 1985.

Van, T., The role of the formalization process on the product innovation results of small and medium-sized private enterprises in vietnam. Turk Turizm Arastirmalari Dergisi, 2023. https://doi.org/10.26677/tr1010.2023.1352

Zastempowski, M., Ignasiak-Szulc, A., & Cyfert, S., Conditions of marketing and organizational innovation of small and medium-sized enterprises. European Research Studies Journal, XXIII(Issue 2), 163-173, 2020. https://doi.org/10.35808/ersj/1586

Ziemba, J., Hawryluk, M., & Rychlik, M., Application of 3d scanning as an indirect method to analyze and eliminate errors on the manufactured yoke-type forgings forged in smed device on modernized crank press. Materials, 14(1), 137, 2020. https://doi.org/10.3390/ma14010137

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