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Original Article

A Production Management Method to Reduce Non-Fulfillment of Orders Based on Lean Tools and Change Management: Case of a Peruvian Apparel Company

Daniela Silva-Castro[1], Rafael Campoblanco-Carhuachin[2], Claudia Leon-Chavarri[3], José Cardenas-Medina[4], Rodrigo Borges-Ribeiro[5]

[1,2,3,4]*Industrial Engineering Program, Peruvian University of Applied Sciences, Lima, Perú.*
[5]*Engenharia de Produção, FACCAT-Faculdades Integradas de Taquara, Taquara, Brazil.*

[1]*Corresponding Author : u201810904@upc.edu.pe*

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Abstract - *In Peru, the textile and apparel industry ranks third in the manufacturing sector. In 2023, there are 44,600 formal microenterprises in this sector. Currently, apparel companies operate with long and inefficient delivery times and other obstacles that erode their competitiveness. One of the most relevant problems is the non-fulfilment of orders. In addition, resistance to change, lack of training, and a lack of business culture are some of the most frequent obstacles in this industry. For this reason, it is proposed to implement a method to manage production that combines 5s, SMED, standardization and change management techniques are proposed to improve the existing gap in the level of order fulfillment. The sustainability of the proposal is evaluated by considering the economic, social, and environmental aspects. After validation, the results obtained were an order fulfillment level of 77.9%, a reduction of non-value-added activities by up to 6.45%, shorter set-up times with a reduction of up to 52% and a reduction of defective seams by up to 4.38%. In addition, a pollution reduction of up to 22% of non-usable waste.*

Keywords - *Apparel industry, Change management, Fulfillment, Lean manufacturing, Textile waste*.

1. Introduction

World textile trade has declined over the last decade, from US$251 billion to US$223 billion in 2019. The largest textile exporters are Asian countries. The capacity of Asian textile companies globally is clear; 75% of their apparel exports go abroad, indicating their competitiveness in the markets. China is the country with the largest amount of exports, occupying a 30% share of the world market. [1] Latin America and the Caribbean (LAC) account for only 4% of the world's demand for clothing. The products exported in the region lack diversification and are long-term, meaning the region has to compete with Asian countries. Mexico leads exports in the region; however, at the international level, it lags behind Asian competitors due to lower labor productivity and lack of product diversity, among others. Exports from Brazil, Colombia, and Peru have a small share of regional production; however, they are the most important countries in South America [1]. In the context of the COVID-19 pandemic, the number of Peruvian apparel companies decreased by 26% in 2020 compared to 2019. However, in 2023, there were approximately 44,600 formal micro-enterprises in the textile and apparel sector, showing a recovery after the negative effects of COVID-19. The apparel industry is characterized as being the one that generates the most employment. In 2023, the number of workers will increase by 2.3% compared to 2022. [2] Along with the adverse effects of the pandemic, Peruvian microenterprises are characterized by inefficient management due to the limited use of business management tools. Moreover, they do not develop strategies that contribute to increasing the value of their products [3]. Currently, apparel companies are operating with long and inefficient delivery times. [3,4] In a survey of Peruvian apparel SMEs, the objective was to identify the problems that would make it difficult for them to meet demand, and the biggest problem was the non-fulfilment of orders. [5] Monetary penalties can be a problem and can also affect the credibility of the organization. [6,7] Therefore, the garment industry must respond effectively and efficiently to constant changes, especially micro-enterprises that generally work in small batches. For this reason, it is crucial to know the current state of your industry in order to process orders on time. Faced with this problem, work has been done on adopting lean tools, which reduce delivery time and improve the level of excellence of the products [8]. Likewise, companies, in addition to seeking economic prosperity, also have an obligation to reduce their environmental impacts. For this reason, sustainability has become necessary because it involves economic development, environmental challenges, and social difficulties for the organization. [9] Lean practices contribute to reducing environmental damage by improving the quality of products by extending their lifetime and less waste generation. [10,11] Waste reduction contributes to social sustainability by improving workplace health. [12]

In research combining Lean-Kaizen tools, the production time was reduced by 69.47%, in addition to decreasing delivery times by 18 to 5.5 days. [13] The second research, which combined 5S tools and Line Balance, showed a decrease in lead times from 7 to 3 days. Also, there was a 15% increase in the number of orders served. [14] However, one of the biggest challenges in implementing LM in the textile industry is resistance to change. In one case study, implementation was initiated in a textile company, but the organization was not improving and was resistant to this type of change [4]. Lean Manufacturing (LM) has shown great potential to address the obstacles apparel companies face. However, some challenges include a lack of company culture, ineffective communication, and resistance to change. [7,16] It is complicated for the organization's employees to change to a new work system. Therefore, the barriers that hinder the proposal's implementation must be eliminated for the change to be sustainable over time. [4, 16, 17]

Consequently, this research aims to contribute to the existing literature on increasing order fulfillment. The proposed Lean Manufacturing tools are 5S, SMED and standardization based on change management. The proposal seeks to avoid incurring additional costs due to penalties for late deliveries and operating cost overruns. In addition, to ensure the sustainability of the proposal, the economic, social and environmental aspects are analyzed. In this sense, other manufacturing organizations with similar conditions could apply the proposal. This research, through its findings, contributes to the literature and provides a combination of lean manufacturing practices. The development of the research consists of 5 chapters. The first chapter corresponds to the introduction of the topic. The second chapter presents the state of the art, where an exploration and analysis of previous research carried out by experts is developed. The third chapter presents the method, where the contribution and resources used to develop the design are detailed. The fourth chapter presents the results obtained after a pilot application and a simulation for the case study, which will be compared and contrasted with previous results obtained in the investigated area. In addition, a discussion of the most significant results is presented. The fifth chapter presents the conclusions of the study.

2. Literature Review

2.1. Lean Manufacturing to Increase Order Fulfillment

The difficulty of the garment industries due to the constant changes in operations, processes, quality or on-time deliveries can result in penalties or losses due to non-delivery. [7,13,16,17] The cost of penalties for non-fulfilment of orders decreases the firm's profits and affects its credibility. [6,7] In that sense, studies have shown a strong negative impact in terms of off-time deliveries of orders. For example, operational cost overruns due to labor requirements, penalties for late deliveries and increased production lead times. [13,14]

A number of studies in relation to this problem have yielded several proposed solutions. One of them was the combination of lean manufacturing and kaizen tools, where a significant decrease in delivery time from 18.016 days to 5.50 days was achieved. [13] On the other hand, in another case study, where LM tools were applied, manufacturing times were reduced from 47 min to 38 min, which allowed a 15% increase in the number of orders served and a reduction in lead times from 7 days to 4 days. In addition, penalties were reduced by up to 33%. [14] Both researchers argue the authors that lean tools effectively and reliably improve and, in turn, help to address all kinds of inefficiencies in organizations. [14,18] Finally, the application of LM gave the best results, thus solving the problems related to order fulfillment. [8,13]

On the other hand, there are several problems related to environmental pollution in the textile industry. Synthetic fibers increase pollution from microplastics, carbon emissions and resource consumption during production. [19] On the other hand, producing natural fibers also causes pollution from using chemicals that impact the environment and people. [20] Recycling both types of fiber is even more complicated when they are mixed in the manufacture of garments. [21] Manufacturing a quality product leads to direct efforts to reduce the amount of waste generated and its environmental impact. Consequently, environmental and labor improvement will help to increase economic prosperity. [22] According to various authors claim that Lean implementation helps to increase sustainability within the organization. [9,23,24,25] The company's working conditions have been improved with the help of Lean Manufacturing by increasing the level of safety, training and incentives. In the environmental aspect, Lean helped achieve optimal use of resources. [9]

