7th European Conference on Industrial Engineering and Operations Management
Augsburg, Germany, July 16-18, 2024
Publisher: IEOM Society International, USA DOI: 10.46254/EU07.20240215
Published: July 16, 2024

Optimization of the Clothing Production Line in Peruvian SMEs through the Implementation of Lean Manufacturing: A Case Study

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Abstract

The sector of small and medium enterprises (SMEs) of clothing in Peru faces significant challenges that affect its efficiency and competitiveness, such as high production cycle times, delays in transfers due to inefficient plant design, lack of standardization of defective processes and products. These problems negatively impact profitability, product quality and customer satisfaction, making it imperative to develop improvement strategies. This study implemented lean manufacturing tools to address these inefficiencies. Systematic Layout Planning (SLP) and Poka Yoke were applied to reorganize the layout of the packaging area and prevent errors in the production process. The 6S methodology was used to improve the organization and safety of the work environment, while time and movement studies optimized the activities at the workstations. These tools were systematically selected and applied, based on rigorous data analysis to identify and mitigate the root causes of inefficiencies. Highlights include a reduction in cycle time from 15.5 minutes to 12.1 minutes, representing a 22% decrease. The 6S audit improved significantly, from a score of 1.4 to 4.5, an increase of 221%. The distance travelled by the operators was reduced from 738 meters to 470 meters, reflecting a reduction of 36%. Finally, reprocessing rates decreased significantly; for machine 1, from 15.9% to 5.16%, and for machine 2, from 13.3% to 3.57%, indicating improvements of 68% and 73% respectively. These improvements not only increased production efficiency and quality, but also increased daily production capacity from 690 to 895 garments and raised operational efficiency from 68.5% to 88.8%. In conclusion, the study shows that the implementation of Lean Manufacturing tools can significantly transform the efficiency of clothing SMEs in Peru, providing a clear and replicable methodology that can be adopted in other regions and industrial sectors to improve productivity and competitiveness.

Keywords
Lean Manufacturing, Operational Efficiency, Systematic Layout Planning, Poka Yoke, Continuous Improvement.

1. Introduction
The sector of small and medium-sized enterprises (SMEs) clothing manufacturers plays a crucial role in the global economy, in Latin America and specifically in countries such as Peru. These companies represent a significant part of the clothing industry, contributing both to job creation and economic development in the regions where they operate (Jung, 2023). In the case of Latin America, garment SMEs are often the backbone of the textile industry, providing employment opportunities to a large number of people and being an important driver for the local economy (Hossain

& Baars, 2022). In Peru, specifically, garment manufacturing SMEs play a vital role in diversifying the economy and promoting the textile industry nationally and internationally (Haider, 2022).

However, despite their importance, the SME clothing manufacturing sector faces a number of production challenges that affect its efficiency and competitiveness in the market. Problems such as high production cycle times, delays in transfers due to poor plant design, lack of process standardization and the presence of defective products are common in this industry (Mohammad et al., 2023). These problems not only impact the profitability of companies but can also affect the quality of final products and customer satisfaction (Lekamge & Ekanayake, 2021). Inefficiency in production can also lead to higher costs and reduced ability to compete in an increasingly globalized and demanding market (Wijethilake et al., 2021).

Addressing these issues in the SME clothing manufacturing sector is critical, as addressing these issues can have a significant impact on the sustainability and growth of these enterprises. Improving cycle times, optimizing production processes, implementing quality standards and reducing the presence of defective products can not only increase the operational efficiency of SMEs, but can also improve its reputation in the market and its ability to attract new customers (Sharma et al., 2021). By addressing these challenges, companies can improve their profitability, competitiveness and ability to expand both nationally and internationally (Hamja et al., 2021). In addition, by improving production efficiency and quality, garment SMEs can contribute more effectively to the economic and social development of their local communities (Albuquerque et al., 2021).

In conclusion, the SME clothing manufacturing sector plays a crucial role in the global economy, in Latin America and in countries like Peru. Despite their importance, these companies face significant challenges in terms of production that affect their efficiency and competitiveness. Solving these problems is critical to improving the sustainability and growth of clothing SMEs, which in turn can have a positive impact on the economy, society and the market in general.

