Proceedings of the International Conference on Industrial Engineering and Operations Management

Publisher: IEOM Society International, USA DOI: 10.46254/GC02.20240185
Published: December 01, 2024

Implementation of Lean Manufacturing to Increase the Productivity of a Peruvian Textile SME

Santiago Andrés Zegarra Rosell, Sebastian
Career of Industrial Engineering
Faculty of Engineering and Architecture
University of Lima
Lima-Perú
20183470@aloe.ulima.edu.pe

Sebastian Dario Ramos Tenorio
Student
Career of Industrial Engineering
University of Lima
Lima, Perú
20183129@aloe.ulima.edu.pe

Abstract

Textile MSEs in Peru play a leading role in business fabrics. However, small and medium-sized companies are facing different problems. Since they do not have the same purchasing power as large companies, it is difficult for them to implement advanced technologies or expensive machines that help reduce waste and improve production times, which leads to a decrease in productivity. The research has a mixed approach and a sequential design with a qualitative priority. It consists of two phases: in the first phase, qualitative tools will be applied to know and describe 100% of the problem to be addressed, and in the second phase, quantitative tools will be applied. The first tool to be used will be the Value Stream Map, which is used to know the current situation of the company and the future situation after implementation. It will be used to diagnose the company's problems and to model the solution. The second methodology to be implemented was the 5S, which follows a five-step process aimed at the correct division of resources, creation of culture and formation of discipline. The main objective of the research was to increase the productivity of the MSE, this was fulfilled by the application of the VSM and 5S tools, and the proposed improvements, reducing cycle times by 28.47% and shrinkage percentages by 18.43%.

Keywords
Lean Manufacturing, Productivity, MSE, Lean Manufacturing, Value Stream Map.

1. Introduction
The Peruvian textile industry faces various challenges that hinder its productivity, particularly within small and medium-sized enterprises (SMEs). Due to their limited purchasing power compared to larger companies, SMEs often struggle to implement advanced technologies or expensive machinery that could help reduce waste and improve production times, ultimately affecting their overall efficiency. This issue is prevalent across the industry, manifesting in low-quality production, disorganized labor and machinery, inefficient processes, and poorly defined maintenance routines, among others (Mahmood, 2020).

Considering these challenges, this research seeks to explore alternatives that do not require large financial investments but still deliver significant improvements within the organization. One such solution is the implementation of Lean Manufacturing tools, which are designed to eliminate waste and non-value-added activities in manufacturing processes (Kalyar et al., 2019). These tools, including VSM and 5S, have shown positive results in various industries, and this study aims to replicate those results in the Peruvian textile sector, focusing specifically on SMEs. The objective is to enhance productivity, reduce operational inefficiencies, and increase competitiveness through the adoption of these cost-effective methods.

Recent data underscore the importance of addressing these challenges. The textile and garment industry in Peru accounts for 7.9% of the manufacturing GDP and 1.4% of the national GDP, employing over 422,000 workers (Zamora-Gonzales et al., 2021). However, without addressing the internal inefficiencies, such as disorganized production flows and delays, Peruvian SMEs risk falling behind in a competitive global market where technological advancements and cost reductions have become standard practices (Zamora-Gonzales et al., 2021; Kalyar et al., 2019).

This research employs a case study methodology to examine the effectiveness of Lean Manufacturing in improving productivity within a Peruvian textile SME. Using a combination of qualitative and quantitative data, the study assesses the application of VSM and 5S in reducing waste and improving production times without the need for significant capital investment. Ultimately, the study demonstrates that the systematic application of Lean principles can bring measurable improvements to SMEs in the textile industry, contributing to increased competitiveness and productivity.

Despite the existing studies on the implementation of Lean Manufacturing tools in our country, there is a lack of articles specifically addressing the application of these tools in Peruvian textile SMEs. While gathering sources, we found very few documents focusing on increasing productivity in SMEs using Lean Manufacturing tools, likely due to the specificity of the topic and its limited application within the textile industry in Peru. Therefore, the research question guiding this study is: Is the implementation of Lean Manufacturing tools, such as VSM and 5S, feasible for increasing productivity in textile SMEs in Peru?

The primary objective of this research is to propose an efficient work model through the implementation of Lean Manufacturing tools (VSM and 5S) to enhance productivity in the textile industry. To achieve this, the research will focus on diagnosing and improving key performance indicators such as waste, defects, productivity, and production costs by applying VSM and 5S tools and identify critical stages of the production process that lead to delays in textile production within SMEs.

2. Literature Review

The Peruvian textile industry is a significant part of the national economy, contributing approximately 7.9% to the manufacturing GDP and 1.4% to the national GDP, with over 422,000 workers employed in the sector (Zamora-Gonzales et al., 2021). However, small and medium-sized enterprises (SMEs) within this sector face numerous challenges that hinder their productivity, such as limited purchasing power, inefficient production flows, and lack of standardization in operations. These SMEs struggle to invest in advanced technologies or costly machinery, which limits their ability to reduce waste and improve production efficiency (Mahmood, 2020).

The implementation of Lean Manufacturing tools like VSM (Value Stream Mapping) and 5S presents a cost-effective solution to address these challenges. These tools have been widely applied in other industries globally, leading to significant improvements in operational efficiency, waste reduction, and productivity. Studies by Gallardo Huamaní & Rau Álvarez (2020) and Cáceres et al. (2018) demonstrate that the adoption of these tools in manufacturing environments can reduce overtime costs, minimize waste, and streamline production processes. For example, the 5S methodology has led to significant improvements in work organization and efficiency, with reductions in waste and cycle time.

In Latin America, similar results have been observed in textile SMEs. Quiroz-Flores et al. (2023) found that implementing Lean tools, including 5S and SMED, improved operational efficiency by 11.01% in a Peruvian textile SME. The study emphasized that these improvements were achieved through optimized machine use and reduced downtime, which contributed to better production capacity without requiring heavy capital investment.