2.2. 5S Tool to Minimize Out-Of-Service Parts

Some of the benefits highlighted by the authors of the various studies after implementing LM tools are increased customer satisfaction, reduced delivery times, and improved quality, among others. [8] The implementation of 5S helped to optimize compliance in the delivery process. In that sense, defined and systematized processes could increase the on-time delivery rate. [26,27] In addition, a previous study showed that after a 5S implementation, there was a reduction of up to 25% in downtime caused by the loss of tools in the plant. [14] Also, 32% decrease in non-value time; these activities corresponded to the search for materials needed for the production process [28]. Several studies aimed at reducing the number of activities that do not add value to the production process have successfully implemented the 5S tool. The authors mention that a considerable amount of effort and time is wasted just in searching for equipment and preliminary preparations before starting the work. [29] A case study evidenced improvements in reducing up to 32% of the downtime caused by the loss of tools in the shop. [28] On the other hand, in another investigation, up to 42.4% reduction was obtained in eliminating time lost in the search for parts and reducing changeover times by up to 5,502 minutes per month. [30] According to the authors' conclusions, Lean implementation in textile companies has not yet reached its full potential. [4,9,17]

2.3. SMED Tool Focused on Reducing Set-up Times

Nowadays, companies prefer to produce in smaller batches. In this sense, the SMED technique approach is the most viable solution for reducing setup times. [31,32] The different studies that were conducted agree on a common problem: excessive machine setup times. [31,32,33] Likewise, it is also argued that the learning process generates losses; however, the SMED methodology showed benefits in the organization; therefore, correct training for the operators that execute the configuration process must be considered. Some of the most important improvements made in sector companies were a reduction of between 48% and 60% approximately [32-34].

In the first study conducted, the reduction from 209.36 min to 167.09 min of preparation time and a significant increase in production to 70956 pieces per year was achieved. [35] In a second study, the setup time decreased from 196 min to 87 min. [36] In another study, time spent on setups was reduced by 60%, reducing the average setup time to 7 min. The positive results have enabled companies to apply the technique in their processes and various projects. [31,32,33] In contrast, in other studies, the application of the SMED methodology was not the only technique proposed by the authors since they found that it could be complemented with other methods and thus achieve better results, for example, lean tools. [33,34] If the SMED tool is successfully adopted, it would result in a reduction of machine setup time and also improve coordination within the organization [31,33].

2.4. Standardization to Reduce Sewing Defects

The need to standardize processes has been identified due to increased defective products, high manufacturing times and constant reprocessing due to product failures. [37] Several authors state that process standardization can benefit organizations by reducing costs. Through the correct application of the tool, errors in production processes are anticipated, and, at the same time, optimum procedures are defined, reducing the possibility of defects [38,39]. Different studies, due to the increase of defective parts, have shown different solution procedures by analyzing the process of the case study and determining the best tool to attack the problem. [38-40] One study shows that after the application of the standardization technique, a reduction of 68.83% in the number of defective products and up to 68.86% in nonconforming seams and measurement errors was achieved. [40] In another study, positive results were also achieved, increasing the quality percentage to 83.7% and reducing the number of defective products. [41] This technique can be applied to textile and apparel processes to optimize their production processes and increase their competitiveness in the industry. [38,39]

2.5. Change Management in Textile SMEs

Previous studies have identified that the main significant obstacles to the implementation of Lean management in MSMEs are resistance to change, poor LM training and the absence of a Lean team. [4,16] Several studies agree that those difficulties can affect the implementation of Lean in textile companies, so it is important to reduce their impact. [42,43] Collective work is fundamental to achieving the success of changes. [42,44] Operational superiority must be complemented by strategic and change management excellence. [44]

Today's fashion market requires companies to implement new ideas and even modify production at any time. Those involved must be constantly updated on changes. [44,45] It is difficult to modernize the current state while maintaining the attitude of teams and operators. Communication and change management are key to managing different scenarios in a limited time. [44-46] In the case of small and medium-sized industries in the garment sector, change management helps to achieve transitional structural change positively and effectively by inducing employee acceptance and participation. [44, 47]

3. Materials and Methods

A method is proposed to solve the non-fulfillment of orders in a clothing company. This is done based on scientific research that integrates authors' knowledge according to the sector and its techniques, where it is necessary to incorporate change management. This is due to the fact that gaps were found in the apparel sector regarding the application of Lean Manufacturing. These gaps are resistance to change and a lack of communication and training in the techniques used by employees. [8,17] In this sense, this proposal combines the necessary techniques to solve the main causes of variability in the garment industry. From this analysis and state of the art, the 5S, SMED and Standardization tools were linked based on Change Management. Table 1 presents the comparative matrix with the objectives of this case study and the main research for the construction of the proposal.

The proposal aims to optimize the existing gap in the level of order fulfillment by reducing root causes such as parts outside the operating area, excessive machine set-up time and the number of defects identified in the products in the manufacturing process. In addition to satisfying its customers and making profits, the company must also maintain a commitment to sustainability. For a business to be sustainable, it must also prioritize respect for the environment and social equity. [48,49] Currently, there are technological tools that help companies measure the environmental impact of their operations. For this reason, it is essential to consider the sustainability performance of companies in the garment and apparel sector and, in this case, the microenterprise under study. The proposed method takes into consideration the economic, social and environmental prosperity of the company. Developing a social system that facilitates and preserves employees' health is necessary to achieve social sustainability. On the other hand, to achieve environmental sustainability, it is necessary to reduce the amount of natural resources used. [28] In that sense, the present study will consider the evaluation of economic, environmental, and social impacts. The 5S tool is considered a means to eliminate waste and establish order and cleanliness. This will allow the materials and tools that interact in the manufacturing process to be placed in the correct locations and to be used optimally during the production process. It will help eliminate non-value-added activities such as searching for materials or workpieces. In this case, the SMED tool focuses on reducing machine setup times by analyzing each of the activities that interact in the preparation process. Due to the lack of standardization in working methods, defects occur in the manufacture of pants. It is also based on the TexChange change management model for textile industries. This sequential model comprises five steps, making it possible to successfully implement the proposed model in the organization and adapt to a constantly changing environment. As well as strategically influencing the fulfillment of the proposed objectives. In summary, 5S reduces the collection of material or tools in the sewing process. [22] SMED to reduce machine setup times. [7] Standardization to reduce defects. [14]

