Production management model to reduce non-fulfillment of orders in Peruvian garment SMEs through 5S, SMED and standardization tools

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***Abstract*— Currently, formal SMEs in the textile sector represent 16.4% of Peru's manufacturing SMEs, in other words, there are approximately 32,137 companies in this sector. The textile industry is the third largest contributor to manufacturing and is intensive in the generation of approximately 400,000 direct jobs. However, one of the main problems that prevents it from competing effectively with other countries in the region is related to non-fulfillment of orders. Also, lack of communication in the organization, inadequate operator training and employee resistance to new changes are the main barriers faced by companies in the sector during lean implementation. This research study will focus on reducing order non-compliance in an SME in the apparel sector using 5s techniques, SMED and standardization. An improvement is expected in relation to the problem, in addition, it is intended to develop a framework of lean practices that will serve companies in the sector. In this way, it contributes to the existing literature.**

***Keywords*—Garment industry, on time delivered, 5S, SMED, Standardization**

I. Introduction

The textile and apparel sector is one of the most important industries in the Peruvian economy. Their contribution to the generation of employment and foreign exchange supports this importance. Regarding the latter, the exports of this industry have generated in the last two years about $1,421.1 million dollars on annual average, contributing to 3.00% of the total foreign exchange generated by Peruvian exports. The textile sector has fallen 1.5% each year in the last decade (S/. 548 million less), while the Peruvian GDP has grown 3.6% annually (S/. 345,692 million more) and the Manufacturing GDP has had a positive variation of 1.7% (S/. 34,284 million more). As a consequence of a lower productive activity, which has differed from the evolution of manufacturing and the economy, the sector has reduced its participation in the Peruvian economy by 0.9 percentage points and in the manufacturing GDP by 4.2 percentage points [1].

The business segment of micro, small and medium-sized enterprises (MSMEs) represents 99.6% of the total number of formal companies in the Peruvian economy. Of these, 96.04% are microenterprises, 3.44% are small, and 0.12% are medium-sized companies.

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Of the MSMEs, 87.9% are engaged in commerce and services, and the rest (12.1%) in productive activities (manufacturing, construction, agriculture and livestock, mining and fishing) [1]. The textile and clothing sector is the third largest contributor to manufacturing and is intensive in generating approximately 400,000 direct jobs. [2] In 2017, the formal SMEs dedicated to the manufacture of textile products represented 16.4% of the manufacturing SMEs in Peru [3].

The apparel sector, specifically companies that work with small batches of orders, must respond to style changes quickly. In that sense, it is important to know a system that allows processes that especially those working with small batches of orders, must respond quickly to style changes. It is essential to know the status of a system to process orders on time. [4]. This is based on the need of SMEs textiles and clothing, especially those that handle small batches of order, to improve their processes to meet their orders on time and achieve customer satisfaction.

The implementation of lean in the apparel industry has great potential, since lean can serve as the appropriate approach to successfully combat the challenges facing this industry. However, the adoption of lean in this type of company is not yet very popular [4]. Also, lack of awareness for lean implementation, company culture, lack of communication and employee resistance are the main barriers faced by companies in the industry during lean implementation [5].

This research study will focus on the design of a production management model that allows the reduction of non-fulfillment of orders in an SMEs by integrating lean techniques such as the 5s, SMED and standardization. Through the combination of these techniques, it is expected to obtain great results with a lower investment, since this study focuses on the study of SMEs, which comprise approximately 32,137 companies in this category. In this sense, the present production management model could be applicable to companies in the sector with similar characteristics. In addition, the conclusions of this research are intended to develop a framework of lean practices that can be used by companies in the sector. In this way, it contributes to the existing literature.

This article will be divided into four parts for the development of the research. In relation to the first section, a review of the state of the art will be presented, which consists of a review and analysis of previous studies by expert authors. The second section will detail the contribution in relation to the previously reviewed case studies, which proposes a model that can be applied to the textile industry. The third section covers the validation of the result through the pilot application, which shows the quantitative data that validate the proposed model.

