3rd Australian Conference on Industrial Engineering and Operations Management
Sydney, Australia, September 24-26, 2024
Publisher: IEOM Society International, USA DOI: 10.46254/AU03.20240073
Published: September 24, 2024

Increasing Productivity in Paper Bag Manufacturing through Lean Manufacturing: A Case Study in Perú

Yoreli Nicole Ramirez-Palomino
Bachelors in industrial engineering
Facultad de Ingeniería, Universidad de Lima, Peru
20163476@aloe.ulima.edu.pe

Daniela de Fatima Vasquez-Morales
Bachelors in industrial engineering
Facultad de Ingeniería, Universidad de Lima, Peru
20163700@aloe.ulima.edu.pe

Abstract

The industry of small and medium-sized enterprises (SMEs) dedicated to the manufacturing of paper bags in Peru faces various challenges related to production efficiency and quality management. Previous studies have shown that implementing Lean Manufacturing methodologies can significantly improve these aspects by optimizing processes and reducing waste. This study focused on addressing production inefficiencies in SMEs in the sector, which manifest in high rates of non-conforming products and prolonged format change times, affecting the competitiveness and sustainability of these companies. To solve these problems, a production model based on Lean Manufacturing tools was proposed, specifically SMED, 5S, and Standardized Work. These tools were selected for their proven effectiveness in improving operational efficiency and reducing waste. The implementation of the model involved an initial diagnosis, followed by the systematic application of each tool, focusing on the transformation of internal to external tasks, workspace organization, and process standardization. The key results of the study included a 60% reduction in format change time, an increase in operational efficiency from 47.66% to 91.15%, and an improvement in product quality reflected in the decrease of defective products. These findings validate the effectiveness of the proposed model, demonstrating significant improvements in productivity and quality in paper bag manufacturing. The academic and socioeconomic impact of this research is notable, as it provides a practical and structured framework for addressing production inefficiencies in manufacturing SMEs. Waste reduction contributes to environmental sustainability, while improvements in productivity and quality strengthen the competitiveness of companies in the global market. This study provides new evidence to the existing body of knowledge on the application of Lean Manufacturing in specific sectors. In conclusion, this research highlights the importance of adopting Lean Manufacturing methodologies to transform production processes and achieve continuous improvement in the manufacturing industry. Researchers and practitioners are encouraged to explore and adapt these methodologies in various industrial contexts, promoting innovation and sustainable growth.

Keywords
Lean Manufacturing, Paper bag manufacturing, Productivity Improvement, 5S Methodology, Process Optimization.

1. Introduction

The sector of small and medium-sized enterprises (SMEs) engaged in the manufacturing of paper bags plays a crucial role in the global economy, particularly in regions like Latin America and Peru. These SMEs contribute significantly to the economy by providing employment opportunities, fostering innovation, and meeting the growing demand for sustainable packaging solutions (Tsarouhas, 2020). In Latin America, the paper industry has been a key player in driving economic growth and promoting environmental sustainability through the production of eco-friendly packaging materials like paper bags (Liao & Wang, 2019). Similarly, in Peru, the manufacturing of paper bags by SMEs not only supports the local economy but also aligns with the country's focus on sustainability and environmental conservation (Cespedes-Pino et al., 2020). The sector's emphasis on biodegradable and recyclable products resonates with the global shift towards eco-conscious consumerism, making it a vital component of the packaging industry (He & Jiang, 2019).

Production inefficiencies pose significant challenges for SMEs involved in the manufacturing of paper bags, with issues such as a high number of non-conforming products and reprocessing activities affecting operational performance. These problems are often rooted in inadequate format changes and paper roll transitions during the printing process, leading to quality defects and increased waste (Byrne et al., 2021). The implementation of Lean Six Sigma methodologies has shown promise in addressing such challenges by streamlining processes, reducing defects, and enhancing overall operational efficiency (Chae et al., 2019). By focusing on continuous improvement and waste reduction, SMEs can optimize their production processes, minimize rework, and improve product quality, ultimately leading to cost savings and enhanced competitiveness in the market (Agyeman, 2021). Addressing these production challenges is crucial for SMEs to ensure sustainable growth, meet customer expectations, and maintain profitability in a competitive industry landscape (Cespedes-Pino et al., 2020).

Resolving the production challenges faced by SMEs in the paper bag manufacturing sector is of paramount importance for various reasons. Firstly, enhancing production efficiency and reducing waste not only improves the bottom line for businesses but also contributes to environmental sustainability by minimizing resource consumption and waste generation (Tsarouhas, 2020). Secondly, by optimizing production processes and ensuring product quality, SMEs can enhance customer satisfaction, build brand reputation, and gain a competitive edge in the market (He & Jiang, 2019). Moreover, efficient production practices enable SMEs to meet market demands promptly, adapt to changing consumer preferences, and capitalize on emerging opportunities in the packaging industry (Antony et al., 2023). Therefore, addressing production inefficiencies is not only beneficial for individual SMEs but also for the overall growth and sustainability of the paper bag manufacturing sector.

Despite the importance of addressing production challenges in the SME sector of paper bag manufacturing, there exists a significant gap in the literature regarding effective methodologies to improve production processes. This research aims to bridge this gap by proposing a production model based on Lean Manufacturing principles, specifically incorporating tools such as Single-Minute Exchange of Die (SMED), 5S, and Standardized Work. These Lean tools have been proven effective in enhancing operational efficiency, reducing waste, and improving overall productivity in various manufacturing settings. By integrating these Lean methodologies into the production processes of SMEs manufacturing paper bags, this study seeks to provide a comprehensive framework for optimizing operations, minimizing defects, and enhancing quality control measures. Through the implementation of Lean Manufacturing principles, this research aims to offer practical insights and actionable strategies for SMEs to overcome production challenges, improve competitiveness, and achieve sustainable growth in the paper bag manufacturing sector.

