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Improvement of the spreading process in a textile company applying SLP, 5S and standardized work

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***Abstract*– The textile and apparel sector in Peru accounted for approximately 1% of the national GDP in 2023, contributing between 4 and 5 billion dollars annually and generating around 400,000 jobs, with the majority of its revenue coming from exports. Given the sector's growth potential, the main objective of this study is to propose an improvement of the spreading area in a Peruvian textile company through the implementation of the 5S methodology, standardized work, and Systematic Layout Planning (SLP). The validation of these methods was based on pilot tests and two simulation models developed using Arena and FlexSim. The results showed an improvement in capacity utilization, achieved through a 40.62% reduction in scheduling errors via standardized work, a 49-second reduction in raw travel time, and a significant improvement in the maintenance area, doubling its 5S methodology indicators. The findings highlight the potential for substantial improvements in operational efficiency, with positive implications for productivity, economic performance, and the competitiveness of the sector.**

***Keywords*-- SLP, textile sector, 5S methodology, standardized work, lean manufacturing.**

I. Introduction

The textile and apparel sector in Peru represents approximately 1% of the GDP. One of the factors driving growth in this sector is exports, which amount to 1.358 billion dollars, due to the quality of the materials used in garment production, such as Pima cotton and wool from native animals (alpaca, vicuña, etc.). These garments, manufactured in Peru, are primarily exported to the United States market, which accounts for 67% of Peru's textile product exports [1].

This article focuses on a textile company that recorded an FOB export value exceeding 9 million USD in 2023 and over 13 million USD in 2022. This success is due in part to its client portfolio, which includes a big clothing chain.

Despite having advanced technology, the company's productivity is not optimal due to various challenges. One of the most significant issues occurs in the spreading area (also called cutting and stretching). The machinery has a capacity equivalent to 76 rolls per day (operating for 8 hours in two four-hour shifts), yet the average daily output is only 31 rolls, resulting in a utilization rate of just 40.79%.

To improve plant utilization, three tools were employed, two of which are from lean manufacturing: 5S, standardized work, and SLP. The first tool was applied in the maintenance area to keep it clean and organized, measured using five indicators: sorting, order, cleanliness, standardization, and discipline. The second tool was used to define processes correctly and ensure worker understanding through manuals and training. The third tool was used to analyze and reorganize the plant layout, thereby improving efficiency.

This document is structured into four sections. The first section presents a literature review, examining the textile sector and the application of lean manufacturing tools in improving other companies. The second section outlines the methodologies and tools used in the improvement proposal. The third section focuses on the validation of the selected tools through simulation and discussion of results. Finally, the fourth section presents conclusions and highlights key takeaways from the proposed improvements.

II. State Of Art

With a clear understanding of the current industry landscape, research was conducted to identify useful tools for addressing industry-wide challenges, including the bottleneck problem identified within the company. Bottlenecks are a common issue in manufacturing, where any part of the production process can limit the system's overall capacity. These bottlenecks can arise due to factors such as outdated or poorly implemented machinery, quality issues, inventory management deficiencies, and more. Identifying and resolving bottlenecks is crucial for improving operational efficiency, reducing costs, and increasing productivity in manufacturing plants [2].

To address these manufacturing industry challenges, lean manufacturing tools emerged as an effective methodology for eliminating waste, optimizing processes, and enhancing operational efficiency. Lean manufacturing aims to maximize customer value while minimizing costs, promoting continuous improvement and the active participation of all organizational levels, from operators to top management, in problem identification and resolution [3]. Among lean manufacturing tools, several are designed to optimize industrial processes. After an extensive review, two tools stood out for their effectiveness in the required context: 5S and standardized work.

Regarding the 5S methodology, it was identified as an efficient tool that had already been implemented in the textile manufacturing industry with positive results in organizing, cleaning, and standardizing order [4]. Implementing this tool in an inefficiently managed area results in time reductions, process optimization, and overall productivity improvement for the company, whether at a large or small scale [5].