Despite these positive outcomes, there is still a need for deeper empirical analysis to better understand the long-term effects of Lean Manufacturing in Latin American SMEs. Marmolejo et al. (2023) underscore that while VSM and 5S are effective tools, their long-term success relies on continuous monitoring and adaptation to the specific needs of SMEs, particularly in a rapidly changing global market. These findings highlight the importance of customizing Lean tools for local conditions and further validating their effectiveness through case studies and long-term assessments.

This research builds upon these insights by proposing the adoption of Lean Manufacturing tools for Peruvian textile SMEs to enhance their productivity, reduce operational inefficiencies, and boost their competitiveness in the global market. By focusing on cost-effective methods like VSM and 5S, this study aims to demonstrate how SMEs can achieve significant improvements in their production systems without needing substantial capital investment.

3. Methods

The main objective of this research is to analyze the impact of implementing Lean Manufacturing tools, specifically VSM and 5S, on the productivity of a Peruvian textile SME. A mixed-methods approach was employed, combining both qualitative and quantitative data to provide a comprehensive understanding of the effects of these methodologies. The qualitative phase focused on diagnosing current inefficiencies, while the quantitative phase measured the improvements in productivity, waste reduction, and production costs. Key findings indicate that the application of Lean tools resulted in a 15.67% increase in productivity, demonstrating the effectiveness of these methods in small-scale textile production (Gallardo Huamaní & Rau Álvarez, 2020). In the first stage, data will be collected and analyzed through an interview and observation to conduct an initial diagnosis. Then, data will be analyzed through indicators to apply Lean tools (VSM and 5S) and assess the feasibility and validity of the hypothesis.

Additionally, a case study will be conducted on a textile SME using a pretest design. Regarding the type of research, this will be quasi-experimental, as the study subject will not be randomly selected and will focus on identifying the relationship between the independent variable (Lean Manufacturing) and the dependent variable (Production process performance of a textile SME). The scope of this research will be descriptive, as it will detail how, in what aspects, and to what extent the productive processes in the textile sector will improve once the selected Lean Manufacturing tools are applied.

As for the techniques used in the research, first, an interview will be conducted with the production manager using a questionnaire. Then, through non-participative systematic observation, data such as the total time for each process, amount of waste generated, number of defective items, and idle times will be collected. In the case of cycle times and idle times, these will be measured with a stopwatch and recorded in a timetable (Figure 1).

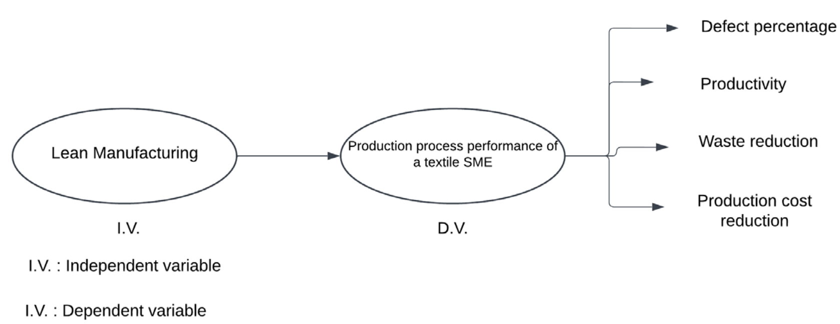

Figure 1. Conceptual Model of Research

Within the population, which consists of Peruvian textile SMEs, a sample has been selected from a hoodie production workshop.

The variables chosen for our study are: "Lean Manufacturing", defined as the independent variable, and the "production process performance of a textile SME", which will be our dependent variable. This dependent variable will be measured through the following dimensions: Waste Reduction, Defect Percentage, Productivity, and Production Cost Reduction. Additionally, with the help of the following indicators, we will be able to verify whether the initially stated research objectives are being met.

$$Mermaids = \frac{Gross\ Weight - Net\ \ Weight}{Gross\ Weight} \times 100$$

$$Defect\ Rate = \frac{Defective\ items\ in\ a\ batch}{Total\ items\ in\ batch} \times 100$$

$$Productivity\ = \frac{Output\ Production}{Production\ Factors\ Used}$$

$$Production\ Costs\ =\ Raw\ Material\ Cost\ +\ Direct\ Labor\ Cost\ +\ Indirect\ Costs$$

The first tool to be used will be the VSM (Value Stream Mapping), which is utilized to understand the current state of the company, as "one cannot begin the improvement process without a clear understanding of where to start, how to act, and what resources are needed" (Rajadell Carreras & Sánchez García, 2010, p.34).

The first step in applying this tool, according to Rajadell and Sánchez (2010), is to select a product from a product family that is involved in the most processes within the production chain. For our research, the chosen product will be a hoodie. The next step is to identify the stages the product will go through from its arrival at the warehouse as raw material until it becomes a final product. To accomplish this, a process flow analysis form will be used to collect all this information.

The next step is to calculate waiting times and create information flows, to ultimately draft the current state map of the company.

Once the current state of the company is understood, the next step is to perform an analysis of the future VSM, which involves information about the processes, the required number of equipment, the number of operators needed, etc. This analysis will be supported by indicators such as Takt time, waiting time, and workload content. Through the current VSM, the current weaknesses of the company are identified, which are potential improvement points, to design a future VSM in which the maximum amount of waste is eliminated, achieving an optimal value chain that aligns with customer needs. Finally, an action plan should be established for the implementation of the future VSM and a monitoring plan to achieve operational excellence, as the goal is continuous improvement.

The second methodology to be implemented will be the 5S. According to authors Rajadell and Sanchez (2010), it follows a five-step process aimed at the correct allocation of resources, culture creation, and discipline formation. This helps to systematize the work in a way that reduces waste, maintains a safe, pleasant, and clean work environment, and organizes work areas. Lastly, it promotes productivity and discipline among workers.