II. State of the Art

A. Order fulfillment level in the apparel sector

The textile industry faces problems in work allocation, waste minimization and on-time deliveries [6]. Inadequate processing in practice, disorganization in structure and lack of communication in the organization lead to the occurrence of large losses and wastage in enterprises, causing the organization to be inefficient [7].

The inability of some textile companies to respond quickly to changes in production, process, quality, delivery and cost change, to cope with the changing or unstable environment and circumstances, can make them liable for penalty or losses due to failure to deliver. Penalties can sometimes be large and severely damage the credibility of the company when orders are delivered late [8].

Quality, on-time delivery and flexibility should be the main components of the manufacturing strategy that textile companies should have. These strategies would help to improve their performance and lead the company towards competitive advantages [9]. There are a variety of success stories in which textile companies are working on the adoption of Lean techniques and principles. This occurs with the application of continuous improvement programs or activities, which results in product cost minimization, shorter lead times and improved quality of the products they offer. The results after the implementation of Lean-Kaizen report a significant reduction in production time of 69.47%. In effect, this brings great benefits to the organization [10].

B. 5S tool for minimizing out-of-work parts

The competitiveness of MSMEs is important and key to their survival. This can be achieved through Lean Manufacturing. The Lean implementation approach will lead apparel companies to achieve competitive advantages [10]. Adopting lean tools or techniques is known to improve quality, increase productivity, reduce preparation time, reduce product costs, increase customer satisfaction and reduce lead times [11].

Studies reveal that the 5S technique acts as a solid foundation and in turn can be successfully integrated with other quality tools such as TPM, kanban, quality circles, kaizen and lean. The 5S practices require less resources in addition to training issues, so SMEs could be adapted to the microenterprise context [12]. The implementation of 5S tool positively affects the delivery process. When processes are systematized and improved, a better on-time delivery rate can be achieved. Thus, ensuring fast delivery with the help of supplier practices. After implementation, there is evidence of up to 25% reduction in downtime caused by lost tooling on the shop floor, and a 32% decrease in non-value time [13].

C. Standardization to reduce sewing defects

Standardization is one of the techniques that can be best applied to continuous improvement in companies. In addition, standardized work is one of the most powerful lean tools, but it is also one of the most underutilized. The lack of standardization in production processes is mainly evidenced by increased manufacturing time and constant rework, due to failures in the products in process [14]. The authors mention that, with a correct application of standardization, companies can reduce their costs. Likewise, as advantages it provides a clear, standardized activities and insurance.

With the application of norms and standardization of processes, defects in the production process are prevented and, in turn, procedures are established so that the appearance of other errors that may have an impact on production can be avoided. In this sense, it is desirable to standardize all processes carried out in the manufacturing sector[15].

The application of standardization in textile companies allows improving practices for work execution. After implementing standardization, a reduction in the number of defective products is evidenced. In relation to the number of defective products, there is a reduction of 68.83% and 68.86% in fabric misdirection and template measurement error, respectively. Also, the percentage of the quality indicator was also increased up to 83.67% by reducing the number of defective products [16].

D. SMED tool focused on configuration reduction

Nowadays, companies are forced to produce smaller batches. Most of the setup time reduction initiatives have been associated with Shingo's (SMED) methodology. SMED seeks to perform Set up (changeover) operations of equipment in less than 10 min, in other words, the number of minutes expressed by a single digit [17].

In that sense, a SMED approach is the best solution when setup times need to be reduced. Can outsource internal activities, in turn, reduce them through simplification or standardization. It has also proven to be an effective tool to eliminate unproductive time [17] [18]. Regarding setup times, they are reduced by about 60% after converting some internal activities into external ones [18].

In the conventional SMED method, setup activities are mainly performed by machine improvements; however, not only machines but also operators are involved in the setup process [19]. A major shortcoming of the SMED methodology is the consideration and motivation of the operators. If the SMED concept could be incorporated and implemented correctly, it can not only reduce machine setup time, but also improve department coordination [20]. Due to the results obtained and the success of the SMED technique, companies are currently implementing this type of approach to other remaining lines in the factory, as well as to other projects [21] [22].