As for standardized work, this tool aligned well with the company's needs. However, its implementation was initially based on management's assumption that low productivity stemmed from inadequate employee training. To confirm this, a factor analysis was conducted prior to the implementation of standardized work. Factor analysis was crucial as it has been used in various studies as both an exploratory and confirmatory tool [6]. After this analysis, standardized work was implemented, as it has been successfully applied in manufacturing companies requiring line balancing, achieving its intended goal [7].

Finally, another evident problem in the company was the existence of unnecessary movement, contributing to the bottleneck issue. Research was conducted on different methods for optimal plant layout distribution. As manufacturing industries evolved, so did their layout planning, with advancements such as virtual reality-based plant layouts [8]. However, due to data constraints and experimental limitations, a more traditional method, Systematic Layout Planning (SLP), was chosen. SLP was determined to be an optimal tool due to its long-standing history of successful implementation in manufacturing industries and its proven effectiveness in these settings [9].

III. METHODS

According to an analysis conducted by the National Institute of Statistics and Informatics, the average number of shirts produced per month by textile companies in Peru is 83,944 [10]. While the company under evaluation produces only 50,660.

Additionally, production delays occur due to underutilization of installed capacity, particularly in the stretching area, which is the company's main bottleneck as it operates at less than half of its capacity. Even when operating at maximum capacity, the plant reaches only 40.79% utilization, processing 31 rolls per workday instead of the possible 76 rolls. In contrast, the industry standard is 69.7% [11].

A. *Phase 1: Diagnosis*

Identifying the root causes of the problem is a crucial step, as it helps determine which aspects of the company need improvement to resolve the issue. The root causes of the main problem, which is the low utilization of the cutting and stretching (spreading) machine, were determined. Various reasons were found, such as unnecessary movements, programming errors, and delays in cleaning and maintaining the machine, as shown in Table I.

TABLE I
Frequency of root causes

No	Motives	Frequency	Percentage	Cumulative
1	Unnecessary transportation	64	44%	44%
2	Programming errors	54	37%	81%
3	Delays in cleaning and maintenance of machinery	27	19%	100%