Each of the 5S's has a meaning translated from Japanese as follows: Seiri (Sort), Seiton (Set in Order), Seiso (Shine), Seiketsu (Standardize), and Shitsuke (Sustain).

The first "S" begins with sorting, which aims to eliminate processes, tools, and everything unnecessary, as accumulation leads to increased waste. This can be done by asking, “Is it useful or useless?” This is often done using “red tags,” where all potential checkpoints are listed to assess if they are obsolete or not.

The second "S" relates to organizing all useful items and designating an area so all workers can easily identify them, which helps reduce unnecessary time, quality issues, and more. The goal of this step is to arrange the tools in a visible and accessible way, minimizing complications for workers.

The third step, cleaning, seeks to eliminate all sources of dirt so that, when a tool or object is needed, it’s available. This step improves machine utilization, reduces accidents, increases the lifespan of equipment, and decreases downtime due to maintenance. The goal here is to find and eliminate defects after organizing.

The fourth step, standardization, aims to automate the previous three steps, making them part of the company culture. While the previous steps focused on improving the company’s work areas, this step focuses on keeping things “in order" over time. This will be achieved through continuous quality, organization, and cleanliness checks. A helpful tool here is creating visible guidelines for workers, such as photos of how items should be arranged, standardized documents, operational flow maps, and more (Figure 2).

Figure 2. Example of Image for Standardization

Note. Adapted from *5S: Order, Cleanliness, and Sustainable Habits*, by Rajadell and Sánchez, 2010, (https://www.cemiot.com/inicio/las-9-eses-organizacion-orden-y-limpieza-en-la-empresa/).

The final step, discipline or workplace normalization, aims to instill these practices into employees' behaviors and mindsets. This step isn't measured because the goal is permanent over time. After implementing the 5S tool, the most challenging aspect is maintaining the changes, so the purpose of the last "S" is to build a culture of discipline throughout the company. This will be done through audits, rules and penalties for non-compliance, training sessions, and more.

4. Data Collection

The first step for the correct implementation of improvement is to know the initial situation of the company, currently it is dedicated to the manufacture of clothing such as: T-shirts, Hoodies, Divers, Coats. This textile MSE is of the functional type, since each part of the production process is divided and has an operator in charge. Below are the details of the participation of each of the products in the company's production, which will help us identify the product that it sells the most to monitor it throughout the production process (Table 1).

Table 1. Ranking by percentage of sales

Product	Production	% of sales	Classification
T-shirts	550	28 %	B
Hoodie	800	40 %	To
Divers	400	20 %	B
Coats	250	12 %	C

From Table 2, the hoodies have a higher percentage of sales, so it will be the product to be analyzed. Once the unit to be evaluated is obtained, a graph is made of the operations necessary to obtain the final product.

The process of making a hooded shirt begins with the arrival of supplies at the workshop. The raw material (flannel) is laid out, traced with chalk, and stretched again to begin cutting. Molds of the shirt parts are placed on the flannel layers, which are cut according to the required quantity. After cutting, the assembly begins: the hood and its base are overlocked and basted, followed by the pocket attachment. The kangaroo pocket is glued to the front, and the shoulders are joined to the back and front, followed by attaching the hood and sleeves to the body. The sleeves are closed, and the waistband is attached to the bottom, along with the cuffs. Once the sewing is complete, finishing details are handled, including passing the cord through the neck and finalizing the stitching. Cleaning then follows, cutting excess threads, and quality control checks ensure the garments are flawless. If any issues are found, the process returns to cleaning. Finally, the finished product is moved to the warehouse to be sent to the end customer. The company's working day is 9 hours with 1 hour of break, providing 32,400 seconds/day of availability, operating 22 days per month. The DOP of all parts of the process is shown below (Figure 3).

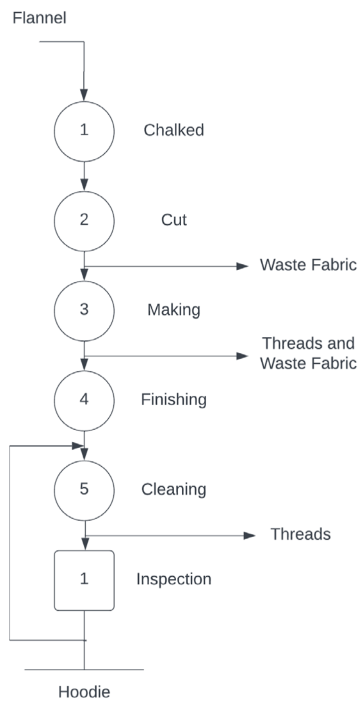

Figure 3. PDO for obtaining shirts

Once the data from the production process was obtained, together with the flow of information from the company (suppliers and customers), the current VSM was diagrammed (Figure 3).

Once each of the operations is known, data is collected to then make the diagram of the current situation of the company, the main data collected by operation are the following:

Table 2. Data collection

Data	Court	Confection	Finishing and Quality Control
Cycle time, CT (sec)	1500	810	85
% shrinkage	14.81%	1.00%	1.00%
% defective	3%	2.63%	2.70%
Available Time, D (sec.)	32400	32400	32400
Number of machines	1	2	1

Through the VSM, the initial diagnosis of the company was carried out, through which we can observe that the area that presents the greatest number of inconveniences is the "cutting" stage, this is due to the fact that high amounts of waste are generated (14.81%), in addition when the visit to the workshop was carried out, it could be seen that this area lacks adequate lighting and that the operator who performs the operation is not fully trained. which gives us an idea of why the cycle time of this operation (1500 sec.) is so high compared to the articles reviewed in the literature (approx. 900 -1000 sec.), it is for these reasons that it has been decided to implement the improvements in the cutting area. (Alanya et al., 2020)