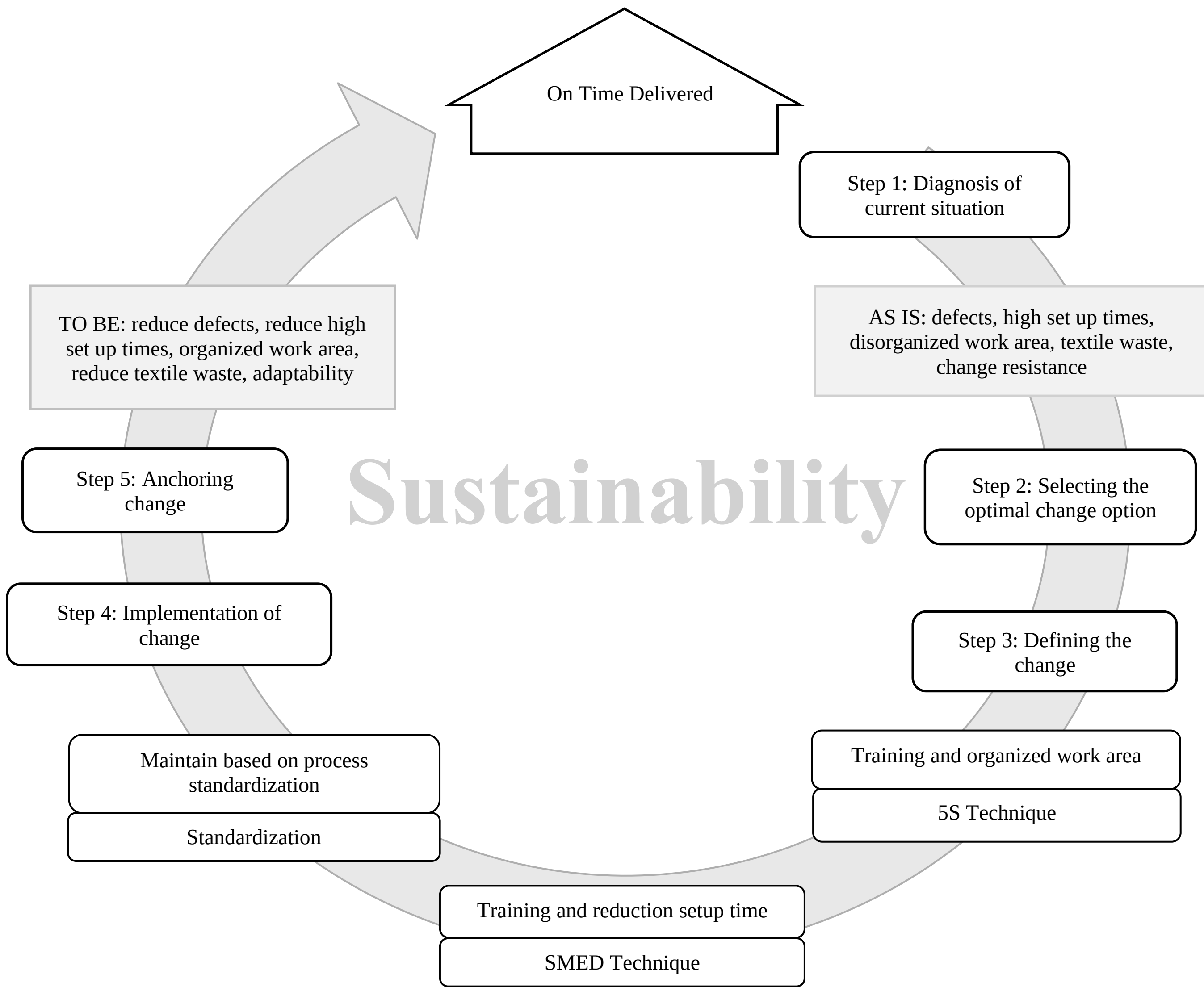


Fig. 1 Proposed method

Table 1. Matrix of the objective of the method and state of the art

Papers vs Objectives	Reduced Search for Parts Outside	Reduced Setup Times	Reduction of Defects in the Sewing Area	Reducing Resistance to Change
Kumar, D. V., Mohan, G. M., & Mohanasundaram, K. M. (2019)	5S			
Ali, S.M., & Haque, M.N. (2024)		SMED		
Barrientos-Ramos, N., Tapia-Cayetano, L., Maradiegue-Tuesta, F., & Raymundo, C. (2020).			Standardization	
Tudor, L. (2018)				TexChange (Change Management)
Proposed Model	5S	SMED	Standardization	Change Management

The set of techniques supported by change management will attack the main barriers to implementing Lean Manufacturing in the textile sector. The aim is to reduce by 32% the activities related to the collection of parts located outside the work area. [28] Similarly, the aim is to reduce machine set-up time by up to 70%. [33] and pant defects by up to 5%. [37] With respect to delivery compliance, through the literature review of micro-garment companies, the order fulfillment indicator is expected to reach approximately 69.47%. [13].

According to the literature review analysis, integrating these three techniques to support change management is expected to benefit the case study greatly. Likewise, it will be validated that the proposed solution is sustainable regarding economic, environmental, and social aspects. It is intended through this research to contribute with a framework of Lean practices that provide benefits to organizations with similar characteristics that implement it. The proposed method is shown in Figure 1.

3.1. Detailed Proposal Process

3.1.1. Diagnosis of the Current Situation

In this first step, the organization's results are analyzed, and then the problem that generates the most impact and its main causes are identified. The study corresponds to a Peruvian microenterprise in the apparel sector, whose main activity is the production of garments, given the considerable assortment of products manufactured by the organization. The PQ-ABC analysis was applied to determine the standard product. For this purpose, the database for the year 2021 was compiled and analyzed. The result was the pants line (See Figures 2 and 3). It is concluded that the company's standard product is pants since they represent a high demand in units as well as a 52.38% share of the income generated. The diagnosis of the situation and a detailed description of the problem were obtained. In this regard, it was verified that delivery compliance represents 59.3% of the production of garments. In that context, the analysis of the information provided by the organization reveals a problem concerning the delivery of scheduled pants orders.