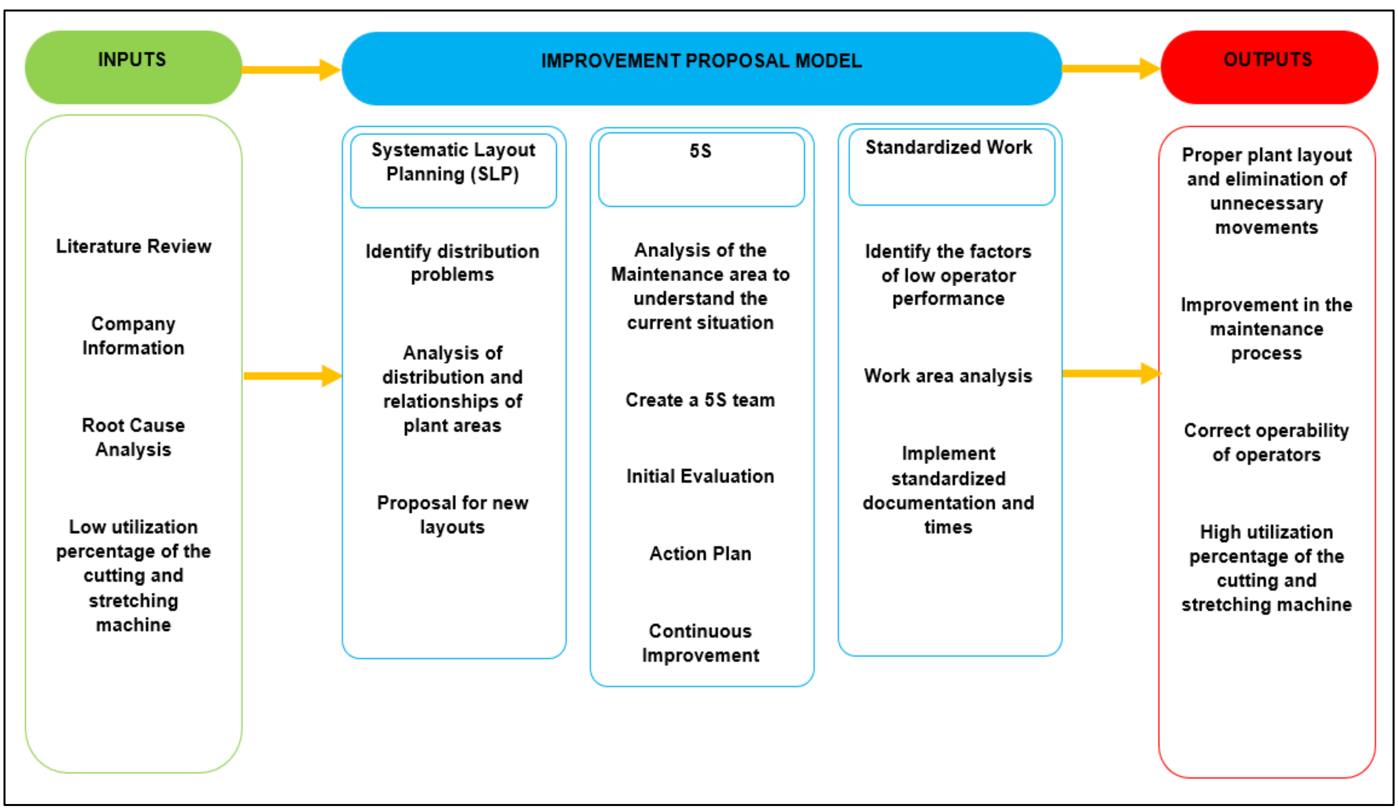

Fig. 1 Macro Design of improvement proposal

With this in mind, we can make a macro design of the improvement proposal, as shown in Fig. 1, based on a tree problems diagram constructed, alongside the root causes as shown in Fig. 2. The tools SLP, standardized work, and 5S are proposed with the aim of increasing the utilization of the cutting and stretching machine.

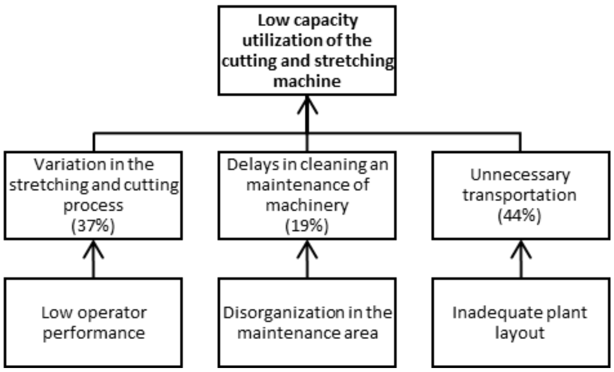

Fig. 2 Problem Tree Diagram.

B. Phase 2: Implementation of Systematic Layout Planning (SLP)

For the application of SLP, a relational table was created where, in Fig. 3, the importance of each activity with the others can be seen. Then, a relational diagram was made to visualize it graphically in Fig. 4.