Then, according to the data initially collected, we obtained the following indicators that will help us in the analysis of the current VSM:

$$\boldsymbol{TAKT\ TIME = \frac{Available\ time}{Daily\ demand} = \frac{32400\ seconds}{36\ shirts} = 900\ seconds\ /\ hoodie}$$

$$LEAD\ TIME = AV\ (added\ value) + NAV\ (non\ added\ value)$$
$$LEAD\ TIME = 0.03\ days + 8.59\ days = 8.62\ days$$

$$PRODUCTION\ COSTS\ = Raw\ material\ cost + Direct\ labor\ cost +\ Indirect\ costs$$
$$PRODUCTION\ COSTS\ = 20944 + 2000 + 132 = 23076\ s/./mes$$

$$PRODUCTIVITY\ = \frac{Obtained\ production}{Production\ factors\ used} = \frac{800\ shirts}{23076\ s/.} = 0.0347\ \frac{hoodies}{s/.}$$

The first two indicators will allow us to carry out the analysis of the current VSM to later propose the future VSM (once the 5S have been implemented), while the other 2 indicators, together with the % of shrinkage and defective, will give us a basic idea of how the company is currently doing to contrast the results and verify if the indicated objectives and the hypothesis were met at the end of the implementation
With the information observed in the VSM, improvements are made through the implementation of the 5'S methodology.

Once the data from the production process was obtained, together with the flow of information from the company (suppliers and customers), the current VSM was diagrammed (Figure 4).

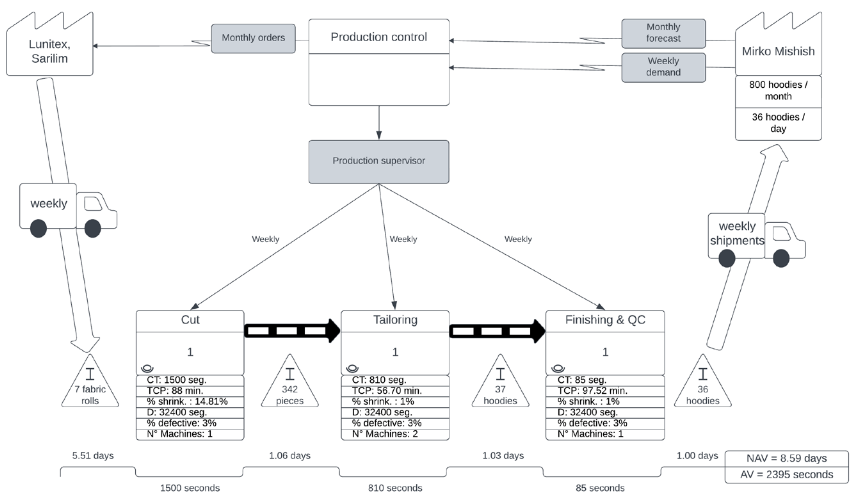

Figure 4. Current Company VSM

5. Results and Discussion

5.1 Proposed Improvements

With the information observed in the actual VSM, improvements are made through the implementation of the 5'S methodology

First S: Sort (Separate)

In this phase, what is sought is to analyze all the areas to find all the elements that are unnecessary. That is why in the following Table 3 a list was made of all the elements that were found in the workshop, in which the division of necessary or unnecessary materials was made.

© IEOM Society International

Table 3. Bill of Materials

Bill of Materials		
Area	Materials Needed	Unnecessary Materials
Court	Chalk	Fabric scraps from old models
	Industrial Scissors	Fabric Scrap Storage Buckets
	1m ruler.	MP Delivery Bags
	Slicer	Notebooks
	Hoodie parts mold by sizes	Food Tapers
	Pencils/ Pen	Boxes
	Trash can	
	Cutting table	
	Repository of previous models	
	Support table	
	Gloves	
	Protective eyewear	
	Flannel Fabric (MP)	
Confection	Serger	Misplaced cones
	Bastera	Shrinkage of fabric and threads on the table
	Thread cones in cone holders	Bags
	Pincers	Paint buckets
	Cutting Hoodie parts	Needle Box
	Working Group	
	Chair	
	Trash can	
	Sewing scissors	
	Thread Cone Holder	
	Tape measure	
Finishing & DC	Sewing scissors	Unnecessary thread cones
	Magnifiers	
	Working Group	
	Chair	
	Tags	
	Brushes	
	Cleaning Equipment	
	Stamping Material	

After identifying the unnecessary materials, they are separated through the "Red Card" format. In which each item is categorized and the reasons why it was categorized as unnecessary material will be placed. Then, all materials and

© IEOM Society International

equipment will be checked by the operators or those in charge of the area to see if these materials should be discarded or stored. The selection process was done twice so that all unnecessary items can be removed correctly and move on to the next part of the process (Table 4, Figure 5).

Table 4. Red Card Format

Red Card Format				
Description				
Quantity			units	
Value	S/ .			
Category	1	Raw material	5	Antique Accessories
	2	Products in Process	6	Stationery
	3	Finished Products	7	Other
	4	Unused equipment		
Reasons	1	Unnecessary		
	2	Faulty		
	3	Obsolete		
	4	Surplus		
	5	Waste		
Disposal	1	Throw away		
	2	Store		
Current date		Date Card		Date of Disposition

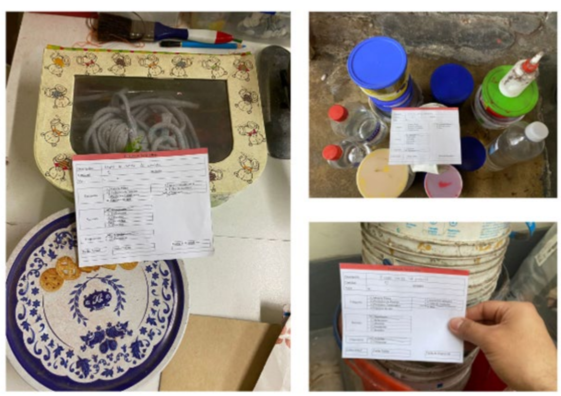

Figure 5. Implementing Red Cards

Below are the materials that received these cards and the number of materials that were discarded and stored. In addition, we will show the number of items that were discarded and stored and their percentage (Table 5).