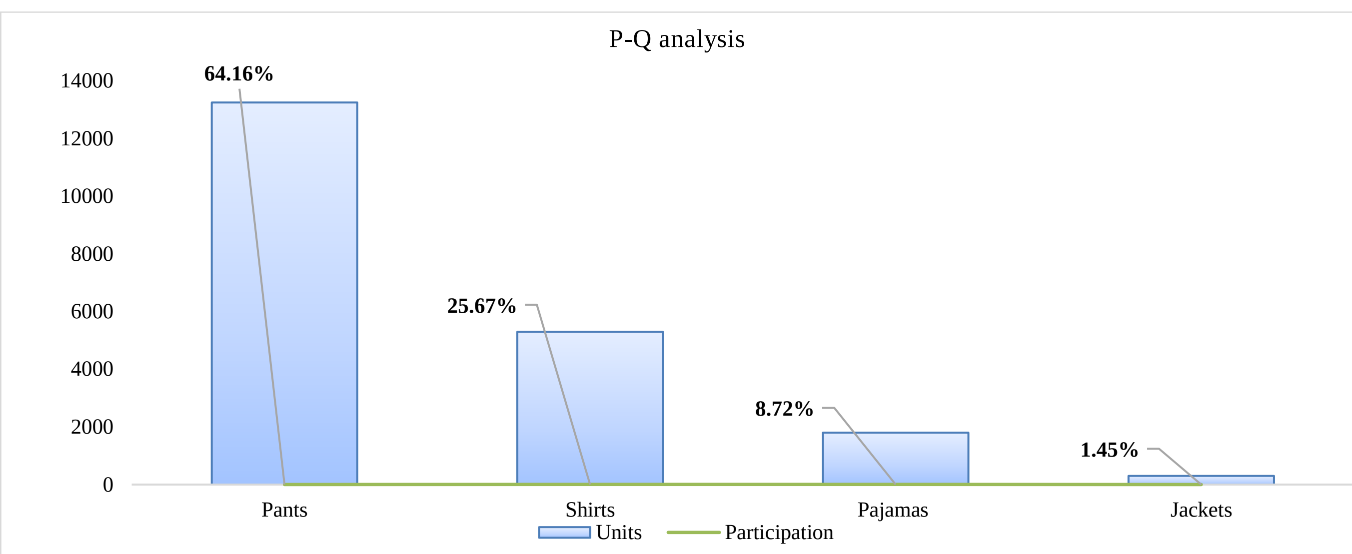


Fig. 2 P-Q Analysis

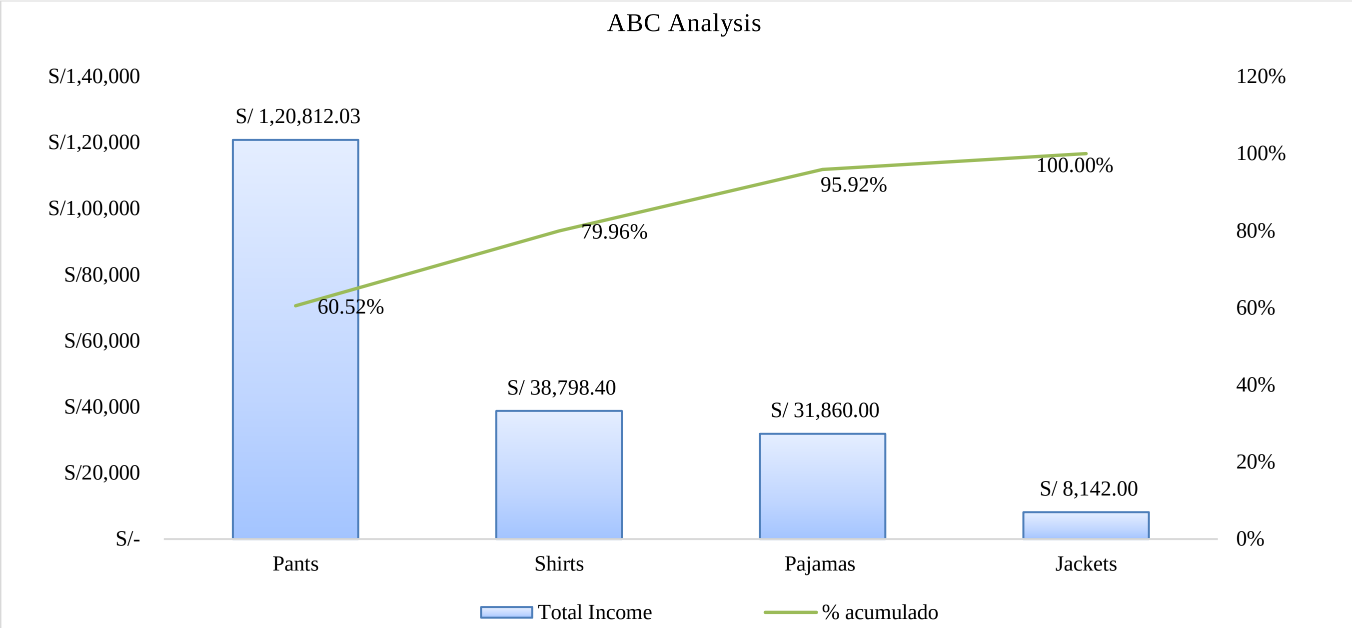


Fig. 3 ABC Analysis

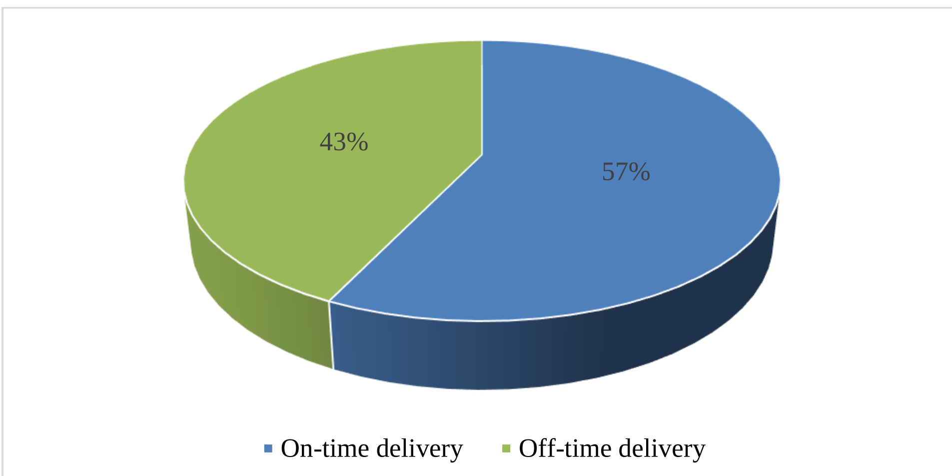


Fig. 4 On-time delivery vs. off-time delivery

Figure 4 shows the percentage of orders delivered on time. Likewise, it can be seen that the percentage of orders fulfilled amounts to 59.26%, which indicates that there is a problem in the apparel company. When comparing the indicator "On-time delivery" (Percentage of order fulfillment level) to compete in the apparel market is 69.47%; therefore, the technical gap is 10.21%. It is concluded that the problem of late delivery of orders in the garment company represents an important gap that needs to be improved.

Thus, by means of the information gathered, the main causes that generate the problem will be analyzed, and the prioritization of these causes found in the case study will be established using a Pareto diagram. According to the analysis carried out previously, the results show that the root causes of the problem are tools outside the workspace, pants with seam defects and long preparation time. These represent 87.19% of the main problem (See Figure 5).

3.1.2. Selecting the Change Option

For the development of the second step, it is important to identify the root causes of the problem. Reviewing the literature and success stories in the industry will allow us to find the right tools. The combination of these selected techniques will form the optimal change. The most effective techniques to optimize the process have been established in this sense. To achieve an optimal distribution of the tools used in sewing, the 5S technique was applied. Likewise, the SMED technique was implemented to decrease the preparation time of the sewing machines. On the other hand, standardization was used to decrease the number of defects in the manufacture of products.

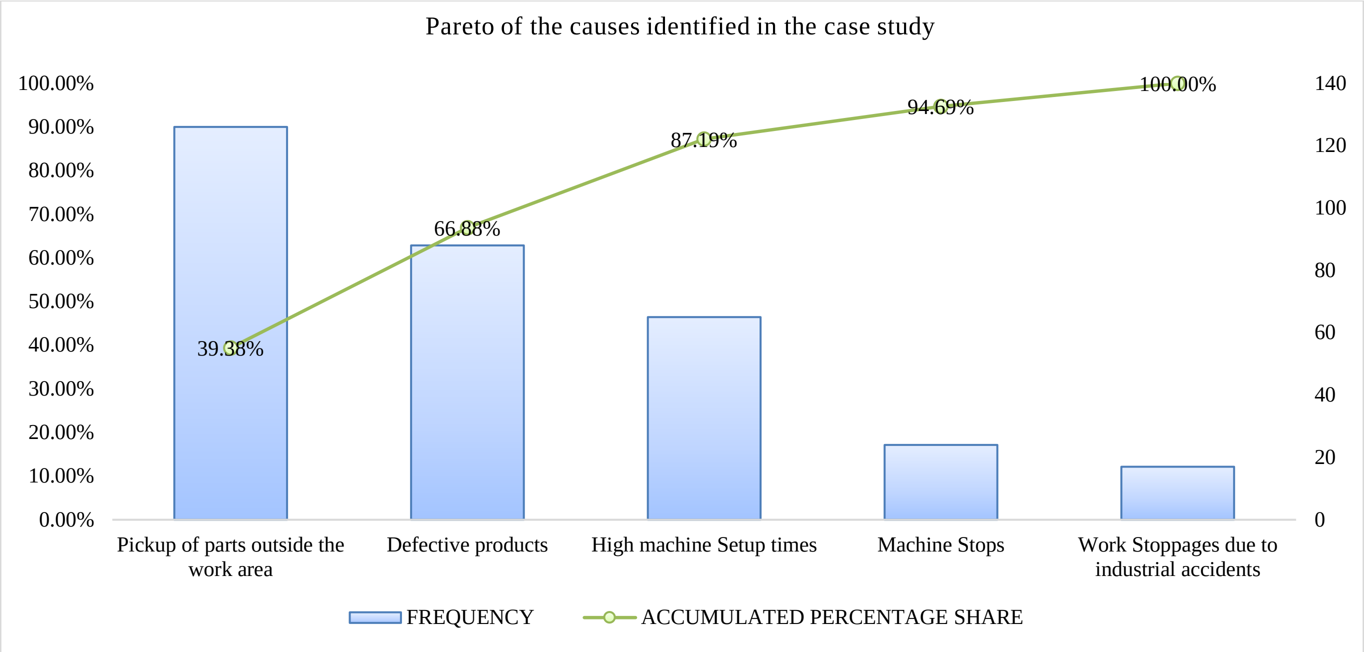


Fig. 5 Pareto chart - case study

3.1.3. Define the Change

The third step is to define "the change". Once the appropriate tools are in place, it is necessary to establish the step-by-step. The proposed method consists of three components that integrate the selected tools. In addition, it seeks to address the main obstacles in applying Lean tools. Therefore, it will be accompanied by change management. In this sense, each component will consider key aspects such as operator training, establishing a culture of continuous improvement and forming a Lean implementation team for better results. In this way, with the support of change management, it will be possible to guide and lead the organization effectively. Figure 6 illustrates the design components.