III. CONTRIBUTION

A. Fundamentals

One of the main problems facing the apparel sector is the non-fulfillment of orders. Likewise, another barriers facing the sector is the lack of knowledge, communication, training and management skills necessary to implement lean management techniques. In this sense, we will focus on contemplating these existing gaps in terms of operator training, since in this way we guarantee the solidity and sustainability that this proposal will be maintained in the organization. In this sense, we propose a production management model based on lean techniques to attack the causes of variability in the sector.The causes of parts outside the work area, high machine set up times and sewing defects were identified. In this regard, the 5S, SMED and Standardization techniques were associated. The 5S technique focused on the reduction of material or tool collection in the sewing process. The Standardization technique focused on the reduction of defects in the manufacturing of garments. The SMED technique with the purpose of reducing the time of machine configurations.

The 5S technique, which is a potential means to eliminate waste in an organization, in this case will facilitate that the tools or materials are in the designated places for easy handling during the production flow. In that sense, it will contribute to a better working environment and the elimination of non-value-added activities. The SMED technique aims to reduce time of machine configurations by analyzing the activities involved in the setup process. The standardization technique focuses on the reduction of defective parts that occur in the manufacture of pants due to the lack of standardized work methods. It should be noted that we will also focus on training the operator in each of these lean techniques associated with the proposed model. In that sense, it is expected to reduce out-of-work parts by 25% [22], reduce sewing defectives by 5% [14] and reduce machine setups by 60% [19]. In relation to on-time deliveries, after reviewing the existing literature, in micro textile enterprises, it is expected to reach 69.47% [7]. According to the literature review analysis, the proper integration of these three tools is expected to achieve relevant benefits in the present case study.

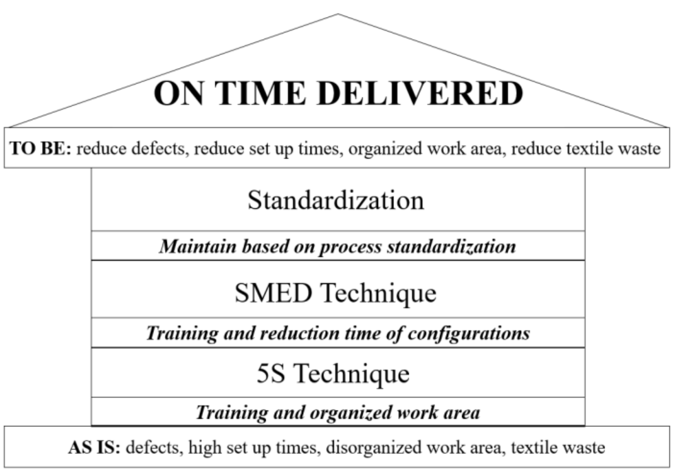


Fig. 1 Proposed model

B. Components

In this section, we will detail the components of the solution design and proposal.

1) Training and organization of the work area

The purpose of this component is to organize the work environment to enable the manufacture of garments in a clean and orderly work environment. In this way, the aim is to reduce the collection of materials outside the work area. Since disorganized areas, where the main materials and tools are located outside the work stations, do not allow an adequate flow of the process. From the literature reviewed, the existing barriers to the implementation of lean techniques are observed. In that sense, it is necessary to have the support of management, provide training to employees and have an agile implementation team that allows a successful implementation. In fact, by training and educating the teams of operators, the continuous sustainability of the technique can be guaranteed. This is achieved by regularizing adequate communication among employees.

2) Training and reduction time of machine configurations

The purpose of this component is to reduce the time of machine configurations involved in the manufacture of pants. Therefore, the SMED technique is intended to reduce set-up times by converting all possible internal set-up operations into external set-ups. This allows the machines to remain in operation for longer periods of time, thus increasing production capacity without the need to invest in new equipment or increase the production line. In this sense, the operator will be able to continue with his activities in a timely manner and the incidence of errors when adjusting the machinery is reduced. Likewise, SMED opens the way for the application of other management tools, among them is the Lean Manufacturing system, working mainly with the cultural theme of the production environment and simultaneously using the 5S technique. It should be noted that the successful application of the tool requires the involvement of operators in the project and, subsequently, training in the SMED methodology.