Table 5. Number of items discarded and stored

Disposal	
Throw away	52%
Store	48%

Second S: Set in Order (Situate)
After storing and disposing of the unnecessary materials, continue with the next S. For this step, the cutting area has been chosen as the unit of work. In this part, the instruments will be relocated to the different workstations according to their functionality. In addition, other tools will be used to help organize the materials.

A 40kg container was used to store the fabrics, so there will be easy access to it, the other container was used to store the printing materials, since the company does not currently perform this service. On the other hand, all the materials for the tracing such as the ruler, pencils, brushes, screwdrivers, among others, were stored in an organizer. Finally, the messy molds were hung on a metal coat rack according to the established sizes: S, M, L. The cutting area is shown below in its initial situation (Figure 6) and after implementing the second S (Figure 7).

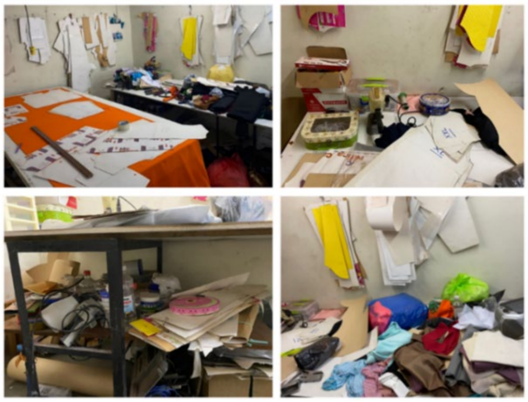

Figure 6. Initial situation of the cutting area

Figure 7. Current situation (including improvement) of the cutting area

Third S: Shine (Delete)
After placing all the parts and parts of the workshop in place, the next step will continue, cleaning the workshop. This process will begin with the cleaning and disinfection of the walls, worktables (Figure 8) and under them (Figure 9), which was carried out in 3 days from 6:30pm to 9pm.

Figure 8. Top of the artboard before 5'S

Figure 9. Bottom of the artboards before 5'S

After having carried out all this process, larger garbage cans will be placed to store the waste in the work areas. In addition, a schedule was created to delegate cleaning functions to all workers, in which the area and day are specified according to each operator. Cleaning will be carried out at the end of each working day. Finally, on Saturdays, a cleaning staff will carry out the general cleaning of the entire workshop to make it easier and faster for operators to find their work tools (Table 6).

Table 6. Weekly Cleaning Schedule

Work	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
Clear and clean worktables	Hayde	Alonso	Michelle	Sofia	Hayde	Cleaning Service
Sweep floor	Sofia	Hayde	Alonso	Michelle	Sofia	
Throw away the trash	Michelle	Sofia	Hayde	Alonso	Michelle	
Save the tools	Alonso	Michelle	Sofia	Hayde	Alonso	

© IEOM Society International

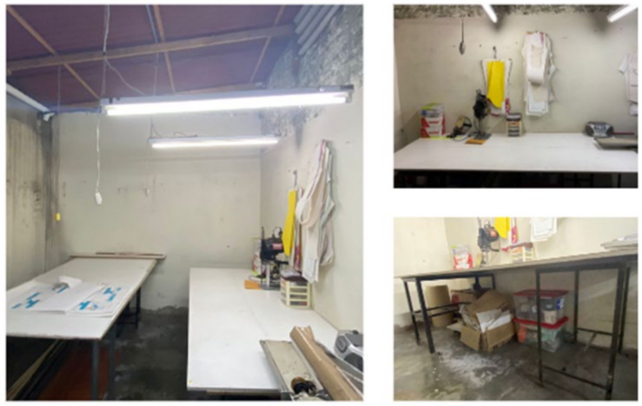

Figure 10. Current situation after implementing the third phase

Two other measures to be carried out will be the creation of a schedule of quarterly quality and cleaning observation visits and the creation of an operator's manual. The first measure implemented will be through an in-depth inspection of all equipment, in which all operators will collaborate to get to know the sources of dirt (FS) and places that are difficult to access for cleaning (LDA). The second measure implemented will be through the creation of instructions for all the company's operators on the correct maintenance and conservation of all machines and tools (Figure 10). This instruction must be brief and concise because complexity can cause operators to lose interest in it. All these improvements must be known by all workshop workers, so the schedule and instructions must be placed in a visible area such as at the entrance of the establishment.

Fourth S: Standardize
Once all the practical steps are completed, the process of raising awareness and creating culture begins. In this part, what is sought is the automation of all the previous steps to reduce delays, dirt and inefficiency. To carry it out, a standardization format will be used for the order and cleaning process of the entire workshop. It will include information about the elements of each area, as well as personnel in charge, time of use and safety elements, if needed. Table 7 below presents the format of the process of standardization of order and cleanliness.

Table 7. Order and Cleaning Standardization Process Format

Order and Cleaning Standardization Process				
Created by	Hayde T.		Area	
Reviewed by	Sebastián Ramos		Date	25/10/2022
Zone	Elements	EPP'S	Person in charge	Time/Frequency
Court	Cutting Machine Scissors	Gloves	Hayde T.	18-20 min.
Armed	Threads Small scissors	There's none	Michelle L.	14-15 min.

In addition, a technical specifications format will begin to be used for each order that is made (Table 8) to have the necessary quantities of material and that there is less residual fabric. This form will be filled out by the client. Below is the table with the specifications of the final product.

Table 8. Garment Request Format by Order

Format by garments						
Garment	Shirt					[redacted]
Model	Standard Hoodies			Date:	25/10/2022	
Description	Hooded shirt with grip on the cuffs and waistband			Colors:		
Cloth	Flannel			Orange	Black	
Composition	Hood, sleeves, waistband, cuff finishes and bottom of the shirt					
Sizes	XS	S	M	L	XL	
Suppliers	Items	Quantity	Quantity per garment		Details	

Fifth S: Sustain
For this last step, two actions will be taken to be implemented, the first will be the motivation of the workers. Annual bilateral talks will be held between all areas of the company in which all improvements will be presented, and feedback time will be given. These activities will require the collaboration of the workshop manager to collect information such as before and after photos, manuals, sales data, recognitions, among others.