2. Literature Review

2.1 Improving Productivity in Small and Medium-Sized Manufacturers of Paper Bags

Small and medium-sized enterprises (SMEs) in the manufacturing sector, particularly those producing paper bags, face challenges in enhancing their productivity. Research by Zamora (2023) highlights the application of Lean Manufacturing and Total Productive Maintenance (TPM) as a production model to boost efficiency in the textile industry. This study serves as a valuable methodological foundation for similar research in SMEs manufacturing paper bags, offering insights into operational enhancements that can be adapted to optimize processes and productivity levels (Zamora, 2023; . Sun et al., 2016) emphasize the significance of leveraging product-related review features for fake review detection, showcasing the importance of utilizing data-driven approaches to enhance operational processes and decision-making within manufacturing environments (Sun et al., 2016; . Guillon et al., 2019) present a methodology for implementing a product-centered bid model for suppliers, underscoring the importance of structured approaches in enhancing operational efficiency and supplier relationships, which can be extrapolated to SMEs in the paper bag manufacturing sector (Guillon et al., 2019). Additionally, Khemir (2021) discusses experiences with product development methodologies in research campuses, emphasizing the value of innovation workshops and collaborative practices in driving product development, which could be beneficial for SMEs seeking to improve their productivity and innovation capabilities (Khemir, 2021).

2.2 Application of Lean Manufacturing in Paper Bag Production

The implementation of Lean Manufacturing principles in the production processes of companies manufacturing paper bags has been a subject of interest in research. Noamna et al. (2022) delve into the improvement of transformer production through Lean and MTM-2 techniques, highlighting the effectiveness of value stream mapping in streamlining processes and enhancing productivity (Noamna et al., 2022; . Chan & Tay, 2018) explore the application of Lean tools in Kaizen within the printing industry, showcasing the benefits of continuous improvement methodologies in optimizing operations and reducing waste, a practice that can be adapted by paper bag manufacturers to enhance their production efficiency (Chan & Tay, 2018). Furthermore, Gao & Pheng (2013) discuss the application of Kaizen methods in construction firms, shedding light on the practical implementation of Lean principles in enhancing operational processes, which can be translated to the context of paper bag manufacturing for process optimization and waste reduction (Gao & Pheng, 2013). Moreover, Flores et al. (2020) propose a model to reduce waste in label production by applying Autonomous Maintenance, Kanban, and Standardization of work, offering a structured approach that can be beneficial for SMEs in the paper bag manufacturing sector to improve their operational efficiency and waste management practices (Flores et al., 2020).

2.3 Implementing the 5S Methodology in Paper Bag Manufacturing

The 5S methodology, focusing on Sort, Set in order, Shine, Standardize, and Sustain, has been applied in various industries to enhance workplace organization and efficiency. Sayed et al. (2022) discuss the production of paper using the chemical pulping process of sugarcane bagasse, highlighting the importance of efficient processes in the pulp and paper industry, which can be optimized through the application of methodologies like 5S to streamline operations and improve productivity (Sayed et al., 2022; . Emelianova et al., 2020) emphasize the organization of standardization work planning in industrial enterprises, underscoring the significance of structured approaches in enhancing operational efficiency and quality standards, principles that align with the core tenets of the 5S methodology for improving workplace organization and productivity (Emelianova et al., 2020). Additionally, Oster et al. (2016) advocate for the application of composable architectures in designing complex systems, showcasing the value of structured methodologies in enhancing system efficiency and adaptability, which can be beneficial for SMEs in the paper bag manufacturing sector to optimize their production processes through standardized practices (Oster et al., 2016). Lastly, Minicis et al. (2014) discuss the re-design of the recipe development process in the pharmaceutical industry, highlighting the importance of standardized processes in ensuring product quality and consistency, principles that resonate with the 5S methodology's focus on standardization and sustainability in manufacturing operations (Minicis et al., 2014).

2.4 Enhancing Production Efficiency with SMED Methodology

The Single-Minute Exchange of Die (SMED) methodology focuses on reducing setup times in manufacturing processes, thereby enhancing operational efficiency. Kłos and Patalas-Maliszewska (2013) explore the impact of Enterprise Resource Planning (ERP) on maintenance management, emphasizing the importance of efficient processes in enhancing overall productivity and resource utilization, principles that align with the objectives of the SMED methodology in reducing non-value-added activities and improving production efficiency (Kłos & Patalas-Maliszewska, 2013; . Dodge et al., 2021) illustrate the value of critical methodologies in gender studies, emphasizing the importance of alternative knowledge production processes in challenging traditional paradigms, a perspective that can be applied in the context of SMED implementation to drive innovative approaches and enhance production efficiency in SMEs manufacturing paper bags (Dodge et al., 2021). Moreover, Ma et al. (2019) conduct a life cycle assessment of carbon emissions in China's cement packaging, highlighting the importance of sustainable practices in manufacturing operations, a principle that resonates with the SMED methodology's focus on reducing waste and optimizing resource utilization for improved production efficiency (Ma et al., 2019). Additionally, Madan et al. (2013) characterize the energy consumption of the injection molding process, emphasizing the significance of assessing and optimizing energy usage in manufacturing processes to enhance sustainability and operational efficiency, principles that can be integrated into the SMED methodology for improving production practices in paper bag manufacturing (Madan et al., 2013).