3) Maintain based on process standardization

This component focuses on the reduction of defectives in the manufacturing of pants. This is linked to the standardization technique, which is a basic tool in the continuous improvement of the organization. The company under study does not have standardized work methods, which causes defective products that in the end must be reworked to meet the characteristics of a compliant product. In this sense, when current practices are documented, they allow activities and processes to be standardized, which is the baseline for continuous improvement. Furthermore, as the standard is improved, it becomes the baseline for future improvements, and so on. In effect, the quality of products and processes improves.

C. Process

Figure 2 shows the process of how to develop each of the components of the proposed model.

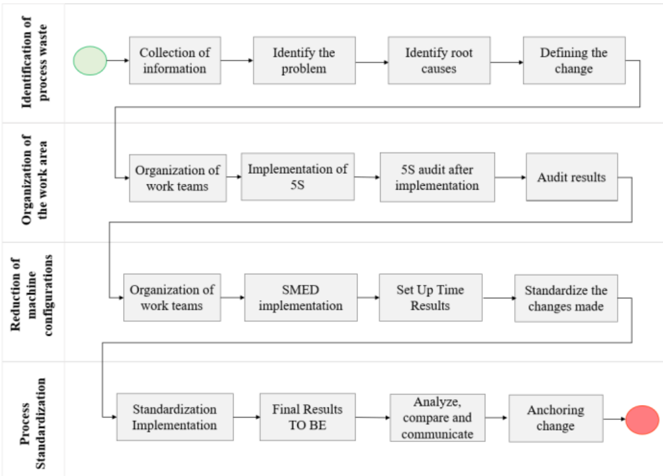


Fig. 2 Implementation process

D. Indicators

This section shows the indicators associated with the improvement proposal that will serve as a starting point for validation.

1) *Percentage of on time deliveries:* Directly measures fulfillment management, on-time delivery of orders from receipt of an inquiry to delivery to customer.

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

2) *Set up Time:* Time required to change a device on one piece of equipment and prepare that equipment to produce a different model.

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

3) *Defective products*: Percentage of products with any error in the entire trouser production.

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

IV. VALIDATION

A. Scenario

For the development of the research, a study was conducted in a Peruvian SMEs in the garment sector, which is dedicated to the service of cutting and sewing garments for adults and children. Due to the wide variety of products, the standard product was determined through a PQ and ABC analysis. The data analyzed cover 2021. The product under study was selected, which is the pants manufacturing line. Regarding the organization's problem, a 59.26% order fulfillment percentage was evidenced. Also, the main root causes are the collection of materials or tools outside the work area, high machine set up times and defective products.

B. Initial diagnosis results

The preliminary analysis carried out for the case study provided quantitative information on the diagnosis made. It showed that the level of on time deliveries is 59.26% for the production of trousers (see Figure 3). In order to quantify this reason and see its impact on the main problem, the on-time delivery indicator was used.

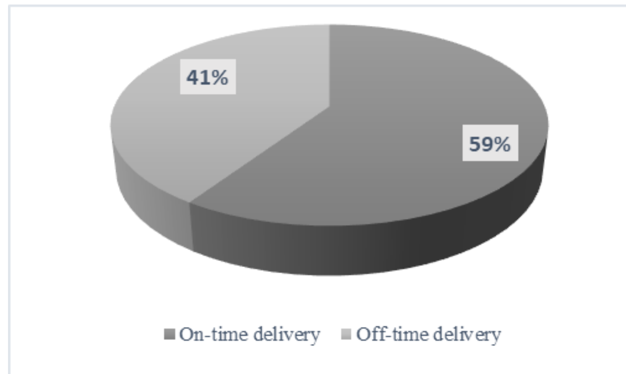


Fig. 3 On-time vs. off-time delivery of trousers

To address the main problem, we analyzed the information provided by the company and proceeded to make a tree diagram (see Figure 4) in which we placed the main root causes. It can be seen that among the main causes are defective parts outside the work area in sewing and high machine set up times. Therefore, it is concluded that 3 of the root causes represent 85.11% of the problem. Likewise, the following tools are assigned to attack the root causes.