On the other hand, the weekly inspection will be carried out during the first two months. A study at the University of London (2009) says that generating a habit takes between 18 and 254 days, with most people commonly achieving it in 66 days. So that period will be taken for the operators to adapt, and the culture is created. After that, random visits will be made over a long period of time. All this will be done through a 5S evaluation format in which it will be graded from 1 to 5 where one is assigned as "Bad" and 5 as "Excellent". The total result of the areas and phases will be considered to analyze the points of improvement over time (Table 9).

Table 9.7 5S Assessment Format

5's Evaluation													
Created for:							Area:						
Reviewed by:							Date:						
5s tool	1	2	3	4	5	6	7	8	9	10	11	12	13
Sort													
Set in order													
Shine													
Standardize													
Sustain													

5.2 Graphical Results
After having implemented the 5'S methodology in the company and the analysis of the initial VSM, we proceeded to diagram the future VSM of the company (Figure 11), of which we can highlight the unification of the "Manufacturing" areas with the "Finishing and Quality Control" and renamed it "Assembly". This change was made because the machines used in these work areas can perform both functions, this is convenient because the transport times and inventories in process between both work areas were eliminated, which in turn decreases the time of non-added value of the product (it went from 8.59 to 6.86 days). In addition, quality control will be carried out constantly during assembly and not only at the end of the operation, which allowed the number of reprocesses to be reduced.

© IEOM Society International

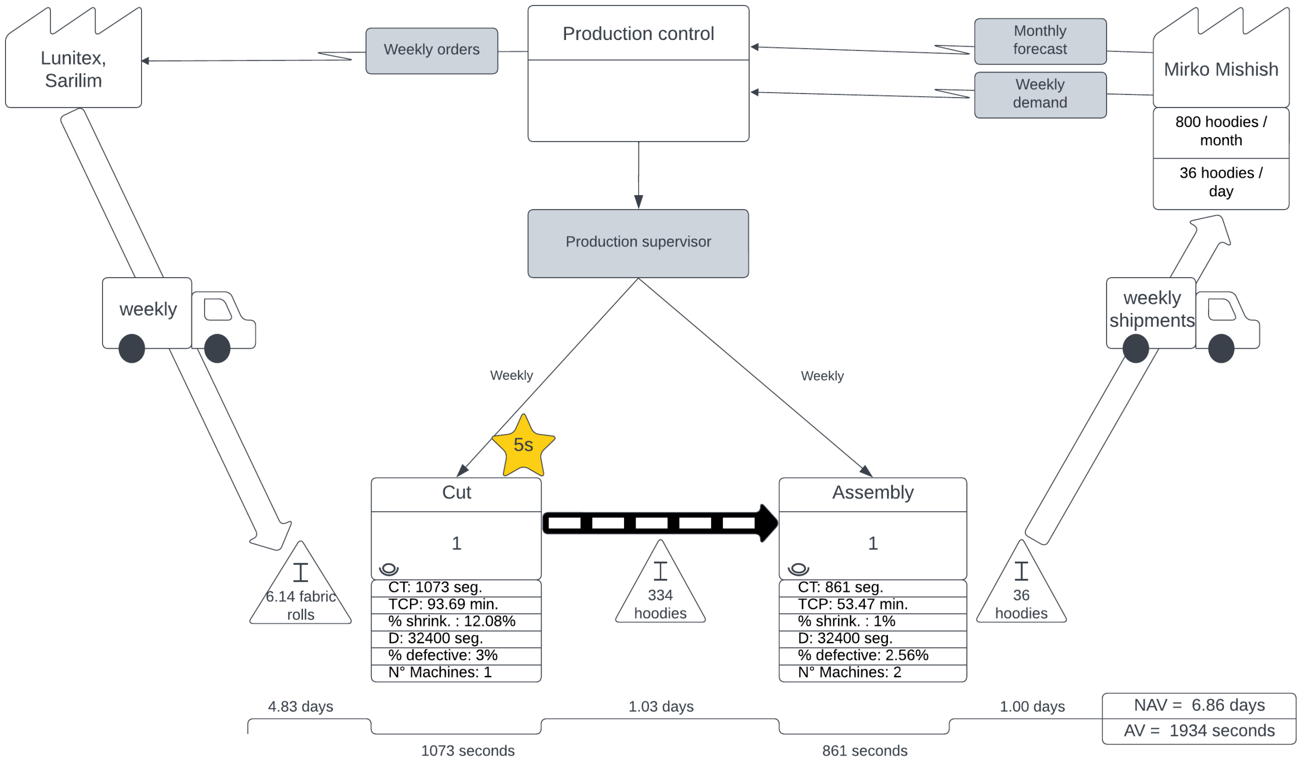

Figure 11. Future VSM of the company

Table 10. Future VSM indicators

Data	Cut	Assembly
Cycle time, CT (sec)	1073	861
% shrinkage	12.08%	1.00%
% defective	3.00%	2.56%

Figure 11 shows the future VSM diagram of the company after the implementation of the 5'S methodology and having made all the improvements with respect to the problems found in the initial VSM. Table 10 shows the main indicators that were evaluated, for which the corresponding implementation was first carried out following the proposed methodology, then the data was collected with the help of a stopwatch that allowed the calculation of the operating times of each of the processes, for which the average of the times taken throughout a week of work was considered. That is, 5 take were considered for this indicator.

Regarding the percentage of losses, it was calculated by dividing the total weight of the losses that came out of the cutting process by the total weight of the fabric that entered, and the third indicator, percentage of defects, was obtained by dividing the number of pieces that had some type of failure by the total number of pieces that were obtained from the process. To determine if a part was defective or not, it was checked manually to see if it had any type of fault.