Training and Organized Work Area

The objective of this component is to address the root cause of the presence of parts outside the work environment. Within the manufacturing area, it is necessary that the spare parts and materials required for the process are in their assigned positions. However, there are currently disorganized areas since essential parts such as cut parts, chalk, strikers, piquettes, and packing balls are outside the workspace.

Therefore, the aim is to organize the work area, ensuring that each element involved in the manufacturing process is correctly located. At the same time, this technique will eliminate the activities that generate added value to the production process, such as searching for and collecting materials outside the work area. As a result, a more efficient flow in the production process will be achieved. To ensure the success of this implementation, it will be essential to train operators to apply this technique.

Training and Reduction Set-up Time

The objective of this component is to address the root cause of high machine setup times. The company under study has records of check sheets and shutdown codes, where unscheduled shutdowns are identified. Among these, there are set-up stoppages, which are related to machinery adjustments and the necessary configuration to maintain the productive flow. The main activities involved in this process include changing the presser foot, changing the needle according to the type and size required, applying lubricating oil and changing bobbins. The optimization of these processes will reduce the set-up time of the machines involved in the production of pants. In this sense, the SMED technique seeks to minimize unnecessary set-up times, allowing sewing machines to operate for longer periods of time and facilitating the production of small batches of garments. To achieve a successful implementation, it is essential to know each of the processes involved in production in detail. Also, the active participation of production and management personnel, together with adequate training in the SMED technique, will be key to guarantee its success.

Maintain Based on Process Standardization.

The objective of this component is to address the root cause of sewing defects. In the case study, the garments ordered by the customer go through an audit process, where a sample of finished garments is taken. The number of samples depends on the volume of garments requested, and it is verified that they meet the requirements of a compliant product. If they do not, the defects are recorded according to their type or failure. Among the most common defects are label gluing failures, defective stitching, uneven seams, size gluing errors, and tape placement failures.

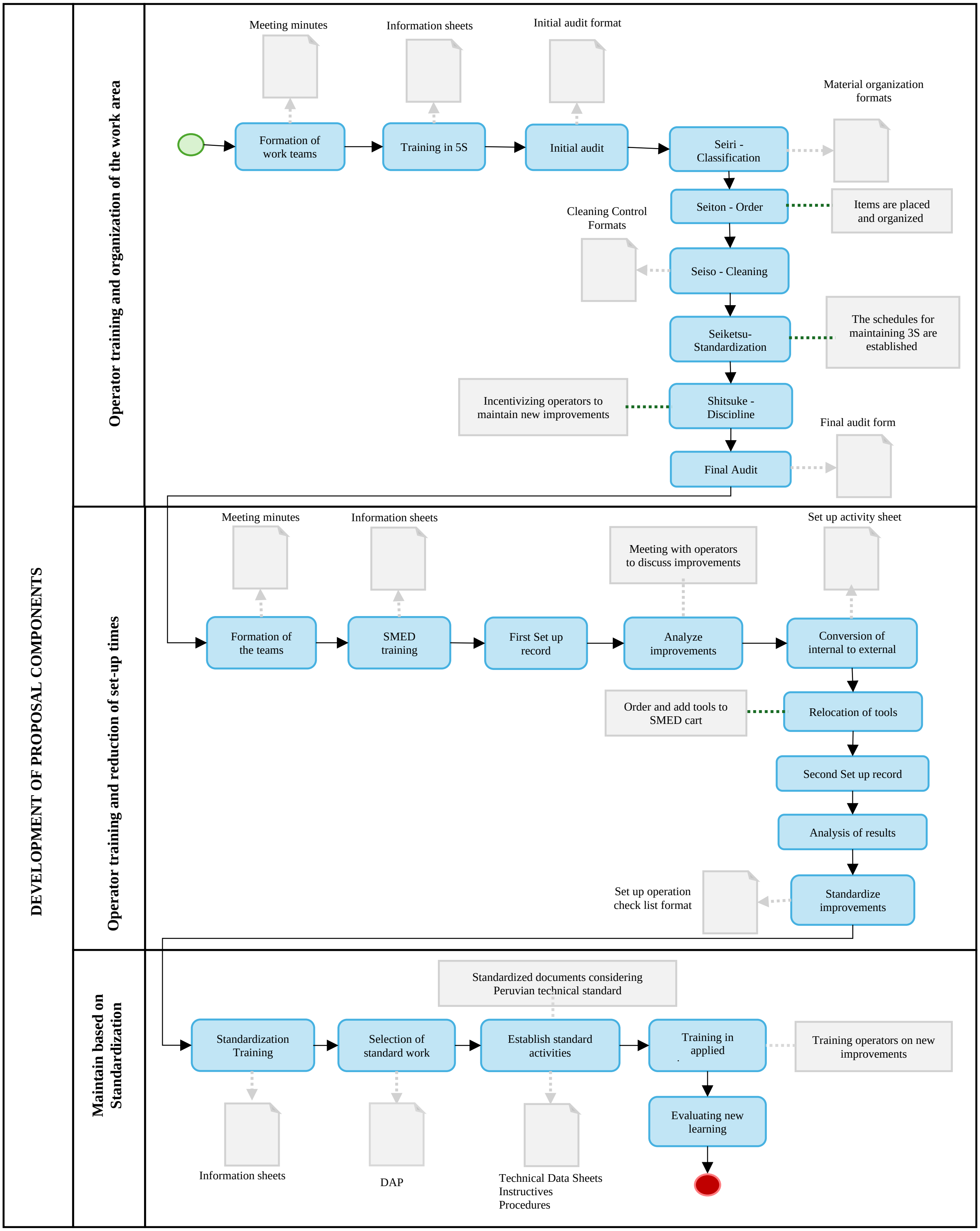


Fig.6 Development of proposal components

The standardization technique will be implemented to reduce the number of defects in garment manufacturing. This will make it possible to document current practices, facilitating the standardization of activities and processes. Standardization not only contributes to the reduction of defective products but also establishes a solid foundation for continuous improvement. As standards are refined, they will become the benchmark for future optimization. To ensure the success of this tool, it will be essential to involve staff and train them in the Lean technique.

3.1.4. Implement the Change

For the fourth step, it is necessary to implement the change. To this end, a pilot test was carried out on the trouser production line. In the case of the 5S tool, it was applied in the sewing area. The SMED technique was implemented on the straight machine since it requires more setup time. On the other hand, the Standardization technique was applied in the sewing area since it has the longest operating time. The times for the pilot implementation were determined by the owner of the clothing company, establishing a range from 8 a.m. to 5 p.m. The pilot will be implemented by the owner of the company and the production manager. In addition, material and training will be provided to the operators so that they can become actively involved in the project and contribute to the expected results. The company has allocated a period of 30 working days for implementing the pilot, during which time improvements in the trouser manufacturing process must be demonstrated. For the implementation of the improvement model, a basic budget will be provided by the organization, while the administrative area will be responsible for managing the resources during the development of the pilot.

Involve the organization

The project was presented to the organization. A detailed schedule of what the proposed model entails was made available. The purpose of this was to motivate and engage the personnel. Likewise, teams were formed to develop the plan.

Formation of Teams

After presenting the project, they were informed that the implementation techniques have a scope for each tool. The team was formed in 5S, and the division of groups proceeded to group the operators to classify, sort, and clean.

Training in the Technique

5S training was given to the operators in the sewing area. In addition, informative material was used to carry out the activities. The benefits, success stories, and training for each of the steps that make up this technique were presented. This training made it possible to hear the opinions and ideas of the operators, which encouraged their participation in the project.

Initial Audit

The initial audit was carried out to evaluate the current status before applying the technique. For this purpose, the Initial Audit format was used to determine compliance with the established criteria. This evaluation will serve as a reference to compare the results with the final audit and measure the effectiveness of the implementation.

Seiri

Item classification records were used to separate the items in the manufacturing area and determine their replenishment level. Red cards were used for out-of-process items.