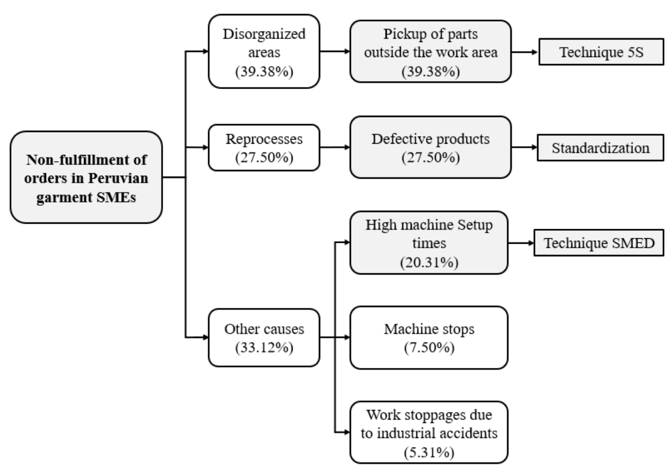


Fig. 4 Root cause tree

C. Implementation of the proposed model

Validation of the combined methodology will be carried out through pilot tests in the sewing process, specifically in the sewing sub-processes. In this way, the 5S technique will be implemented in the sewing area, the SMED technique for the straight machine, and standardization for the sewing sub-process, which has the longest time and the most defective products.

The first tool that is proposed is the application of the 5S in the garment manufacturing area, with the purpose of reducing the number of pieces outside the work area. In this way, the aim is to improve the production flow and avoid unnecessary transfers, which generates waste. It should be noted that the training of the operator in 5S is considered a fundamental pillar. For the application of 5S, the actions described in Table I were considered.

TABLE I
IMPLEMENTATION ACTIONS FOR 5S

N°	Activity	Description
1	Staff training	Training of work teams Training in the 5S technique.
2	Initial Audit	Perform initial 5S audit. Take photos of the AS IS condition.
3	Implementation of 5S	Seiri, Seiton, Seiso, Seiketsu, Shitsuke Further analysis and improvements
4	Final Audit	Perform final 5S audit. Take photos of TO BE status.
5	Results and improvement	Communicate to the entire organization. Feedback and learning lessons.

Seiri: The material classification forms were used. The materials located in the manufacturing area were classified. Together with the responsible persons, we proceeded to know their level of replenishment.

Seiton: Four important elements were identified that should be located close to the operator, since they are the ones that are used at all times. These elements are pickaxe, centimeter, punch and screwdriver. These tools will be located in this bag of materials, which is identified with a number that is associated with the operator who participates in sewing.

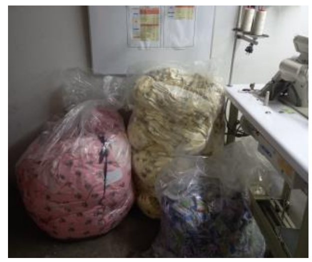
Also, with the use of red cards, textile waste was identified. Therefore, considering the use of the Peruvian Technical Standard "NTP 900.058:2019 Waste Management. Color code for the storage of solid waste", is part of the action plan established for this type of waste that will allow a responsible segregation of textile waste. In this regard, paper and cardboard, plastic and non-usable waste were grouped together.

Cleaning: The general cleaning of the garment area was carried out jointly with all members of the organization. In addition, a cleaning policy was established, which commits all members of the company to comply with the requirements.

Standardize: A procedure was established to maintain the 3S previously mentioned. In this regard, the new habits being adopted by the operators were continuously monitored. To this end, managers were appointed to support the maintenance of these new changes.