2.5 Implementing Standardized Work in Paper Bag Production Processes

Standardized Work methodology focuses on establishing consistent processes to drive efficiency and quality in manufacturing operations. Hedberg et al. (2016) identify research directions for utilizing manufacturing knowledge earlier in the product life cycle, emphasizing the importance of standardized practices in enhancing product development and manufacturing efficiency, principles that align with the objectives of Standardized Work methodology in driving process consistency and optimization in paper bag manufacturing (Hedberg et al., 2016). discusses improving human-robot collaboration in TV assembly through computational ergonomics, highlighting the importance of standardized frameworks and real-time data processing capabilities in enhancing operational efficiency and ergonomics, aspects that can be integrated into Standardized Work practices for optimizing production processes in SMEs manufacturing paper bags (Olivas-Padilla, 2023; . Zelenkov, 2017) explores information efficiency and system design in organizations, underscoring the importance of structured methodologies in optimizing information flow and operational processes, principles that resonate with the Standardized Work methodology's focus on establishing consistent and efficient work practices in manufacturing environments (Zelenkov, 2017). Lastly, Garcia et al. (2010) delve into developing ontologies within decentralized settings, showcasing the value of structured frameworks in knowledge management and process optimization, aspects that can be beneficial for SMEs in the paper bag manufacturing sector to enhance their operational efficiency through standardized work practices (Garcia et al., 2010).

3. Methods

3.1 Basis of the Proposed Model

Figure 1 shows a production model based on the Lean Manufacturing philosophy. This model integrated three key tools: SMED, standardized work, and 5S, aiming to transform low-productivity processes into highly efficient systems. The Lean Manufacturing philosophy focused on waste elimination and continuous process improvement, optimizing operational efficiency and product quality. SMED was employed to significantly reduce tool change times, increasing production flexibility and responsiveness. Standardized work ensured consistency and quality in daily operations by establishing clear and repeatable procedures. The 5S methodology promoted organization, cleanliness, and workplace maintenance, enhancing safety and reducing errors. The primary objective of the model was to increase productivity through the implementation of these practices, minimizing losses and maximizing customer value. This integration of Lean tools enabled a more agile response to market demands, consolidating an organizational culture oriented towards continuous improvement and operational sustainability.

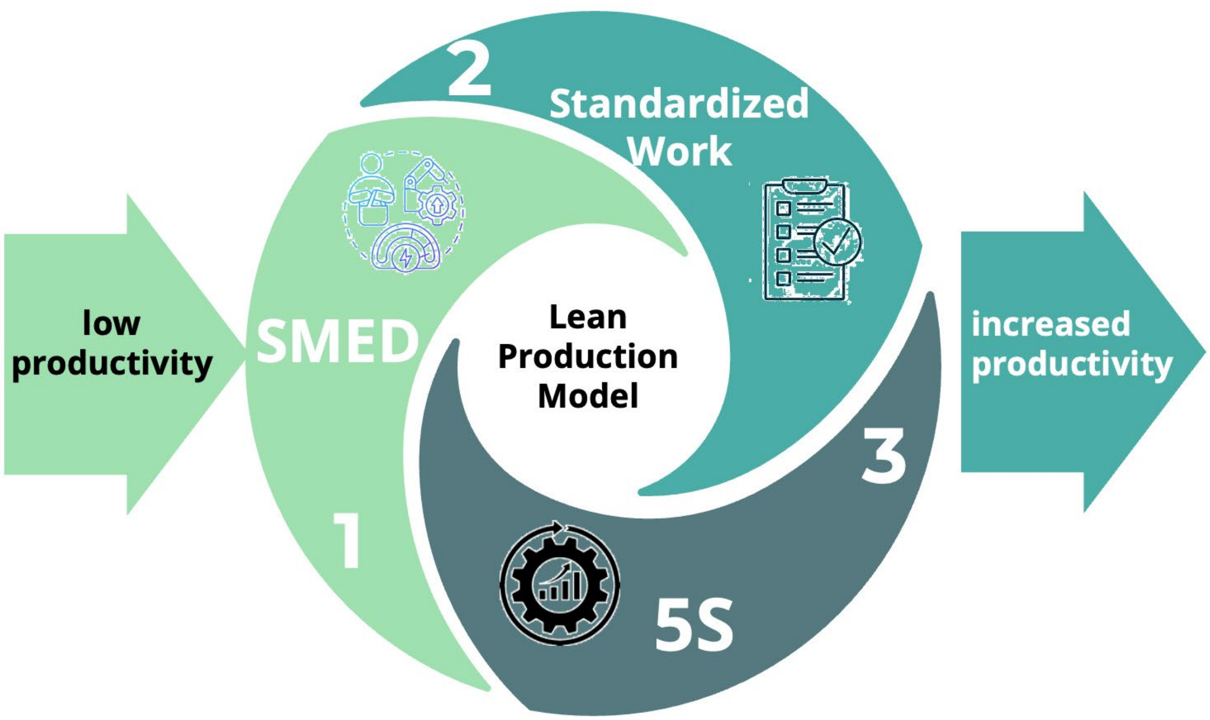

Figure 1. Proposed Model

3.2 Description of the model components

The production model grounded in the Lean Manufacturing philosophy, which integrated three pivotal tools: SMED (Single-Minute Exchange of Dies), standardized work, and 5S. Each component played a crucial role in enhancing productivity and operational efficiency. This comprehensive analysis delved into each stage of the model, elucidating their implementation and impact on manufacturing processes.

SMED: Revolutionizing Changeover Times

The first stage of the Lean Production Model was SMED, a technique designed to dramatically reduce changeover times. Originally developed by Shingo (1985), SMED aimed to transform internal setup tasks, which required equipment to be stopped, into external tasks that could be performed while the equipment was running. This conversion process significantly reduced downtime, enabling more frequent changeovers and smaller batch sizes, which in turn enhanced production flexibility (Feld, 2001). The implementation of SMED involved a thorough analysis of the setup process, distinguishing between internal and external tasks, and systematically converting as many internal tasks to external ones as possible (Van Goubergen & Van Landeghem, 2002). The primary goal was to achieve changeover times of less than ten minutes, hence the term "single minute." Studies have shown that successful SMED implementation led to substantial productivity improvements and cost reductions, making it a cornerstone of Lean Manufacturing (Soderberg & Bengtsson, 2010).