2. Literature Review

2.1 Application of Lean Manufacturing in Small and Medium-Sized Garment Manufacturing Businesses

Lean manufacturing has been widely studied and implemented in various industries, including the garment manufacturing sector. Ibikunle et al. (2023) emphasize the importance of lean manufacturing practices in Malaysian manufacturing SMEs, particularly in the context of intending to implement Industry 4.0 technologies. The study highlights the significance of lean manufacturing principles in enhancing operational efficiency and preparing businesses for the adoption of advanced technologies. By focusing on waste reduction and continuous improvement, lean manufacturing can streamline processes and optimize resource utilization in garment manufacturing SMEs.

2.2 Implementation of Systematic Layout Planning in Garment Manufacturing SMEs

Systematic Layout Planning (SLP) is a method that plays a crucial role in optimizing the layout of production facilities in small and medium-sized garment manufacturing businesses. While there is limited direct research on SLP in the garment sector, the principles of layout planning are fundamental in enhancing operational efficiency. Businesses can benefit from the work of (Chong & Perumal, 2022), who developed a conceptual model for assessing lean manufacturing implementation maturity levels in machinery and equipment of SMEs. This model includes aspects such as cellular manufacturing and setup time reduction, which are integral parts of efficient layout planning strategies.

2.3 Utilization of 6S Methodology in Garment Manufacturing Processes

The 6S methodology, an extension of the 5S system focusing on safety, has been applied in various industries for process optimization. Panayiotou et al. (2021) discuss the application of Lean Six Sigma (LSS) in small and medium-sized enterprises, emphasizing the importance of following the Define, Measure, Analyze, Improve, and Control (DMAIC) method for successful LSS project implementation. While not specific to the garment sector, the principles of 6S can be adapted to enhance workplace organization, cleanliness, and safety in the production processes of garment manufacturing SMEs.

2.4 Integration of Poka Yoke in Garment Manufacturing

Poka Yoke, a method for error-proofing processes, can significantly benefit garment manufacturing SMEs by reducing defects and improving product quality. While direct research on Poka Yoke in the garment sector is limited, the study by Gojković et al. (2021) on the evaluation and selection of quality methods for manufacturing process reliability improvement provides insights into frameworks like Failure Mode and Effect Analysis (FMEA). By incorporating Poka Yoke principles, businesses can proactively prevent errors and defects in garment production, leading to enhanced efficiency and customer satisfaction.

2.5 Study of Methods in Garment Manufacturing Process Improvement

Research on the study of methods for process improvement in garment manufacturing SMEs is essential for enhancing operational effectiveness. While specific studies on this topic are scarce, the work of Silva & Santos (2023) on challenges of product modularization methods in SMEs sheds light on the importance of adopting efficient techniques for product development. Modularization techniques, such as Modular Function Deployment, can aid garment manufacturers in optimizing their production processes, improving flexibility, and responding effectively to changing market demands.

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3. Methods

3.1 Basis of the Proposed Model

The production model shown in **Figure 1** was based on the Lean Manufacturing philosophy, which focused on the efficiency and continuous improvement of production processes by eliminating waste and optimizing resources. In this scheme, company data were initially analyzed and a detailed analysis of the information was carried out to select the appropriate methodology. The core of the model included various Lean tools such as the Problem Tree, ABC and PQ Analysis, AVA Matrix, Time Study, Layout and Planning System (SLP), Poka Yoke and 6S methodology, all aimed at improving production efficiency.

The main objective of the model was to transform the low efficiency of the production line into standardized and evaluable processes using performance indicators. For this, the Kaizen philosophy was integrated, which promoted a culture of continuous improvement through small but constant improvements. This approach allowed specific actions to be implemented based on data entry and analysis, resulting in a significant increase in the efficiency of the production line.