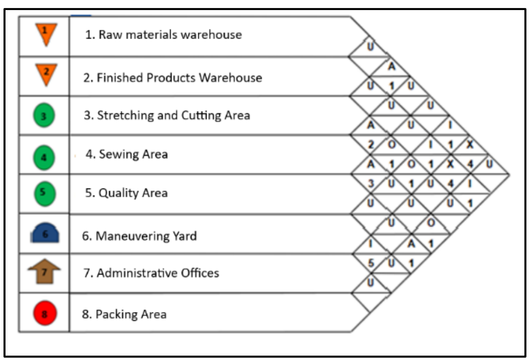

Fig. 3 Relational Table

A	X	I	O
1 3	1 7	6 7	3 6
3 4	2 7		3 5
4 5			4 8
5 8			
1 6			
2 6			

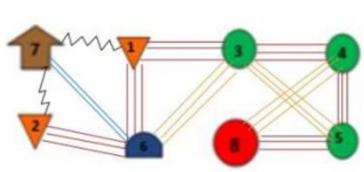

Fig. 4 Relational Diagram

With this information, we can notice that the raw materials warehouse is very far from the cutting and stretching area, and since these are the first two areas where the processes take place, it is necessary for them to be closer together. Given this situation, an evaluation was made, and a new layout of the company was created, considering the same measurements, as it is a plot that cannot be modified. This can be seen in Fig. 5.

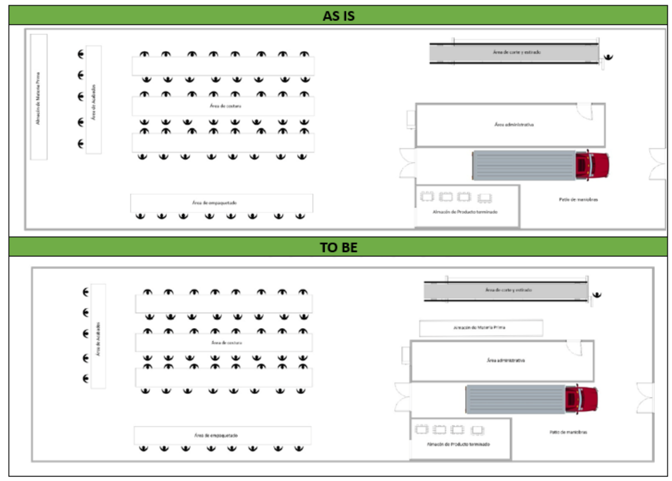

Fig. 5 Layout of the company

C. Phase 3: Implementation of 5S

The first step to apply 5S was to conduct an internal audit to understand the current situation of the company. In this case, the indicators obtained were very low, all being below 50%, as shown in Fig. 6.

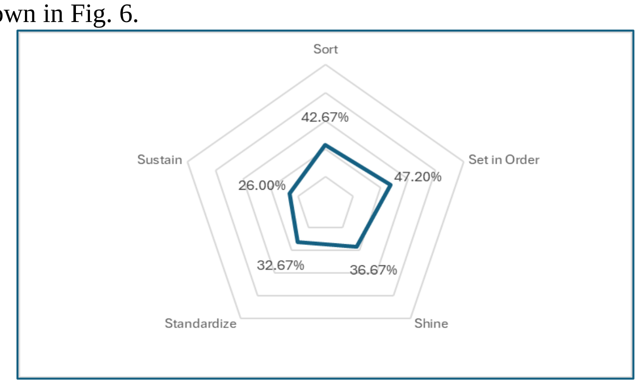

Fig 6. 5S Audit results

Once the current context was known, the red tag strategy was applied to eliminate certain elements and materials that did not belong to the maintenance area. The company stored certain chemicals under the tool area, near power points, which posed a health and flammability risk. These elements were classified and moved to a separate and properly marked area to take the necessary precautions.

Once the elements that did not belong to the maintenance area were removed, the tools were organized and labeled on a panel for easy access, as shown in Fig 7.

Fig 7. Tools organized and labeled

Cleaning routines were also implemented with a schedule where the 5 members of the staff who oversee this area committed to cleaning the maintenance area at the end of the day.