Seiton

For this step, four tools were determined to be kept near the operator based on frequency of use. The tools will be included in a standard material bag. Each bag will have a number and the name of the operator. On the other hand, a large amount of textile waste was found in the work area. For this reason, proper waste management was established, incorporating the Peruvian technical regulations on color coding for solid waste segregation.

Seiso

The maintenance of the trouser production area was carried out with the participation of the operators. Likewise, the cleaning policy and records were made known, committing the collaborators to participate and comply with this step.

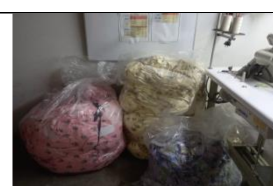
Seiketsu

The procedure to ensure compliance with the 3S step-by-step was presented and trained. In addition, the importance of maintaining lean habits and culture was emphasized to the operators. Responsible were elected who will rotate weekly to follow up on the changes made.

Shitsuke

In this step, personnel are motivated to continue with the improvements implemented. In addition, the new changes must be maintained in their daily routines. Some of the changes are indicated in Table 2.

Table 2. 5S pilot implementation

Before Implementing 5S		

		
After Implementing 5S		
	 	

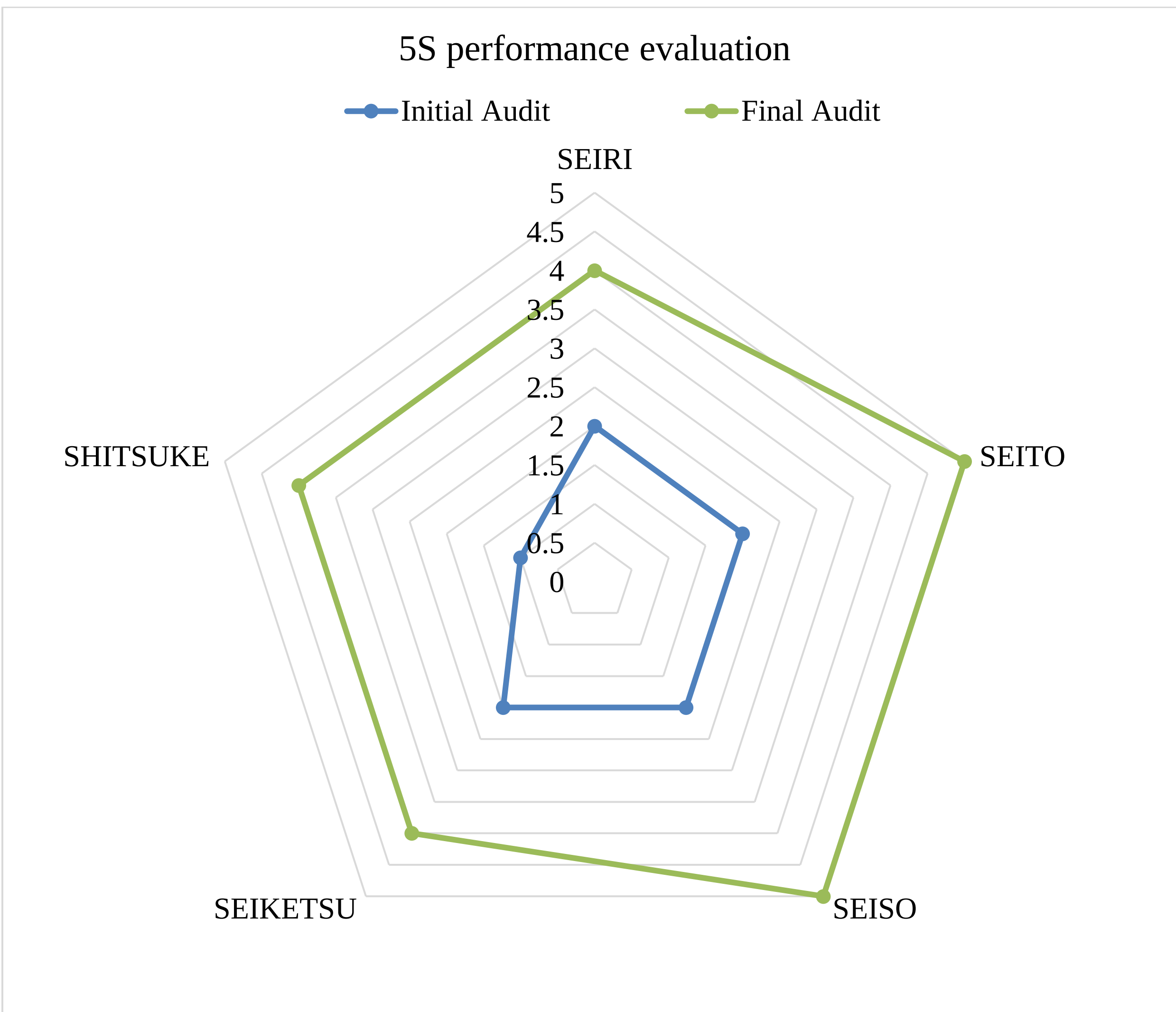


Fig. 7 Audit 5S – Results

Final Audit

This was carried out after validating the criteria and following up on the proposed objectives. After the application, the final results were made known to the team of operators together with the management, allowing them to be aware of the results obtained and to involve them in the process of change (See Figure 7).

SMED Technique Training

Training was provided to personnel involved in setting up and handling machinery. Visual materials and presentations were used to introduce the tool. Also, the benefits and application cases of this technique were presented to the operators involved in the process.

First, Set up Time Recording on a Straight Machine

This will be done on the straight machine, which has a greater number of configurations and a greater number of activities for the change of model (See Figure 8). The first document shows information on the initial state, i.e. no changes have been applied. Some of the materials indicated correspond to the materials used in production and others for cleaning during the preparation of the machinery. The main materials are cloth, threads, needles, screwdriver, rag, and cleaning liquid (benzine).

Analysis of Improvements to be Implemented by Operators

A meeting has been held with the SMED team to show the activities to be outsourced. In that sense, part of the implementation will proceed to use the Toolkit, which will provide the necessary elements to start the configuration.

Externalization of Activities

The external activities are shown in Table 3.

Recolocation of Tools

A meeting was held to show the activities to be outsourced. In that sense, part of the implementation will proceed to use a toolbox that will allow us to have the tools or materials needed to perform the configuration.

Analysis of the Results

The results achieved after the pilot application of the SMED are shown in Table 4. The first time obtained was 9.30 min. From the beginning, this shows a positive impact on the results. Consequently, the setup time obtained is 8.85 min for the straight machine configuration.

It should be noted that this implementation can be replicated in the other straight machines since the organization has about 10 machines.

Fig. 8 Straight machine for SMED application

Table 3. Activities for Straight Machine – SMED

WORK SHEET: SMED - TYPE OF MACHINE: STRAIGHT				
No	**Activities**	**Activity type**		**Observations**
		I	**E**	
1	Switching off the sewing machine	X		
2	Bring clothes and cleaning liquid.		X	Elements to be placed in the tool kit
3	Groom the board and bore	X		
4	Bring yarn, an awl and screwdriver.		X	Elements to be placed in the tool kit

5	Remove the front cover		X	Can run while the machine is active
6	Putting yarn in the upper area	X		
7	Wrapping yarn on the bobbin	X		
8	Installing the thread on the bobbin		X	Can run while the machine is active
9	Put the bobbin with the thread on the machine.		X	Can run while the machine is active
10	Locate sewing needle	X		
11	Verify proper needle positioning	X		
12	Check the tension between the yarn and the sewing needle.	X		
13	Determine the proper stitch type.		X	Shown in Checklist Standard
14	Determine the appropriate berth		X	Shown in Checklist Standard
15	Bringing the lever back	X		
16	Activate the sewing machine	X		
17	Perpendicularly adjust the lever position.		X	Can run while the machine is active
18	Carrying a piece of cloth for test purposes		X	Elements shall remain close to the operator.
19	Test the stitching with the fabric	X		

Table 4. Results SMED

Machine	Activities	Formerly	Now
Straight	Internal	18.55 min	8.85 min
Straight	External	0.00 min	9.70 min

Set Up Operation Standardization

To ensure the effectiveness of the configuration process, standardization of the process will be carried out, consolidating operational changes and new standards. In this regard, a checklist has been developed to standardize the procedure, which will be available in the tool kit, allowing the identification of the necessary elements for machine configuration. In addition, training will be provided on properly using the checklist, ensuring that operators use it correctly and follow the established steps to optimize the process (See Figure 9).