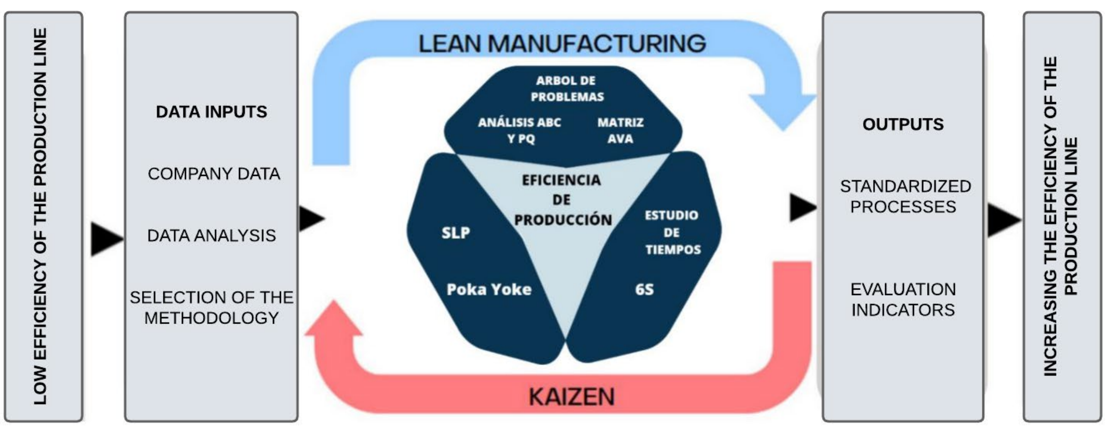

Figure 1. Proposed Model

The process began with the collection and analysis of company data, followed by the selection of the most appropriate Lean methodology for the specific context of production. As Lean tools were applied, activities that did not add value were identified and eliminated, workflows were improved, and processes standardized. Finally, the results were evaluated using performance indicators that provided continuous feedback to ensure the sustainability of the improvements implemented. In this way, the model effectively integrated the principles of Lean Manufacturing and Kaizen to transform production and improve efficiency in a continuous and sustainable manner.

3.2 Description of the model components

The model presented in the image is divided into three fundamental components that guide the process of implementing Lean Manufacturing on a production line. Each stage of the model is described in detail, in academic language and in the third person.

Component 1: Initial Diagnosis

The first component of the model is the initial diagnosis, which aims to identify inefficiencies in the production line and establish a basis for future improvements. This stage includes the application of several specific tools:

ABC and PQ analysis: An ABC analysis was performed to classify products according to their value and frequency of production. This tool made it possible to identify the most critical products that required priority attention to improve operational efficiency. Simultaneously, the PQ (Production-Volume) analysis was applied to categorize products according to their quantity and volume of production. This facilitated the identification of the products that generated the highest income and those that were more expensive to produce.

Value Added Matrix (AVA Matrix): AVA Matrix was developed to evaluate the added value of each stage of the production process. This matrix helped identify activities that did not add value to the final product and could be eliminated or improved. The elimination of non-productive activities contributed significantly to reducing cycle time and increasing process efficiency.

Problem Tree: A problem tree was built to identify the root causes of inefficiencies in the production line. This visual tool facilitated the identification and prioritization of the most critical issues to be addressed. The analysis of root causes allowed us to develop more effective and focused improvement strategies.

Component 2: Optimization of Activities in the Production Process

The second component of the model focused on optimizing activities in the production process. This stage included the implementation of tool 6S, an evolution of the 5S methodology that includes the security dimension:

6S (Classification, Order, Cleaning, Standardization, Discipline and Safety): 6S methodology was implemented in the production area to improve the organization, cleanliness and safety of the working environment. This methodology made it possible to create a more orderly and safe working environment, which helped to reduce the time lost in finding tools and materials, and to reduce accidents at work. The inclusion of safety as an additional component ensured that all improvements made also contributed to a safer working environment.

Classification (Sort): All unnecessary items in the work area were removed.
Order (Set in order): The workspace was organized efficiently, ensuring that all tools and materials were in designated locations and easily accessible.
Cleaning (Shine): Regular cleaning routines were implemented to maintain a clean working environment.
Standardization (Standardize): Standards and procedures were established to maintain organization and cleanliness.
Discipline (Sustain): Discipline was promoted among workers to maintain long-term improvements.
Safety (Safety): Workplace safety risks were identified and mitigated.

Component 3: Optimization of the Manufacturing Area and Improvement Procedure for Defective Products

The third component of the model focused on the optimization of the manufacturing area and the procedure for improvements in defective products. This component included the implementation of Systematic Layout Planning and the implementation of the Poka Yoke tool:

Systematic Layout Planning (SLP): SLP methodology was applied to reorganize the layout of the clothing area. This tool made it possible to design a more efficient workflow, reducing travel times and improving material handling. Several iterations of the layout design were performed using flow diagrams and simulations to find the most efficient configuration. The implementation of the new layout resulted in a significant improvement in the productivity and efficiency of the clothing area.

Poka Yoke: Poka Yoke mechanisms were implemented at critical points in the manufacturing process to prevent errors and defects. These fail-safe devices ensured that defective products were detected and corrected early in the process, preventing their advancement on the production line. The implementation of Poka Yoke resulted in a significant decrease in the rate of defects and an overall improvement in the quality of the final product.