Finally, for the last 2S (standardize and sustain), training sessions were held for the staff explaining what 5S is and how it works. Once the 5S were applied, an audit was conducted according to our sample size to review how these 5S are maintained and to know the previously measured indices. To obtain the representative sample for the case study, the average number of rolls used monthly by the company was selected, this being our unit of analysis. Knowing that each roll yields 100 garments and that 50,660 garments are manufactured monthly according to 2023 data, it is obtained that N=507. To calculate the sample size, it is necessary to use the finite population formula. The values being, "N" equal to 507, "Z" equal to 1.96, "p" and "d" equal to 0.05, and "q" equal to 0.95. Applying the formula, a sample size of 63.91 rolls of fabric is obtained, and rounding to the nearest whole number, we get that the necessary sample size is n = 64. Therefore, 64 uses of the fabric roll will be selected to sample the models.

D. *Phase 4: Implementation of Standardized Work*

For this tool, standardized documentation was implemented, where operators were primarily taught about fabric density and its stretch percentage. These are two important data points that must be entered into the machinery, and if entered correctly, the number of programming errors will be reduced. Once the correct process and information were established for the operators, a second time study was conducted, the first was before the implementation to understand how processes improve after this implementation. With these times, a standard time for programming and the frequency of errors in this activity were established. According to the first-time study, only 15.63% of the time the programming was correct, but after applying the standardized documentation, it reached 56.25% (36 out of 64 rolls were correct).

The standard time was first calculated by obtaining the average time it takes to perform this task, which turned out to be 13.25 seconds. Additionally, a 95% confidence level and a 5% relative error were considered. For allowances, all workers on the machinery are men, so it would be 9% constant allowances (5% for personal needs and 4% for basic fatigue) and an additional 2% for standing work. With this data, the standard time was found to be 13.92 seconds.

IV. Validation and Discussions

A. *Methodology of Validation*

The validation method for the proposed model was separated depending on the tools. First, for SLP, the Flex Sim software was used. A simulation of the process of picking up the fabrics and taking them to the cutting and stretching machine was carried out before and after the layout modification, as seen in Fig. 8.

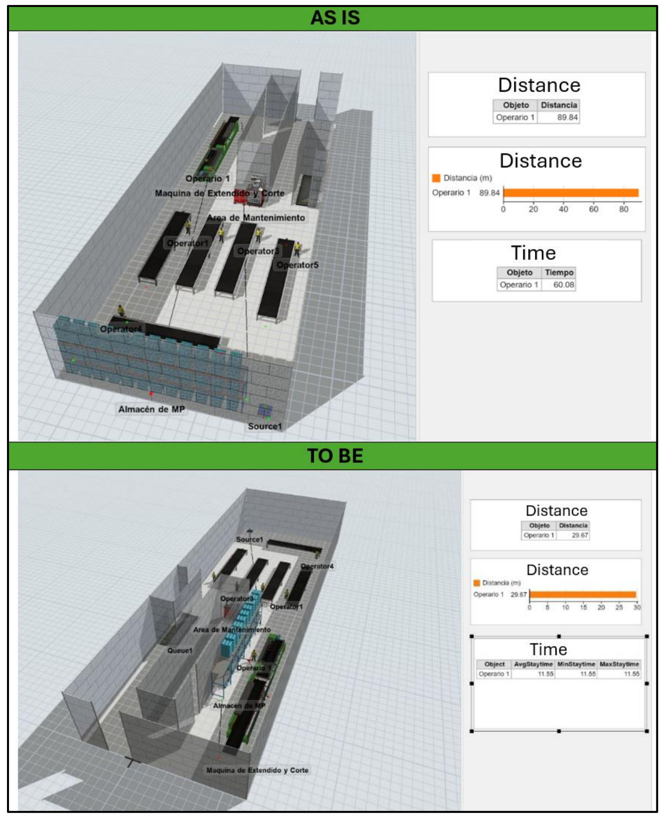

Fig 8. Flex Sim Simulation

One of the main indicators measured when implementing the SLP tool was the distance traveled. The goal was 30m, which was achieved by relocating the raw materials warehouse. Additionally, thanks to the Flex Sim simulation, it was possible to calculate the time it takes for the operator to bring the rolls in the new and old plant layouts, which are 11.55 and 60.06 seconds respectively.