5.3 Numerical Results

One of the objectives initially set in our research was to identify the stage(s) that caused the greatest delay in production. Thanks to the use of the VSM diagram we were able to observe that this area is the cutting area, so the improvements were focused on this work area. Therefore, once the VSM and 5 S tools were applied, improvements can be seen both in cycle times (it went from 1500 to 1073 seconds) and the percentages of waste (it was reduced from

14.81 % to 12.08 %), this is due to the use of the 5 S and the implementation of the tools provided to the operators, which finally increased the efficiency of the process. Next, the results obtained through the indicators set out in the objectives of the research are observed.

Table 11. 9 Indicators

Indicators	**Initial situation**	**Final situation**
Productivity	0.0347	0.0401
Production costs	S/ 23,076	S/ 19,950

Table 11 shows the main indicator of this research (productivity), which was obtained by calculating the average time it took before implementation and the other after. Like cost, it was calculated with the initial fabric of material that was used for the first production vs. the last.

Production costs were calculated by adding the cost of the raw material related to the production of 800 Hoodie, which is the monthly demand, plus the indirect manufacturing costs (costs of electricity, water) plus the cost of direct labor, which was obtained by multiplying the total cost of labor by 40%. since this is the percentage that the hoodies represent of the total monthly sales of the MSE. Once the total cost of production was calculated, the productivity was carried out, since it is calculated by dividing the monthly production obtained (800 hoodies) by the factors of production used for the manufacture of that demand, in this case this factor was measured in monetary units, that is, the cost of production, with which the monthly demand was divided by the costs of production and in this way the final productivity.

As can be seen in Table 11, at the beginning of the research there was a productivity of 0.0347, after including the improvements of the 5S, there was an increase of 15.67 %, thus standing at 0.0401. This translates into the fulfillment of our main objective, which was to increase the productivity of MSE´s.

Finally, production costs were reduced due to the reduction in the number of materials needed for production, for example, the percentages of shrinkage in the cutting area decreased from 14.81% to 12.08%, which allowed a more efficient use of the fabric and thus saved on costs. Another factor that influenced the reduction of production costs is the labor in the finishing and quality control area, since when it comes to unifying this with the clothing area, the operator in charge of this area could be dispensed with.

5.4 Validation

The results obtained and the veracity of our hypothesis can be supported with information from different research, which state that the VSM and 5S methodology, when applied, seek to improve efficiency in any area of the process of a good or service, whether in the productive sector or another. This was seen in this research, since when these tools were applied in the cutting process, the increase in efficiency was evidenced. This was demonstrated by the decrease in waste percentages and operation times, with cycle times reduced from 20 minutes to 10 minutes. This demonstrates that the impact and veracity of applying Lean tools are significant. Furthermore, it was observed that these tools can be adequately complemented, as both promote structure and order for the improvement of productivity and agility, leading to an optimal value chain. This is confirmed by Benham (2018) in his research on a natural fiber clothing manufacturing company and is demonstrated in this research by achieving an increase in the productivity of the MSE (Mejia Carrera & Rau Alvarez, 2019) through the application of these two tools.

Another key result of this work can be seen through the use of VSM, which enabled the visualization of critical points in the processes and the identification of activities that either add or do not add value in the production chain. In this research, the diagnostic process used value stream mapping to define indicators and key activities, offering an improved outlook to carry out the PDO. This also allowed for associating the impact of these activities with waste in the production process. On the other hand, Gallardo and Rau (2020) agree that order and harmony in the workplace have a positive impact on productivity and improve traffic and space in work areas.

This research also demonstrated that implementing Lean Manufacturing tools provides a competitive advantage in terms of productivity, speed, quality, and order fulfillment. Similarly, Mejía and Rau (2019) mention that through practical implementation, it was possible to improve the standard, reducing results by half over the years. This suggests that the results become more evident in the long term, as they will be measured by the profits and sales the company receives. However, these studies do not all agree on the necessity of using external tools such as SMED. The use of 5S yielded favorable results in the production process without the need to add this tool. In the process of creating a culture for workers, the aim was to make the new work system as understandable as possible, which is why only the two tools (VSM and 5S) were used.

Through this research work, it was possible to verify the hypothesis raised, since after the implementation of the 5S methodology and VSM, there was an increase in productivity of 15.67%. This is due to the reduction of downtime caused by dirt, equipment and/or unprepared materials, disorder, etc. Similarly, the work of Ruiz et al. (2019) found that one of the main factors influencing delays and low productivity is the inadequate management of waste generated and the lack of a standardized system.

6. Conclusions

- The feasibility of Lean Manufacturing was validated, showing that significant efficiency improvements can be achieved without large capital investments. However, to sustain success, SMEs should consider expanding their Lean practices to include more advanced tools like TPM and Kaizen, along with proper employee training to maximize implementation.
- Continuous monitoring and data analysis were identified as critical for maintaining Lean improvements over the long term. By implementing KPIs to regularly track performance in productivity, waste, and cycle times, SMEs can adapt their Lean strategies as necessary. This ongoing evaluation ensures that the benefits of Lean are maintained in dynamic market conditions.
- VSM and 5S were highly effective in reducing waste, improving production times, and increasing productivity by 14%, while reducing operational costs by 3,000 soles. To sustain these improvements, continuous training and regular process evaluations are recommended to embed Lean practices into the company’s culture.
- The diagnostic phase and VSM implementation identified key areas for improvement, such as bottlenecks in the cutting and sewing stages, leading to reduced waste, defects, and higher productivity. To further maximize the impact, SMEs should use VSM alongside other Lean tools like 5S for comprehensive process optimization.
- Lean Manufacturing tools positively impacted both economic outcomes, such as productivity and cost reduction, and fostered a culture of continuous improvement. The hypothesis was confirmed, but future studies should explore broader applications across multiple SMEs to validate long-term sustainability.
- The success of Lean Manufacturing tools, such as VSM and 5S, depends on their adaptation to the specific needs and limitations of each SME. While these tools have proven effective in general, the study suggests that customization of Lean strategies, tailored to the size, resources, and operational constraints of the SME, is essential for maximizing results and ensuring long-term sustainability.