SET UP OPERATION CHECKLIST		
Product: Machine Type: Date: Responsible:	Start time: Final hour:	
TOOLS OR SPARE PARTS TO BE USED		
Presser foot ☐ Needles ☐ Sewing threads ☐ Screwdriver ☐ Cleaning cloth ☐		
ACTIVITIES	RESPONSIBLE	COMMENTS
EXTERNAL PRELIMINARIES		
INTERNAL CHANGES		
OBSERVATIONS		

Fig. 9 Set up operation checklist format

Operator Training in Standardization

The operator was trained in the standardization technique to develop this technique.

Triptychs were used as material to inform them about the technique and the importance of standardizing the sewing process. In this sense, they were taught the correct application of the Peruvian textile technical standards in relation to size designation for garments, code of care symbols for labeling, terminology and definitions related to fibers and textile products, and labeling for garments and household linen.

Standard Work Selection

The sequences of standard activities to produce pants are identified and established within the sewing process. The details of this sequence are presented in Table 5.

Standardization of the Production Process

The application of the standardization technique was carried out through the training of the operators involved in the sewing process. The key to this was the implementation of instructions, technical sheets and procedures for manufacturing pants.

According to the results of the analysis, it was found that the biggest defect was in the sewing, label gluing and stitch failure phases. For this reason, operator training in finishing tasks was reinforced.

Likewise, it became essential to know in detail the execution of the activities and tasks performed on the straight machine (See Figure 10).

Training on New Procedures

With the standardization of the sewing process, the personnel in this work area were trained. Although it is true that most of the operators are familiar with the execution of sequential activities, some performed the work according to their own criteria. The technical data sheet contributed by showing the general sequence of activities and the images of how the final garments should be displayed. In this regard, after the training and feedback with the help of the production manager, the number of defectives obtained in batch production of 650 and 500 pants evaluated after the pilot application was evaluated. After analyzing the results of the percentage of the last two orders, an average of 4.38% was obtained. Based on this, the organization continues to be encouraged to maintain the changes implemented for a better result.

Technical Data Sheet for Trouser Design			**Code: FTD-001** **Version: 001** **Validity:**
Product code		Sizes	
Description		Fabric type	
Customer		Product brand	
PRODUCT			
Place Front Place Backrest		**Detail Characteristics**	
		Type of seam to be applied	
		Type of stitch to be applied	
		Seam width	
		Seam allowances	
		Tape width	
		Pockets	
		Aviaries	**Quantity**
		Size label	
		Brand label	
		Care label	
		Tapes	
Route of the Garment			
Process		Description	

Fig. 10 Sewing technical datasheet

Table 5. DAP of the product

	Product: Pants production		**Sheet N° 1**				
No	**Activities**	○	⇨	D	□	▽	**Observations**
1	Inspection of cut parts				X		
2	Highlight key lines of the part with a marker	X					Marked 4 points
3	Sewing of the front part	X					
4	Pass the first seam through the straight machine	X					
5	Sew the piece a second time on a straight machine	X					
6	Sew the imaginary line of the trouser closure	X					
7	Assemble front buttonholes (pants)	X					Making 2 eyelets
8	Sew the pieces of the cover	X					
9	Cut label and trouser garters	X					
10	Sew the label on the trousers	X					
11	Hook the rubber bands together with the boot	X					
12	Secure the waistband of the trousers	X					

13	Pass the garters through the waistband	X					
14	Fasten the garter with the sides of the waistband	X					Fastened at all 4 ends
15	Adjust the waistband	X					
16	Remove fixed parts of elastic (waistband)	X					
17	Place the tape on the part	X					
18	Evaluate the readymade product (Pants)				X		
19	Remove excess threads on the garment	X					

3.1.5. Anchoring the Change

After implementing the change, in order to anchor the change, you can communicate the results obtained from time to time, listen and provide feedback. Also, recognize the support of each one of the collaborators, incentivizing and motivating the continuous improvement of the organization.When monetary incentives are complicated, more creative rewards can be chosen. Likewise, to measure results, it is important to monitor and follow up on the proposed indicators of the method. Below are the main indicators linked to the objectives of the proposal.

Percentage of On-time Deliveries

It directly measures order fulfillment, i.e., on-time delivery. For this purpose, the time elapsed from receipt of the order to its delivery to the customer is considered.

$$OTD(\%) = \frac{N° \; of \; orders \; delivered \; on \; time \; x100}{Total \; number \; of \; orders \; delivered}$$

Set Up Time

It is defined as the time required to set up a machine and prepare it to produce a different item or product.

$$SETUP \; Time = \frac{Total \; SETUP \; time}{Number \; of \; SETUPs \; performed}$$

Defective Product

Calculates the percentage of products that do not meet the characteristics of a conforming product out of the total production of pants.

$$Defects(\%) = \frac{Total \; number \; of \; defect \; x \; 100}{Total \; units \; produced}$$

4. Results and Discussion

4.1. Pilot Test

The pilot implementation was carried out in the clothing area and lasted approximately 14 weeks. Each of the techniques had a scope. The application and execution of the 5S technique were carried out in the sewing area.

The SMED tool was developed for the machine, and more time was dedicated to the configuration, in this case, the straight machine. The standardization technique was applied to the sewing process for the women's trouser line. The main results are presented in Table 6.

Table 6. Results-Metrics of Pilot implementation

Indicator	Current Value	Projected value	Obtained value	Reduction Increase
On-Time Delivered	57%	69.5%	77.8%	36.49%
%NVA (non-value-added activity)	19.4%	9.2%	6.5%	66.49%
Set up time	18.6 min	5.58 min	8.9 min	52.22%
Percentage of defective	12.00%	7.00%	4.38%	3.38%

4.2. Simulation

Next, new scenarios about the simulation of the production process will be evaluated using Arena software. In this sense, the aim is to simulate the current situation (As Is) and the situation of improvement (To Be). In addition to this, three scenarios will be simulated. The production times of each sub-process of the manufacturing process were used for the input data, and about 500 data were collected. These were assigned in the Input Analyzer program to find the appropriate distribution according to the statistical analysis. The results found were of normal distribution for each subprocess. The following are the times for each sub-process in the pants production and the simulation system, which covers the sub-processes of Sewing 1, Sewing 2, Sewing 3, Cleaning, Quality Control and Packaging. Table 7 below shows the distribution of the times. The main results are presented in Table 8.