On the other hand, for 5S, it was validated through a second audit, where the changes in those indicators compared to the beginning can be seen, as shown in Fig. 9.

Additionally, thanks to the simulation conducted in Arena, it was possible to calculate how the time varies due to time study. Before the improvement, the time was between unif(6;7.65) and after the improvement, it was unif(4.5; 5).

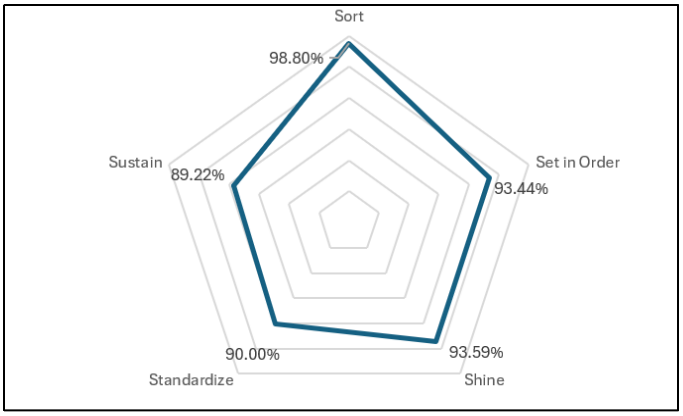

Fig 9. Audit results after 5S implementation

Finally, for the standardized work, a simulation was conducted in Arena, which allowed us to see the complete improvement model, including the times obtained in the SLP and 5S improvements. To observe the improvement, two simulations were conducted, one before the improvement and one after; however, the changes were within the time settings, not the process, as the process was correct, as shown in Fig. 10. In Table II, a table with all the KPI´s and improvements made is presented.

TABLE II
KPI´s and improvements

KPI	AS IS	TO BE	EXPECTED
Distance traveled	90 m	29.67 m	30 m
Time traveled	60.08 s	11.55 s	12 s
Sort	42.67%	98.80%	75.00%
Set in Order	47.20%	93.44%	75.00%
Shine	36.67%	93.59%	75.00%
Standardize	32.67%	90.00%	75.00%
Sustain	26.00%	89.22%	75.00%
Maintenance time	unif(6;7.65)	unif(4.5; 5).	< 6 min
Programming time	unif(17.5, 22.5)	13.92 s	<15 s
Programming errors	0.8437	0.4375	0.5
Rolls per day	31 rolls	35 rolls	53 rolls
Utilization of installed capacity	0.4079	0.4605	0.697
Time between rolls	939 – 959 s	776 – 787 s	< 800 s

B. *Discussion*

The results show a positive trend in several key indicators. Distance and time traveled have improved significantly, surpassing the established goals, confirming the effectiveness of the Systematic Layout Planning (SLP), aligning with findings reported at the state of art, where SLP is recognized for its ability to streamline material flow and minimize unnecessary movement.

The classification, order, cleanliness, standardization, and discipline indices have also recorded notable increases, making the 5S improvement effective, similarly to the SLP, these outcomes reinforce the view that a more organized work environment, enhances efficiency and minimizes time lost.

In terms of standardized work, maintenance time and programming time have decreased, meeting the proposed objectives. This reinforces that standardization not only reduces errors and helps sustain consistent performance but also supports continuous improvement. However, although the programming error index still does not meet the established target, it showed a very good reduction of 40.62%, representing a significant improvement. The daily roll production has also improved but remains below the target, as does the utilization of installed capacity. Although utilization has increased, it still requires attention to approach the goal. According to the literature review, it was known that the sector could reach a utilization rate of 69.07%, but in this case, only 46.05% was achieved (4 more rolls per day), highlighting a significant gap that needs to be addressed.