References

Alanya, B. S., Dextre, K. E., Nunez, V. H., Marcelo, G. E., & Alvarez, J. C. Improving the cutting process through lean manufacturing in a Peruvian textile SME, IEEE International Conference on Industrial Engineering and Engineering Management, vol. 2020-Decem, pp. 1117–1121, 2020, https://doi.org/10.1109/IEEM45057.2020.9309992.

Arteaga Sarmiento, W. J., Villamil Sandoval, D. C., & González, A. J. Caracterización de los procesos productivos de las pymes textileras de Cundinamarca, Revista Logos, Ciencia & Tecnología, vol. 11, no. 2, 2019, https://doi.org/10.22335/RLCT.V11I2.839.

Behnam, D., Ayough, A., & Mirghaderi, S. H. Value stream mapping approach and analytical network process to identify and prioritize production system’s Mudas (case study: natural fibre clothing manufacturing company), Journal of the Textile Institute, vol. 109, no. 1, pp. 64–72, 2018, https://doi.org/10.1080/00405000.2017.1322737.

Carlos, L. H. J., & Polo, J. E. R. Improvement in the sportswear manufacturing process using lean manufacturing tools and mathematical optimization | Mejora en el proceso de confección de ropa deportiva usando herramientas de manufactura esbelta y optimización matemática, Proceedings of the LACCEI International Multi-Conference for Engineering, Education and Technology, vol. 2021-July, 2021, https://doi.org/10.18687/LACCEI2021.1.1.251.

© IEOM Society International

Durand Sotelo, L., Monzon, M., Chavez, P., Dominguez, F., & Raymundo, C. Lean production management model under the change management approach to reduce order fulfillment times for Peruvian textile SMEs, Journal of Physics: Conference Series, vol. 796, no. 1, 2020, https://doi.org/10.1088/1757-899X/796/1/012023.
Gallardo Huamaní, A., & Rau Álvarez, J. Analysis and proposal of improvement of the production process of a company of garments for women garments through the use of Lean Manufacturing tools and an RFID technology system | Análisis y propuesta de mejora del proceso productivo de una empresa de, Proceedings of the LACCEI International Multi-Conference for Engineering, Education and Technology, 2020, https://doi.org/10.18687/LACCEI2020.1.1.121.
Hernández Sampieri, R., & Mendoza Torres, C. P. Metodología de la investigación: las rutas cuantitativa, cualitativa y mixta, Primera edición, McGraw-Hill, 2018, p. 196, http://unisabana22.gsl.com.mx:80/F?func=service&doc_library=CNA01&local_base=CNA01&doc_number=000270929&sequence=000001&line_number=0001&func_code=DB_RECORDS&service_type=MEDIA.
Kalyar, M. N., Shafique, I., & Abid, A. Role of lean manufacturing and environmental management practices in eliciting environmental and financial performance: the contingent effect of institutional pressures, Environmental Science and Pollution Research, vol. 26, no. 24, pp. 24967–24978, 2019, https://doi.org/10.1007/s11356-019-05729-3.
León, G. E., Marulanda, N., & González, H. H. Factores claves de éxito en la implementación de Lean Manufacturing en algunas empresas con sede en Colombia, Tendencias, vol. 18, no. 1, p. 85, 2017, https://doi.org/10.22267/RTEND.171801.66.
Lista, A. P., Tortorella, G. L., Bouzona, M., Mostafad, S., & Romeroe, D. Lean layout design: a case study applied to the textile industry, Production, vol. 31, 2021, https://doi.org/10.1590/0103-6513.20210090.
Mahmood, A. Smart lean in ring spinning—a case study to improve performance of yarn manufacturing process, Journal of the Textile Institute, 2020, https://doi.org/10.1080/00405000.2020.1724461.
Mejia Carrera, S., & Rau Alvarez, J. Analysis of improvement for the implementation of lean manufacturing tools in the clothing line of a textile company in Lima | Análisis y propuesta de mejora para la implementación de herramientas de manufactura esbelta en la línea de confecciones de una, Proceedings of the LACCEI International Multi-Conference for Engineering, Education and Technology, vol. 2019-July, 2019, https://doi.org/10.18687/LACCEI2019.1.1.236.
Ministerio de la Producción. Industria Textil y confecciones: Estudio de Investigación Sectorial, marzo de 2017, https://demi.produce.gob.pe/images/publicaciones/publie178337159547c39d_11.pdf.
Sahin, R., & Kologlu, A. A Case Study on Reducing Setup Time Using SMED on a Turning Line, Gazi University Journal of Science, vol. 35, no. 1, pp. 60–71, 2022, https://doi.org/10.35378/gujs.735969.
Swarna, N. A., & Sayid Mia, M. A. Productivity improvement of leather products industry in Bangladesh using lean tools: A case study, Leather and Footwear Journal, vol. 18, no. 3, pp. 219–230, 2018, https://doi.org/10.24264/lfj.18.3.7.
Zamora-Gonzales, S., Galvez-Bazalar, J., & Quiroz-Flores, J. A Production Management-Based Lean Manufacturing Model for Removing Waste and Increasing Productivity in the Sewing Area of a Small Textile Company, Smart Innovation, Systems and Technologies, vol. 233, 2021, https://doi.org/10.1007/978-3-030-75680-2_49.

Biographies

Sebastian Dario Ramos Tenorio is a current student of the career of Industrial Engineering at the University of Lima.

Santiago Andrés Zegarra Rosell is a current student of the career of Industrial Engineering at the University of Lima.