3.3 Model Indicators

To assess the efficacy of the suggested production model, specific indicators were established to oversee and regulate the outcomes of its implementation in the case study.

Cycle Time on a garment line measures the average time to produce a garment from start to finish. It is calculated by dividing the total production time by the number of units produced. It is crucial to identify inefficiencies and improve productivity.

$$Cycle\ time = \frac{Total\ production\ time}{Number\ of\ units\ produced} \tag{1}$$

Distance Traveled: Total of meters traveled by operators and materials in a garment manufacturing plant.

$$Distance\ Traveled\ = \sum_{i=2}^{n} d_i \tag{2}$$

6S Audit: It is the average score obtained in the verification of compliance of each of the 5S in the work area.

$$5S\ Audit = \frac{\sum(Score\ Obtained\ \ in\ each\ "S")}{Total\ Score} \tag{3}$$

Rate of Reprocessing, Measure the percentage of garments that require correction on the sewing line.

$$Rate\ of\ Reprocessing = \frac{Total\ number\ of\ garments\ produced}{Number\ of\ garments\ reprocessed} \tag{4}$$

4. Validation

4.1 Component: Initial Diagnosis

The problem tree presented in **Figure 2** synthesized the diagnosis of the case study, identifying the causes and root causes that generated the low efficiency in the clothing production line. A significant technical gap was observed, comparing the industry standard operating efficiency of 99.89% (Kumar, 2020) with the efficiency of 65% recorded during 2020 in the case study. This low production efficiency, with an economic impact of 204,953 PEN/year, equivalent to 6.7% of revenues, was attributed to three main causes: delivery of orders after the deadline (71.56%), rejected units (19.17%) and non-compliance with the production programmed (9.27%). Root causes identified for late order delivery included high cycle times due to non-standard processes (45.33%) and excessive transfer times due to poor layout (26.23%). The rejected units were mainly due to defective seams. The model's philosophy was based on rigorous data analysis to identify critical areas for improvement and develop effective strategies to close the efficiency gap. The main objective was to improve operational efficiency by identifying and mitigating root causes that negatively impact production performance.

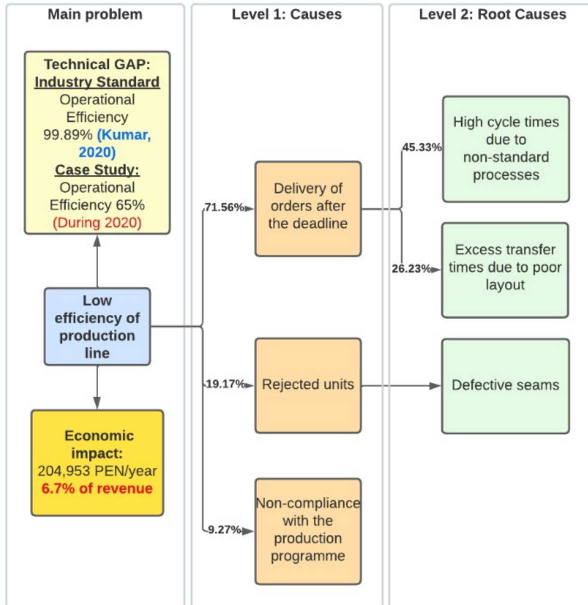

Figure 2. Problem Tree

4.2 Component 2: Optimization of Activities in the Production Process

Component 2 of the proposal focused on the optimization of activities in the production process through the implementation of lean manufacturing tools, specifically the study of methods and times and the 6S. The application of these tools was justified by the identification of root causes such as the excessive time in the manufacturing process due to non-standard methods and the inefficient search for materials. The main objective was to improve efficiency and reduce downtime.

The study of methods and times allowed to analyze and improve the activities in the workstations. Through the development of bimonthly diagrams, movements in waiting, operation or transport were identified and classified. This detailed analysis led to the proposal of specific improvements for each activity, achieving a significant reduction of unnecessary movements. As a result, an increase in productivity was observed, reducing the manufacturing time from 15.5 minutes to 12.1 minutes per garment, which represents a decrease of 22%.

In parallel, the 6S methodology was implemented, covering the pillars of Classify, Sort, Clean, Safety, Standardize and Discipline. Previously, the operators were trained and awareness was raised about the importance of maintaining order and cleanliness in the workstations. This implementation was carried out through initial and final audits, reflecting a notable improvement in results. The initial audit obtained a score of 1.4, while the final audit reached a score of 4.5, evidencing an improvement of 221%.