Standardized Work: Ensuring Consistency and Quality

The second stage involved standardized work, a fundamental aspect of Lean Manufacturing that focused on establishing consistent methods and procedures for tasks. Standardized work aimed to minimize variability in the production process, ensuring that each task was performed in the most efficient manner every time (Liker, 2004). This consistency was achieved by documenting the best practices for each operation and training employees to follow these standardized procedures meticulously (Ohno, 1988). Standardized work not only enhanced product quality by reducing errors and defects but also facilitated continuous improvement by providing a clear baseline against which improvements could be measured (Emiliani, 2007). By creating a stable and predictable production environment, standardized work laid the foundation for other Lean tools and techniques to be effectively implemented (Hirano, 1995).

5S: Organizing and Optimizing the Workplace

The final stage was the implementation of the 5S methodology, which focused on workplace organization and standardization. The five S's stood for Sort (Seiri), Set in order (Seiton), Shine (Seiso), Standardize (Seiketsu), and Sustain (Shitsuke) (Hirano, 1995). This methodology aimed to create a clean, organized, and efficient workplace, which in turn improved safety, reduced waste, and enhanced productivity (Gapp, Fisher, & Kobayashi, 2008). The first step, Sort, involved removing unnecessary items from the workplace. Set in order ensured that tools and materials were organized and easily accessible. Shine focused on cleaning the workplace to maintain a pleasant and safe working environment. Standardize created procedures to maintain the first three S's, and Sustain involved cultivating a culture of discipline to ensure that the 5S practices were followed consistently (Osada, 1991). Implementing 5S not only improved operational efficiency but also boosted employee morale by creating a better working environment (Ho, 1999).

Integrating Lean Tools for Maximum Impact

The integration of SMED, standardized work, and 5S within the Lean Production Model created a synergistic effect that significantly enhanced overall productivity and efficiency. Each tool addressed different aspects of the production process, and their combined implementation resulted in a more responsive, flexible, and efficient manufacturing system (Bicheno & Holweg, 2009). SMED reduced changeover times, enabling more agile production schedules and reducing inventory costs. Standardized work ensured that processes were performed consistently and efficiently, minimizing errors and defects. The 5S methodology improved workplace organization and safety, reducing waste and downtime. Together, these tools fostered a culture of continuous improvement, where employees were actively engaged in identifying and eliminating waste, and constantly seeking ways to improve processes (Womack & Jones, 2003).

Real-World Applications and Benefits

Numerous case studies have demonstrated the tangible benefits of implementing the Lean Production Model. For instance, a study by Alves, Dinis-Carvalho, and Sousa (2012) highlighted the successful application of Lean tools in a Portuguese automotive component manufacturer, where SMED and standardized work led to a 50% reduction in changeover times and a significant improvement in process stability. Similarly, a study by Cudney and Elrod (2011) documented the positive impact of 5S and standardized work in a US manufacturing firm, resulting in enhanced operational efficiency and employee satisfaction. These examples underscored the versatility and effectiveness of the Lean Production Model across different industries and contexts.

In conclusion, the Lean Production Model, as depicted in Figure 1, provided a robust framework for enhancing productivity and operational efficiency through the integration of SMED, standardized work, and 5S. Each component played a crucial role in addressing specific aspects of the production process, and their combined implementation created a synergistic effect that maximized the benefits of Lean Manufacturing. By focusing on waste elimination, process standardization, and workplace organization, this model fostered a culture of continuous improvement and operational excellence. The real-world applications and documented benefits of the Lean Production Model demonstrated its effectiveness and adaptability across various industries, making it a valuable approach for modern manufacturing environments.

3.3 Model Indicators

In order to evaluate the success of the proposed production model, specific metrics were established. These metrics were designed to systematically track, monitor, and manage the outcomes associated with the model. This approach ensured a comprehensive assessment of the model's effectiveness and efficiency within the context of the case study.

Productivity rate: this indicator measures the efficiency of a plant by calculating the ratio between the total output of paper bags and total inputs.

$$\text{Productivity rate} = \frac{Total\ outputs}{Total\ inputs} \tag{1}$$

Efficiency rate: this indicator assesses how close a plant's actual production is to reaching the expected production of paper bags.

$$\text{Effienciency rate} = \frac{Actual\ Production}{Expected\ Production} \times 100 \tag{2}$$

Effectiveness rate: this indicator measures the extent to which a plant achieves its set production targets for paper bags.

$$\text{Effectiveness rate} = \frac{Actual\ production}{Production\ Targets} \times 100 \tag{3}$$

4. Validation

4.1 Initial Diagnosis

In Figure 2, a problem tree is presented, summarizing the diagnosis conducted in the case study to identify the causes and root reasons behind the research problem. The central issue identified was low productivity, with a technical gap in standard productivity, as evidenced by a case study showing a productivity rate of 47.6%. This low productivity resulted in an economic impact estimated at 93,846 PEN per year, representing 12.6% of sales. The first level of causes included a high rate of non-compliant products and a high rate of reprocessing, along with other unspecified factors. The high rate of non-compliant products and reprocessing were attributed to several root causes. These included poor change of printing format, slow change of paper rolls, lack of cleanliness, other stoppages, stoppages by raw material, and stoppages due to machine failures. Each root cause contributed to the overall inefficiency observed in the production process. This analysis provided a clear visualization of the hierarchical relationship between the main problem, its immediate causes, and the deeper root causes, offering a structured approach to address the productivity issues identified in the study.