Table 7. Distribution of production times

Sub-process	Distribution	Unit
Sewing 1	NORM (2.57, 0.243)	Minutes
Sewing 2	NORM (3.09, 0.233)	Minutes
Sewing 3	NORM (2.15, 0.182)	Minutes
Cleaning	NORM (2.09, 0.121)	Minutes
Quality Control	NORM (1.09, 0.152)	Minutes
Finishing	NORM (3.46, 0.243)	Minutes

Table 8. Results-Metrics of scenario simulations

Scenarios	Indicator	Current Value	Obtained Value
(1) Shorts Line	TSystem1	200.81 min	133.14 min
	SizeColaSewing1	26.841	15.556
	Conforming Parts	2644	2871
	Defective Parts	356	129
	Defect Rate	13.46%	4.49%
(2) T-Shirts Line	TSystem2	112.2 min	76.234 min
	SizeColaSewing1	8.2884	5.2021
	Conforming Parts	1302	1395
	Defective Parts	198	105
	Defect Rate	15.21%	7.53%
(3) Shirtmakers Line	Tsystem3	136.35 min	92.508 min
	SizeColaSewing1	9.8105	6.6046
	Conforming Parts	1358	1378
	Defective Parts	142	122
	Defect Rate	10.46%	8.85%

The results obtained in validating the proposal are linked to the proposed indicators for measuring the proposed objectives. Indeed, the overall objective of the proposal is to increase order fulfillment, which is achieved by the production management method combining the 5S, SMED, Standardization, and Change Management tools, which brings about improvements in the technical gap. For this case study, during the year 2021, 27 orders for batches of pants were placed, of which 11 of them were delivered outside the deadline agreed with the customer. The OTD was 59.26%. Consequently, due to the non-delivery of pants orders, the company incurred expenses of S/. 13,596.61, which represented 9.19% of the turnover of pants. Previous studies where Lean Manufacturing tools were implemented show an OTD of 67.5%. However, the present study obtained an OTD of 77.22%. In addition, an increase of 20.8% in the number of orders handled, thus surpassing the 15% obtained in another case study. [14] In addition, the results obtained in the simulation are encouraging since they show significant improvements in production times. In this case, it is evaluated for a batch of 100 garments (Shorts, Polo Shirts and Shirt Shirts), reducing the average production time by 33.7%, 32.06% and 32.15%, respectively. These results are very close to those obtained in previous studies, where 34% of the production cycle time was reduced. [9]

Likewise, the first specific objective corresponds to reducing the search for parts or tools outside the work environment. These activities qualify as non-value-added activities. After an AVA DAP analysis of the trouser process, the NVA% was reduced by up to 12.90%. According to other studies, including the 5S technique, non-value-added activities were reduced by up to 32%. [28] The second specific objective corresponds to reducing sewing defects. In this sense, sewing defects were reduced by 3.38%. In another investigation of companies in the sector and with similar processes, the ratio of defective seams was reduced by up to 5%. [37] The third specific objective corresponds to the decrease in setup times, which was achieved by reducing the set-up time of the straight machine from 18.55 min to 8.85 min, which translates into a percentage reduction of 52.22%. In a study conducted on a shoe machine, set-up times were reduced by up to 0%, which is a significant improvement. [33] However, according to the literature, the SMED and Standardization techniques came close to the improvements indicated by the authors. In contrast, the 5S tool exceeded the predicted values. The research conducted argues that the results obtained are not far from the reality of the sector, so they are valid and accepted. These tools, together with Change Management, would help obtain favorable results for the other production lines of the company since they have similar processes. However, a relevant point to mention is that the pilot implementation was evaluated during the low season, giving immediate and optimistic results. For future research, it would be advisable to measure it over a longer period of time and obtain a more realistic level of compliance.

4.3. Evaluation of Impacts

4.3.1. Economic Impact

An initial investment of S/. 3,754.00 was projected. In implementing LM tools, the authors agree that the implementation and evolution of improvements can occur in the short term. In addition, they are tools that adapt to the current working conditions of MSMEs, which makes their implementation feasible [32,37]. When analyzing the NPV, it can be inferred that the investment for its implementation will generate benefits to the company for S/ 5,884.29.

On the other hand, when observing that the IRR (69.32%) is higher than the CPPC or, also called WACC of 17.50%, it is advisable to make the investment. Likewise, a profitability index of 1.57 has been obtained. In addition, the amortization period of the investment is 1.73 half-years, in which an adaptation time of 6 semesters has been considered.

4.3.2. Environmental Impact

The generation of solid waste from the textile industry causes significant negative impacts on the environment. Implementing the 5S technique, which incorporates the technical standard for waste management, is helping to reduce environmental damage. In addition, the application of Lean tools helps to reduce fabric scraps and other materials that must be used to correct human errors during manufacturing due to the lack of standardization. These materials are considered waste and do not have a useful life again. Table 9 shows the comparative projection of the amount of non-usable waste used in producing a batch of pants after applying the model.

Table 9. Analysis of environmental impact results – Open LCA

	Estimation of the quantity used to produce a batch of pants	
	Before	After
350gsm cotton fabric of intensive cultivation	36.50 kg	28.40 kg
Polyester yarn	13.40 kg	10.60 kg
Integrated ground newsprint	0.82 kg	0.55 kg
Sticky tape Kraft paper	0.95 kg	0.81 kg
Imported hard-drawn steel	1.50 kg	1.20 kg
Other	1.15 kg	0.80 kg

The decrease in the amount of unusable waste of up to 22% generates a positive impact on the environment by preventing it from ending up in incineration or landfills. [50] As part of the life-cycle analysis, two moments of carbon storage are known for cotton textiles. The first moment is related to cotton cultivation in the field, and the other moment occurs when it is used as raw material for manufacturing garments. Cotton fiber retains its biomass in the textile garment. Likewise, materials such as stains, dyes, bleach, and packaging materials, among others, are used to transform cotton fibers, and resources such as electricity and water are consumed for their production. [15] To a lesser extent, the elements used in labeling pants, such as paper, ribbons, and metal fasteners, among others, were also reduced.

4.3.3. Social Impact

To measure the social impact, a brief survey was conducted to gather the opinion of the local population on the solid waste management of the microgarment company. Respondents were chosen with varied profiles that are affected to varying degrees by the waste generated by the company. They were asked to evaluate on a scale of 1 to 10, where 1 is total negligence in waste management and 10 is effective control of solid waste. The company obtained an overall average of 8 points. This result is interpreted as a positive reflection of the adequate management of the company; however, it is important to know what aspects the neighbors consider should be improved. Finally, it is advisable to maintain adequate control of solid waste to avoid the accumulation of garbage in public spaces, which could end up causing illness among the local population.

5. Conclusion

The proposed solution achieved good results with a lower investment. An order fulfillment level of 77.88% of the trouser line was achieved. With the 5S technique, non-value-added activities, such as picking materials outside the work area, were eliminated. These activities were reduced from 19.35% to 6.45%. Using the SMED tool, the machine setup time decreased from 18.6 min to 8.9 min. This represents a reduction of 52.22%. At the same time, a document was implemented to verify the condition of the sewing machine. The amount of defective products was reduced from 12% to 4.38% with the help of standardization. The results were verified against Peruvian textile technical standards.

In the environmental dimension, thanks to the reduction of waste of some raw materials, the environmental impact of the organization was minimized. In addition, the proper segregation and disposal of waste contribute to social sustainability since both workers and neighbors will not have to live with the waste. Implementing this project will help the company reduce the generation of non-usable waste by up to 22%. It will also help reduce polluting emissions from the textile industry. In the social dimension, the objective of reducing by up to 50% the accumulation of solid waste on public roads, a consequence of inadequate waste segregation and disposal, was achieved. In the economic dimension, a profit of S/. 5,884.29 would be obtained from the implementation of the project. On the other hand, observing that the IRR (69.32%) is higher than the CPPC or WACC of 17.50%, it is advisable to make the investment. Likewise, a profitability index of 1.57 has been obtained. Therefore, the sustainability of the proposal can be affirmed. Finally, the present research focuses on some 24,000 textile companies in Peru. The proposed method could apply to other case studies with similar characteristics.

This study has certain limitations that should be analyzed in greater depth. As for the results obtained, the analysis focused only on the sewing area, so it would be ideal to extend the study to other areas in order to contrast the results. Due to the time frame established by the organization and the project, only a pilot test was carried out. Also, accessibility to information was a relevant factor since the study was based on a single product, which restricts the scope of the analysis. In addition, a significant gap in organizational culture and change management within the garment companies was identified. For this reason, additional days were taken to sensitize the team on the importance and benefits of applying the proposed techniques. Fostering teamwork between operators and managers is key to generating synergy and ensuring sustainable results. As part of continuous improvement, it is essential to continue monitoring indicators and standardizing processes. Therefore, it was recommended that the organization hold periodic meetings to evaluate progress, identify opportunities for improvement and ensure the sustainability of the changes implemented.

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