The combination of these tools not only improved the efficiency of the manufacturing process, but also contributed to the standardization of activities and reduced search times. There was a decrease in material search time from 0.775 minutes to 0.121 minutes, representing an improvement of 84.4%. In addition, the implementation of 6S improved occupational safety, reducing risks and increasing operational discipline.

In conclusion, the optimization of activities in the production process through the study of methods and times and the implementation of the 6S allowed reaching a production efficiency of 88.8%, significantly increasing productivity and reducing downtime in the clothing company (Figure 3).

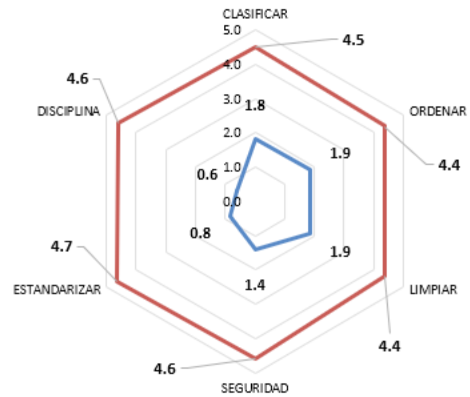

Figure 3. Final vs Initial Audit 6S

4.3 Component 3: Optimization of the Manufacturing Area and Improvement Procedure for Defective Products

Component 3 of the proposed model focused on optimizing the manufacturing area and implementing improvement procedures for defective products. Two main tools were used to achieve this optimization: Systematic Layout Planning (SLP) and Poka Yoke. The application of the SLP allowed to reorganize the layout of the clothing area, developing a relational table that helped to place the machines in strategic positions. Three layout proposals based on proximity and efficiency criteria were considered. After analyzing the matrix tables, the final proposal was selected which showed an 82.45% increase in productivity compared to the other options.

Prior to the implementation of the new layout, the 6S were executed to ensure that the environment was clean and tidy. A specialized team was then hired to move the machines to their new locations. The quantity or weight matrix, the distance matrix and the effort matrix were key tools in this phase, allowing to evaluate and optimize material flows and the effort needed in the manufacturing area.

On the other hand, the Poka Yoke tool focused on reducing defects in clothing. Initially, the reproaches on straight machines 2 and straight 3 were 15.9% and 13.3% respectively. With the implementation of Poka Yoke, these percentages were reduced to 5.16% and 3.57%, demonstrating a significant improvement in the quality of the garments made. In addition, production efficiency increased from 68.5% to 88.8% after the implementation of these improvements.

In quantitative terms, the layout reorganization resulted in a reduction in cycle time from 15.5 minutes to 12.1 minutes and a decrease in travel time from 30.5 minutes to 19.6 minutes. These improvements not only optimized the workflow, but also increased production capacity from 690 to 895 daily garments (Figure 4- Figure 5).

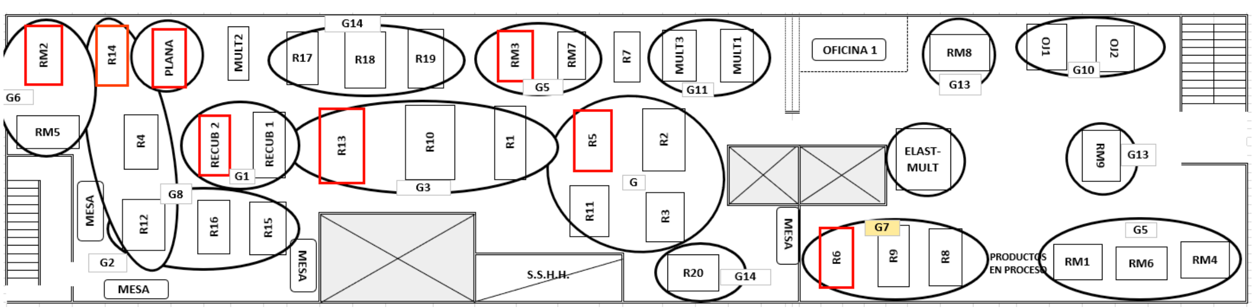

Figure 4. Proposed layout

TIPO DE OPERACIÓN CONREPROCESOS	USO	TIPO DE ADITAMENTO/ PRENSATELA
Pespunte de cuello Pespunte de pechera Pespunte de hombro Pespunte de bolsillo	Realiza pespunte de medida 1/16	
Ruedo de basta	Dobladillo de basta	
Ruedo de basta	Guiador de imán	

Figure 5. Poka Yoke: Accessories according to clothing activity

5. Results

Table 1 shows the most important results of the optimization of the manufacturing line in terms of reduced cycle times, improved space organization and reduced reprocessing rates.