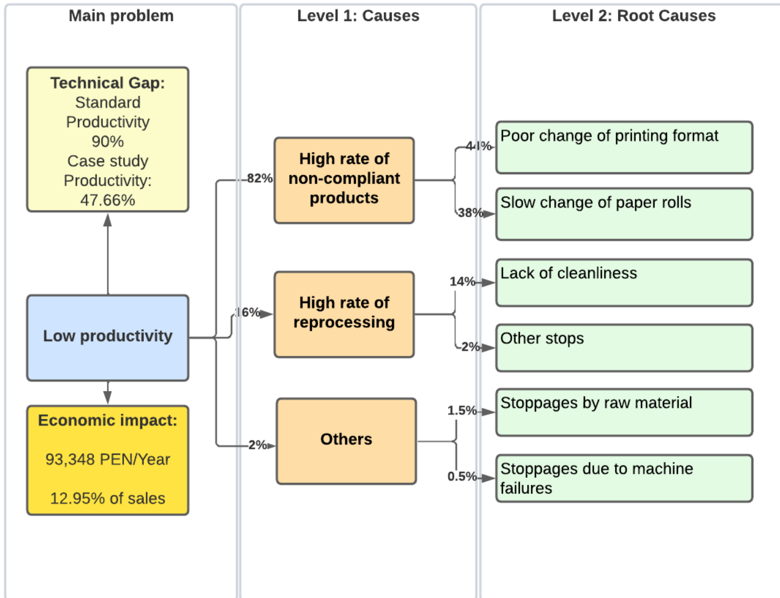

Figure 2. Problem Tree

4.2 Implementation of the model in the case study

Phase 01: Application of the SMED tool

The Single Minute Exchange of Dies (SMED) methodology was implemented to address bottlenecks in the format change process. The average time for format change was 297.90 minutes, collected from the company's database. The process began with identifying internal and external activities related to bottlenecks, aiming to transform as many internal activities as possible into external ones. After making these changes, external activities were identified within the format change process, allowing for parallel execution with internal activities. This adjustment reduced the format change time from 297.90 minutes to 118.70 minutes, demonstrating the effectiveness of the SMED approach.

The implementation of SMED included identifying bottlenecks when the takt time was less than the average time of each activity. Observations pinpointed potential improvements in the process, focusing on external activities that could be executed without halting production. These activities, once converted to external, allowed for simultaneous execution with other internal tasks, significantly reducing the overall format change time.

The three-phase framework for SMED implementation consisted of: identifying internal and external activities, converting internal steps to external ones, and standardizing all activities in the format change process. This structured approach facilitated a systematic reduction in setup times and enhanced overall productivity. The reduction from 297.90 minutes to 118.70 minutes underscored the impact of converting internal activities to external, aligning with the SMED methodology's objectives.

The success of SMED was highlighted by a case where the internal setup time decreased from 375 minutes to 215 minutes, equivalent to a 57.33% reduction. This significant improvement illustrated the potential of SMED in streamlining production processes, reducing waste, and enhancing efficiency by minimizing downtime during format changes.

By involving all stakeholders, including senior management, the SMED implementation ensured comprehensive engagement and support. This holistic approach was crucial for identifying and addressing bottlenecks, leading to more efficient and productive operations. The involvement of all relevant parties facilitated a smooth transition and adherence to the new processes, ensuring sustainable improvements in setup times and overall production efficiency.

Figure 3 shows the implementation of SMED in the format change process. It compares the current process and the improved process, highlighting steps in red (inefficient) and green (efficient). The projected improvement would increase efficiency to an annual average of 86%, with a range of 82% to 90%, and a PNC probability of 0.812.

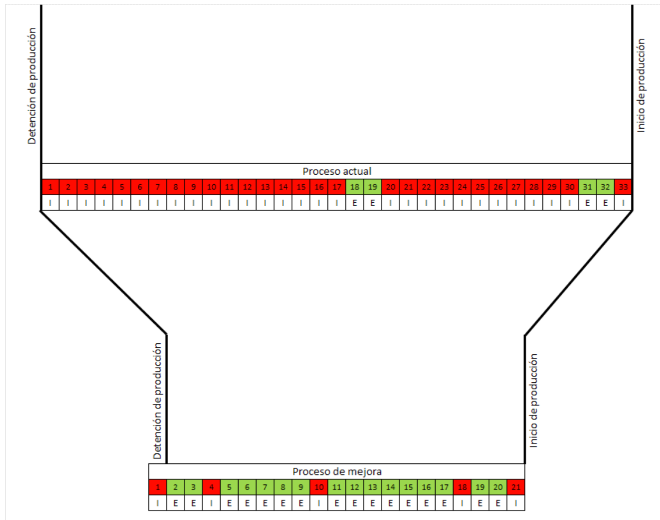

Figure 3. Implementation of SMED in the format change process

Phase 02: Implementation of the Standardized Work Methodology

In section 3.2.3.2.2, the standardization of work was implemented specifically for the process of placing a new roll of paper into the packaging machine. The analysis identified activities with and without added value (VA and NVA). The observations column indicated changes that needed to be made to the NVA activities. Initially, the total VA time was 2.33 minutes, representing 19% of the total average process time of 12.25 minutes. The NVA activities accounted for 9.92 minutes, which was 81% of the total time. After the improvements were made, the VA time increased to 3.67 minutes, which constituted 84% of the projected process time of 4.38 minutes, while the NVA time decreased to 0.71 minutes, or 16% of the projected time. The projection of the results based on these improvements indicated that efficiency would increase to an annual average of 98%, with an annual range of 90% to 100%. This demonstrates a significant enhancement in productivity through the elimination of non-value-added activities and the optimization of value-added activities, thus illustrating the effectiveness of work standardization in improving process efficiency and productivity.

Figure 4 details the improved process for changing paper rolls in a 40kg cement bag production line. The process involves five steps, totaling 4.38 minutes per roll, with 84% value-added (VA) activities and 16% non-value-added (NVA). The chart categorizes activities as operations, transportation, inspection, and storage.