Discipline: The final audit was carried out after 3 weeks to validate the criteria and see if the proposed objectives were met. For this point, it is carried out with the objective of encouraging workers with the 4s implemented. Employees should be motivated to continue making improvements and adopt these activities that will allow the sustainability of the technique. Continuous improvement should be part of the expectations and routine activities of the workday. The before and after improvements implemented in table II are shown below.

TABLE II
ORGANIZATION OF THE PRODUCTION AREA

Before	After
	
	
	
	

The second tool proposed is the application of SMED with the objective of reducing the time of machine setups. In this way, unwanted activities are eliminated, internal activities are outsourced, if possible, and reduced through simplification or standardization. It should be noted that operator training in SMED is considered a fundamental pillar. For the implementation of SMED, the actions described in the table below have been considered.

TABLE III
IMPLEMENTATIONS ACTIONS FOR SMED

N°	Steps	Description
1	Strategic	Training of work teams Training in SMED technique Filming the first set up record.
2	Preparatory	Analyze improvements Conversion of internal activities to external Relocation of tools
3	Operational	Filming second record of Set up. Analysis of results
4	Test	Standardize the proposed improvements

The internal activities that are part of the textile machine configurations require the machine to stop to make changes. In this sense, for the pilot implementation it is relevant to perform an analysis together with the operators involved in the manufacturing of pants to identify the internal activities that can be improved. In this way, we proceed to separate the internal and external configurations and convert the possible internal configurations into external ones.

The first record has been made. It shows the initial state without adjustments or changes to be proposed, in other words, the AS IS state. Then, the activities to be outsourced were proposed through an analysis of the improvements together with the operators involved. The conversion of activities was carried out and the tools or materials required in the configuration were taken into consideration. Some of these materials are used in the machinery and others are related to the cleaning of the equipment that is part of an activity in the configuration. These materials are made up of needle, screwdriver, cloth, benzine, rags, thread. These materials were placed in a toolbox located near the production area. A second record was made and the set up time was 9.45 min. Finally, a standardization sheet was shared to sustain the technique over time. As detailed in Table IV.

The study also proposes the application of the standardization technique, whose main objective is to reduce defects in production and to achieve a basis for improvement activities. In this sense, the trouser manufacturing process does not follow a certain sequence. For the application of standardization, the actions described in the table V were considered.

TABLE IV
ACTIVITIES FOR STRAIGHT MACHINE- SMED

SMED DATA SHEET - STRAIGHT MACHINE					
N°	**Activities**	**Time (min)**	**Activity type**		**Observations**
			I	***E***	
1	Turn off straight machine	0.10	I		
2	Bring rags and benzine for cleaning	1.40		E	Materials to be placed inside toolbox
3	Clean table top and machine hole	1.00	I		
4	Bring thread, needle and screwdriver	2.40		E	Materials to be placed inside toolbox
5	Remove front cover of straight machine	0.50		E	Can be done with the machine on
6	Place thread on top of machine	2.20	I		
7	Wind the thread on the bobbin	1.30	I		
8	Thread the bobbin	1.40		E	Can be done with the machine on
9	Insert the bobbin with threaded bobbin	1.10		E	Can be done with the machine on
10	Insert the selected needle no.	1.40	I		
11	Check correct needle positioning	1.15	I		
12	Check the thread and needle tension compensation	0.45	I		
13	Select type of stitches to be required	0.40		E	Can be done with the machine on
14	Select the required tacking	0.40		E	Can be done with the machine on
15	Sewing lever backwards	0.30	I		
16	Start machine straight	0.10	I		
17	Set lever position to be perpendicular to base	0.55		E	Can be done with the machine on
18	Bring fabric to test sewing	1.10		E	Materials to be placed inside toolbox
19	Test sewing	1.30	I		
Total		18.55			

TABLE V
IMPLEMENTATION ACTION FOR STANDARDIZATION

N°	Steps	Description
1	Evaluate	Operator training in standardization. Select standard work.
2	Standardize	Establish standard activities Elaborate files, instructions, and procedures Training in applied improvements.
3	Sustain/Control	Evaluating new learning

To start the implementation plan for the standardization of the manufacturing process, it will be based on 2 main points, the first will be the training of the operating personnel and the second will be the implementation of the standardization. The pilot application will be made in the sewing sub-process. In that sense, for the process standards, an analytical diagram of the pants process is presented. The following sequence of activities is selected and qualified as "standard" to carry out the cards, instructions, and procedures. Below is the sequence of activities to be standardized, which can be seen in the standard work combination sheet. As detailed in Table VI.