First, the cycle time was significantly reduced from 15.5 minutes to 13.1 minutes, and finally to 12.1 minutes. This represents a 22 per cent decrease, indicating a significant improvement in process efficiency due to the standardization and optimization of activities.

Second, the 6S audit improved markedly, going from a score of 1.4 to 3, and then to 4.5. This improvement of 221% demonstrates a significant increase in the organization and cleanliness of the work area, which contributed to operational efficiency and occupational safety.

In addition, the distance travelled by the operators was reduced from 738 meters to 410 meters, and finally to 470 meters, reflecting a reduction of 36%. This reduction was achieved thanks to the reorganization of the layout using the SLP tool, optimizing the flow of materials and reducing transfer times.

Finally, reprocessing rates also showed notable improvements. For machine 1, the reprocessing rate decreased from 15.9% to 5.16%, and for machine 2, from 13.3% to 3.57%. These reductions of 68% and 73%, respectively, indicate a significant improvement in the quality of the garments produced, thanks to the implementation of Poka Yoke.

Together, these results highlight the effectiveness of Lean Manufacturing tools in improving efficiency, quality and organization in the manufacturing line, demonstrating a positive and quantifiable impact on production performance (Table 1).

Table 1. Results of validation of the proposed model

Root Cause	Tool	Indicator	As-Is	To-Be	Reference	Results	Variation (%)
High cycle times due to non-standard processes	Time Study	Cycle Time (min)	15.5	13.1	Saravanan et al. (2023)	12.1	**-22%**
	6S	6S Audit	1.4	3	Sari et al. (2017)	4.5	**221%**
Excess transfer times due to poor layout	SLP	Distance Traveled (m)	738	410	Saravanan et al. (2023)	470	**-36%**
Defective seams	Poka Yoke	Rate of Reprocessing - Machine 1 (%)	15.90%	3.10%	Vargas et al. (2022)	5.16%	**-68%**
		Rate of Reprocessing - Machine 2 (%)	13.30%			3.57%	**-73%**

6. Conclusions

The main findings of the study showed that the implementation of Lean Manufacturing, through tools such as Systematic Layout Planning (SLP) and Poka Yoke, resulted in significant improvements in the efficiency of the manufacturing production line. The layout reorganization, based on the SLP, reduced cycle time from 15.5 minutes to 12.1 minutes, and travel time from 30.5 minutes to 19.6 minutes. In addition, the reprocessing rate decreased from 15.9% to 5.16% for machine 1, and from 13.3% to 3.57% for machine 2, evidencing a considerable improvement in product quality. These results translate into an increase in daily production capacity from 690 to 895 garments, and an increase in production efficiency from 68.5% to 88.8%.

The research carried out is of great importance for the SME clothing sector in Peru and other developing countries, where competitiveness and operational efficiency are crucial for economic sustainability. The adoption of lean manufacturing practices allows these companies not only to improve their productivity and quality, but also to reduce costs and production times. This is especially relevant in a globalized market where rapid and efficient response capacity can determine the viability of small and medium-sized enterprises. In addition, reducing defects and improving the organization of the workplace contribute to a safer and more motivating working environment for employees.

Contributions to the field of study include a clear and replicable methodology for process optimization in the garment industry, using lean manufacturing tools. This study provides empirical evidence on the benefits of rearranging production layout and applying error-proofing techniques such as Poka Yoke. In addition, it provides a framework for the implementation of 6S audits, which significantly improve the organization and safety in the work area. The research also highlights the importance of a systematic and data-based approach to identifying and mitigating root causes of production inefficiencies.

Concluding remarks and suggestions for future studies include the need to explore the application of Industry 4.0 technologies in combination with Lean Manufacturing, to further enhance the efficiency and responsiveness of clothing SMEs. Additional studies could focus on the implementation of real-time monitoring systems for early detection of defects and dynamic optimization of production processes. It would also be beneficial to investigate the integration of lean techniques with environmental sustainability strategies, to address not only operational efficiency but also ecological responsibility in the garment industry.

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