DAP - Proceso de mejora cambio de rollo de papel						
DIAGRAMA ANALÍTICO DE PROCESOS	OPERARIO / PROCESO / EQUIPO					
DIAGRAMA núm: Hoja num: 01/01	**RESUMEN**					
Objeto:	**ACTIVIDAD**		**ACTUAL**			
Actividad: Producción bolsas de cemento de 40kg, Cambio rollo papel	Operación		05			
	Transporte		0			
Método: Mejora SW	Espera		0			
	Inspección		01			
Lugar: Planta	Almacenamiento		0			
Operarios(s): Ficha num:	Distancia					
	Tiempo					
Por rollo						
Total operarios 2, ejecutan diferentes tareas						

	DESCRIPCIÓN	**Op**	**T (min) promedio**	**SIMBOLO** ●	➡	D	■	▼	**Observaciones**						NVA / VA
Cambio de rollo de papel	Retirar parante con tubo vacío	1	0.94	x											VA
	Aflojar pernos y retirar tubo vación de rollo de papel	2	1.06	x											VA
	Colocar nuevo rollo de papel, enganchar en grúa y ajustar pernos	2	0.98	x											VA
	Colocar parante en locación (grúa) y retirar grúa	2	0.71	x											NVA
	Colocar y alinear papel en máquina y retirar papel no necesario	2	0.70	x			x								VA
	Total de proceso minutos		4.38	05	0	0	01	0				VA		NVA	
	Total de proceso horas		0.07									3.67	84%	0.71	16%

Figure 4. Improved change of paper roll

Phase 03: Implementation of the 5S Methodology

The implementation of the 5S methodology in the studied case aimed to transform disorganized workspaces into orderly environments conducive to efficient operations. The tool focused on eliminating waste and ensuring a clean, organized area free of obstacles that could impede the movement of raw materials, inputs, semi-finished, and finished products. The 5S methodology encompasses five phases: Sort (Seiri), Set in Order (Seiton), Shine (Seiso), Standardize (Seiketsu), and Sustain (Shitsuke), each contributing to the overarching goal of continuous improvement.

The initial phase, Sort, involved categorizing items to identify and remove unnecessary objects from the workspace. This step ensured that only essential items remained, thereby reducing clutter and potential sources of inefficiency. The subsequent phase, Set in Order, required organizing the retained items in a manner that facilitated easy access and efficient workflow. The implementation team designed specific strategies, such as creating designated storage areas, to enhance organization and reduce time spent searching for tools and materials.

In the Shine phase, the emphasis was on cleanliness and maintenance. Regular cleaning routines were established to ensure that the work environment remained tidy and safe, thus preventing potential equipment failures and maintaining a high standard of hygiene. The introduction of cleaning schedules and responsibilities among staff helped maintain these standards consistently.

Standardize, the fourth phase, involved establishing protocols and schedules to ensure the ongoing application of the first three phases. This step was crucial in embedding the practices into the daily routines of employees, thereby fostering a culture of discipline and consistency. The final phase, Sustain, focused on maintaining the momentum of the 5S practices through regular audits and continuous training. This phase aimed to instill a sense of ownership and accountability among employees, ensuring that the improvements were sustained over the long term.

Quantitative results from the implementation of the 5S methodology in the case study demonstrated significant improvements. The average score for workplace organization increased from 6.4 to 15.4, nearing the target score of 21. This improvement indicated a substantial enhancement in the orderliness and efficiency of the workspace, which directly contributed to the overall productivity and effectiveness of the operations.

Overall, the 5S methodology proved to be a powerful tool in transforming the work environment, reducing waste, and improving productivity and safety. By systematically implementing each phase and involving all levels of staff, the company was able to achieve and sustain significant improvements, demonstrating the value of this Lean Manufacturing tool in fostering a culture of continuous improvement and operational excellence.

Figure 5 shows the 5S audit results, comparing initial (As Is), final (Results), and target (To Be) scores. Initial scores were low across all phases: Seiri (0.8), Seiton (0.7), Seiso (0.6), Seiketsu (0.5), and Shitsuke (0.6). Final scores improved significantly but remained below target.

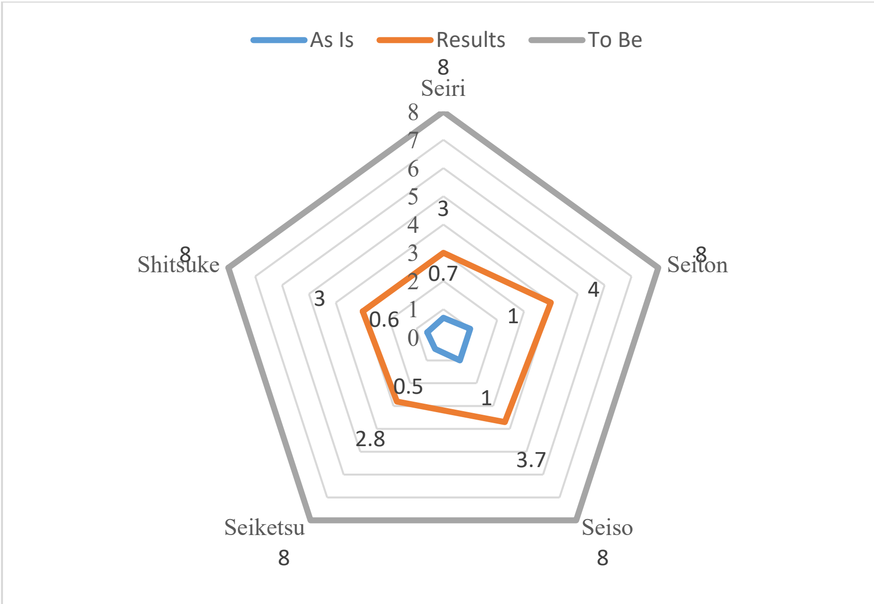

Figure 5. Audit 5S Initial vs. Final

5. Results

Following the implementation of the tools, in Table 1 shows the results of the validation of the proposed model, comparing three scenarios: "As-Is," "To-Be," and "Results." The key indicators include the Operational Efficiency Index, Average Distance Between Areas, Time to Move Between Areas, Time of Organization Between Areas, and Setup Time. The results indicate significant improvements, with a 53.81% reduction in Time to Move Between Areas, a 49.80% reduction in Setup Time, and a 40.82% increase in the Operational Efficiency Index from the "As-Is" to the "Results" scenario.