TABLE VI
STANDARD ACTIVITIES FOR TROUSERS

Product: Trouser production		**SHEET N°1**					
N°	**Activities**	○	⇨	D	□	▽	**Observations**
1	Inspection of trouser fabric cuts				X		
2	Mark key points of the cut with chalk	X					Marked 4 points
3	Joining two trouser fronts	X					
4	Pass the first seam through the straight machine.	X					
5	Second seam on a straight machine	X					
6	Make the imaginary closing seam on the pants.	X					
7	To make the buttonholes of the front trouser leg	X					Making two eyelets
8	Joining pant legs	X					
9	Cutting trouser label and elastics	X					
10	Attach the label to the trouser brand.	X					
11	Banding the elastics of the boot trousers	X					
12	Fasten under the pretensioners with straights	X					
13	Position the elastics of the waistband of the pants.	X					
14	Fasten the elastic at the ends of the waistband.	X					Fastened at all 4 ends
15	Pre-tensioning the pants	X					
16	Remove those fixed in the elastic	X					
17	Tape on the pants	X					
18	Check the length of the pants made up.				X		
19	Eliminate thread residues on the garment	X					

Standardization was carried out through the training of instructions, technical data sheets and procedures that encompass the production of pants. In this sense, from the information analyzed above, it was found that one of the major defects presented in sewing, bad label gluing and failure in the stitching of the garment. For this reason, emphasis was placed on these activities which involve these finishes so that the operator can perform them correctly. To do this, it was necessary to know in detail how the activities are performed and the knowledge of the function of the straight machine execution.

D. Results

The following table shows the results obtained after the pilot implementation, which took place during the months of August and September. With the proposal developed, 80% was obtained in the fulfillment of trouser orders. As detailed in the table below.

TABLE VII
EXPECTED RESULTS - METRICS

Objective	***Indicator***	***Current Value***	***Projected value***	***Obtained value***
Increase order fulfillment	On Time Delivered	57%	69.47%	80.00%
Reduce material collection	%NVA	19.35%	9.24%	6.45%
Reduce Set up time	Set up time	19 min	11.4 min	8:85 min
Decrease defective	Percentage of defective	12.00%	7.00%	4.38%

CONCLUSIONS AND FUTURE RESEARCH

The proposal, obtained great results with a lower investment. After the pilot implementation of the production management model, the result was an order fulfillment level of 80% in pants. Using the 5S technique, it was possible to eliminate activities that do not add value, such as searching for work tools. This was reduced from 19.35% to 6.45%. In addition, safe and visualized work was achieved. By means of the SMED technique, the set-up time was reduced from 18.55 min to 8.85 min. Likewise, standardization was achieved by means of a checklist for the straight machine. By means of the standardization technique, it was possible to reduce the number of defective seams from 12% to 4.38%. This was achieved by incorporating Peruvian textile technical standards. The inclusion of active communication and feedback on improvements was also achieved, allowing operators to adapt quickly to changes and acquire knowledge about the techniques implemented.

This research focuses on micro textile companies, which comprise approximately 32,137 companies in this category in Peru, which through the proposed model can be applicable to companies in the sector with similar characteristics. An important part of its application is the training of the operators that make up the organization, since it will depend on this that it can be sustainable. LM in the apparel industry has great potential and serves as a suitable approach to successfully combat the challenges faced by this industry. It is also recommended to consider change management to achieve better results in a lean implementation as it involves working with people in the acceptance and assimilation of changes.

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