Table 1. Results of validation of the proposed model

Indicator	As-Is	To-Be	Results	Variation (%)
Efficiency	47.66%	90.00%	91.15%	91.25%
Effectiveness	74.84%	95.00%	97.91%	30.83%
Productivity	63.68%	95.000	93.10%	46.20%

6. Conclusions

The main findings of the study indicate a significant improvement in operational efficiency and reduction of waste in the manufacture of paper bags. The implementation of Lean Manufacturing and TPM methodologies led to an increase in the productivity index from 47.66% to 91.15%, and an improvement in equipment efficiency from 74.84% to 97.91%. These figures reflect a remarkable optimization in the production processes, evidencing the effectiveness of the proposed model.

The importance of research lies in its ability to provide a practical and structured framework for addressing production inefficiencies. The study not only addresses sector-specific problems, but also provides solutions applicable to other industrial contexts. By improving productivity and reducing operating costs, companies can increase their competitiveness in the global market. In addition, waste reduction contributes to more sustainable practices, aligning with growing demands for environmental responsibility.

Contributions to the field of study are manifold. This work expands the body of knowledge on the application of Lean Manufacturing and TPM in small and medium-sized enterprises, specifically in the paper bag manufacturing sector. The research provides detailed methodology and empirical data that validate the effectiveness of these tools in improving operational efficiency and product quality. These findings can serve as a reference for future research and practical applications in other industrial sectors.

Concluding observations and suggestions for future studies include the need to explore the long-term sustainability of the improvements implemented. In addition, research into the integration of advanced technologies, such as automation and the Internet of Things (IoT), is recommended to further enhance the efficiency and responsiveness of production systems. A multidisciplinary approach combining lean tools with technological innovations could offer new opportunities to improve productivity and sustainability in manufacturing.

In summary, the research demonstrates the positive impact of Lean Manufacturing methodology on operational efficiency and sustainability in paper bag manufacturing. The findings suggest that adopting these approaches can significantly transform production processes. Researchers and practitioners are encouraged to continue exploring and adapting these methodologies in various industrial contexts to foster innovation and sustainable growth.

References

Agyeman, N., The impacts of lean principles on the production of civil aircraft in boeing. Aircraft Engineering and Aerospace Technology, 93(1), 212-217, 2021. https://doi.org/10.1108/aeat-05-2020-0107

Alves, A. C., Dinis-Carvalho, J., & Sousa, R. M., Lean production as promoter of thinkers to achieve companies' agility. The Learning Organization, 19(3), 219-237, 2012. https://doi.org/10.1108/09696471211219930

Antony, J., McDermott, O., & Sony, M., Revisiting ishikawa's original seven basic tools of quality control: a global study and some new insights. Ieee Transactions on Engineering Management, 70(11), 4005-4020, 2023. https://doi.org/10.1109/tem.2021.3095245

Bicheno, J., & Holweg, M., The Lean Toolbox: The Essential Guide to Lean Transformation. PICSIE Books, 2009.

Byrne, B., McDermott, O., & Noonan, J., Applying lean six sigma methodology to a pharmaceutical manufacturing facility: a case study. Processes, 9(3), 550, 2021. https://doi.org/10.3390/pr9030550

Cespedes-Pino, R., Hurtado-Laguna, J., Macassi-Jauregui, I., Raymundo-Ibañez, C., & Domínguez, F., Lean production management model based on organizational culture to improve cutting process efficiency in a textile and clothing sme in peru. Iop Conference Series Materials Science and Engineering, 796(1), 012004, 2020. https://doi.org/10.1088/1757-899x/796/1/012004

Chae, D., Kim, B., Kim, S., & Kim, S., Incremental feature selection for efficient classification of dynamic graph bags. Concurrency and Computation Practice and Experience, 32(18), 2019. https://doi.org/10.1002/cpe.5502

Chan, C. and Tay, H., Combining lean tools application in kaizen: a field study on the printing industry. International Journal of Productivity and Performance Management, 67(1), 45-65, 2018. https://doi.org/10.1108/ijppm-09-2016-0197

Cudney, E., & Elrod, C., Incorporating lean concepts into supply chain management. International Journal of Six Sigma and Competitive Advantage, 6(1/2), 12-30, 2011. https://doi.org/10.1504/IJSSCA.2011.038589

Dodge, J., Eikenberry, A., & Coule, T., Illustrating the value of critical methodologies through third-sector gender studies: a case for pluralism. Voluntas International Journal of Voluntary and Nonprofit Organizations, 33(6), 1140-1147, 2021. https://doi.org/10.1007/s11266-021-00425-8

Emelianova, D., Kliuchareva, N., Kolesnichenko-Yanushev, S., & Yakovlev, A., Organization of standardization work planning in an industrial enterprise. E3s Web of Conferences, 164, 10013, 2020. https://doi.org/10.1051/e3sconf/202016410013

Emiliani, M. L., Real Lean: Understanding the Lean Management System. The Center for Lean Business Management, 2007.

Feld, W. M., Lean Manufacturing: Tools, Techniques, and How to Use Them. CRC Press, 2001.

Flores, G., Valenzuela, R., Viacava, G., & Carpio, C., Model to reduce waste in the production of labels in peruvian companies of the plastic sector by applying autonomous maintenance, kanban and standardization of work, 2020. https://doi.org/10.18687/laccei2020.1.1.96

Gao, S. and Pheng, L., Understanding the application ofkaizenmethods in construction firms in china. Journal of Technology Management in China, 8(1), 18-33, 2013. https://doi.org/10.1108/jtmc-03-2013-0018

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

Garcia, A., O'Neill, K., Garcia, L., Lord, P., Stevens, R., Corcho, O., … & Gibson, F., Developing ontologies within decentralised settings., 99-139, 2010. https://doi.org/10.1007/978-1-4419-5908-9_4

Guillon, D., Merlo, C., Villeneuve, E., Vareilles, É., & Aldanondo, M., A methodology for implementing a product-centred bid model for suppliers. Proceedings of the Design Society International Conference on Engineering Design, 1(1), 1035-1044, 2019. https://doi.org/10.1017/dsi.2019.109

He, L. and Jiang, P., Manufacturing knowledge graph: a connectivism to answer production problems query with knowledge reuse. Ieee Access, 7, 101231-101244, 2019. https://doi.org/10.1109/access.2019.2931361

Hedberg, T., Hartman, N., Rosche, P., & Fischer, K., Identified research directions for using manufacturing knowledge earlier in the product life cycle. International Journal of Production Research, 55(3), 819-827, 2016. https://doi.org/10.1080/00207543.2016.1213453

Hirano, H., 5 Pillars of the Visual Workplace: The Sourcebook for 5S Implementation. Productivity Press, 1999.

Ho, S. K., The 5S auditing. Managerial Auditing Journal, 14(6), 294-302, 1999. https://doi.org/10.1108/02686909910280363

Khemir, M., Experiences with product development methodology in the public-private research campus mobility2grid, 2021. https://doi.org/10.33422/8th.imeaconf.2021.03.66

Kłos, S. and Patalas-Maliszewska, J., The impact of erp on maintenance management. Management and Production Engineering Review, 4(3), 15-25, 2013. https://doi.org/10.2478/mper-2013-0024

Liao, W. and Wang, T., A novel collaborative optimization model for job shop production–delivery considering time window and carbon emission. Sustainability, 11(10), 2781, 2019. https://doi.org/10.3390/su11102781

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

Ma, X., Li, C., & Li, B., Carbon emissions of china's cement packaging: life cycle assessment. Sustainability, 11(20), 5554, 2019. https://doi.org/10.3390/su11205554

Madan, J., Mani, M., & Lyons, K., Characterizing energy consumption of the injection molding process, 2013. https://doi.org/10.1115/msec2013-1222

Minicis, M., Giordano, F., Poli, F., & Schiraldi, M., Recipe development process re-design with ansi/isa-88 batch control standard in the pharmaceutical industry. International Journal of Engineering Business Management, 6, 16, 2014. https://doi.org/10.5772/59025

Noamna, S., Thongphun, T., & Kongjit, C., Transformer production improvement by lean and mtm-2 technique. Asean Engineering Journal, 12(2), 29-35, 2022. https://doi.org/10.11113/aej.v12.16712

Ohno, T., Toyota Production System: Beyond Large-Scale Production. Productivity Press, 1988.

Olivas-Padilla, B., Improving human-robot collaboration in tv assembly through computational ergonomics: effective task delegation and robot adaptation, 2023. https://doi.org/10.1109/smc53992.2023.10394021

Osada, T., The 5S's: Five Keys to a Total Quality Environment. Asian Productivity Organization, 1991.

Oster, C., Kaiser, M., Kruse, J., Wade, J., & Cloutier, R., Applying composable architectures to the design and development of a product line of complex systems. Systems Engineering, 19(6), 522-534, 2016. https://doi.org/10.1002/sys.21373

Sayed, A., Hamad, K., Eid, Y., Alaa, A., Hassan, A., Mohsen, A., … & Tawab, S., Production of paper using chemical pulping process of sugarcane bagasse. International Journal of Industry and Sustainable Development, 0(0), 0-0, 2022. https://doi.org/10.21608/ijisd.2022.145854.1013

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

Soderberg, B., & Bengtsson, L., Lean Principles in the Automotive Industry. Journal of Manufacturing Technology Management, 21(3), 286-299, 2010. https://doi.org/10.1108/17410381011024304

Sun, C., Du, Q., & Tian, G., Exploiting product related review features for fake review detection. Mathematical Problems in Engineering, 2016, 1-7, 2016. https://doi.org/10.1155/2016/4935792

Tsarouhas, P., Reliability, availability and maintainability analysis of a bag production industry based on the six sigma dmaic approach. International Journal of Lean Six Sigma, 12(2), 237-263, 2020. https://doi.org/10.1108/ijlss-09-2019-0101

Van Goubergen, D., & Van Landeghem, H., Reducing set-up times of manufacturing lines. International Journal of Production Research, 40(17), 4195-4212, 2002. https://doi.org/10.1080/00207540210148497

Womack, J. P., & Jones, D. T., Lean Thinking: Banish Waste and Create Wealth in Your Corporation. Free Press, 2003.

Zamora, P., Production model based on lean manufacturing and tpm to increase efficiency in a company in the textile sector, 2023. https://doi.org/10.18687/leird2023.1.1.589

Zelenkov, Y., Information efficiency, information design and information system of an organization. Business Informatics, 2017(2), 25-32, 2017. https://doi.org/10.17323/1998-0663.2017.2.25.32

Biographies

Yoreli Nicole Ramirez-Palomino holds a bachelor's degree in industrial engineering with experience in the technology sector. She is currently working as a Product Specialist for the leading brand in the technology market, reinforcing its positioning in the market and participating in all commercial processes such as marketing, sales, distribution and after-sales strategies.

Daniela de Fatima Vasquez-Morales holds a bachelor’s degree in industrial engineering with experience in energy sector. She is currently working as a Business Controller for a leading company in the energy market, responsible for reporting order entries and analysis of income statements.