In summary, all indicators have improved, but continuous monitoring is necessary to achieve the objectives and match the sector, validating the implementation and exemplifying how these lean manufacturing tools and be adapted to specific and limited conditions.

Despite the positive results obtained, there are certain limitations within the Peruvian textile sector. The 99.5% of the companies are small and medium-sized enterprises (SMEs) [12]. This means that most of them still rely on manual processes and are unable to allocate even minimal resources to improvement projects, due to tight economic and operational margins. Additionally, the informality rate in the Peruvian labor market reached 71.2% during the period from April 2023 to March 2024 [13].

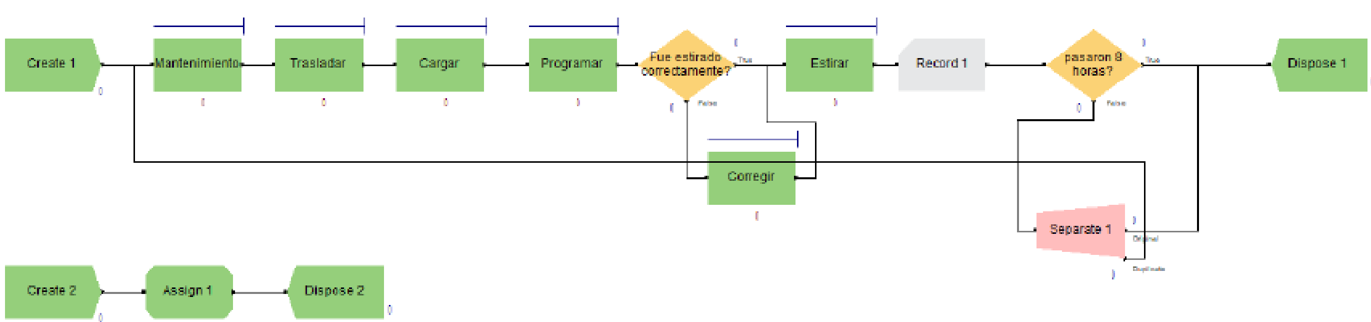

Fig. 10 Arena Simulation

This high level of informality leads to significant employee turnover, which directly impacts the implementation of standardized work and 5S, as both require a stable and committed workforce to be sustainable over time.

C. Economic Impact

An economic cash flow analysis was conducted, and the NPV and IRR were calculated, obtaining S/ 50,239 and 691.53%, respectively. Upon reviewing the indicators, we can see that these values are very high, and this is because the investment is very low (S/ 3,933) and the return is very high, as a great improvement opportunity was found (SLP application) due to a significant reduction in times, leading to an improvement of four additional rolls per day, i.e., 400 more garments produced. This translates to 96,000 garments annually, bringing great benefits, as the company sells everything it produces due to direct contracts with other companies, and sales are total. Additionally, a financial flow was not considered since the investment is very low, and a bank loan is not necessary.

D. Environmental Impact

According to the United Nations, the textile sector generates more carbon emissions than all international flights and maritime shipping combined [14]. By optimizing the plant layout and reducing unproductive time, the company decreases electricity consumption in machinery and internal transport, thereby indirectly reducing associated emissions.

After applying the improvement, we can see a change in waste management, due to a reduction in waste and an improvement in company safety. The implementation of the proposed improvements at work can be considered from different approaches, such as environmental impact mitigation.

The implementation of these tools improves operability and efficiency, reduces resource and energy consumption in the cutting and stretching process. Additionally, by minimizing waste through error rate reduction, the environmental impact generated by waste is reduced.

On the other hand, from the perspective of circular economy and waste recovery, a proposal that can be included is the sale of fabric waste to other companies, as, although they are not suitable for making shirts, they can be used for other products, such as baby clothes, fabric cloths, exhibition samples, etc.

E. Social Impact

The improvement applied in the company generates several social improvements, especially if we relate it to the United Nations (UN) Sustainable Development Goals (SDGs). The first SDG that we can identify as being met is 8, decent work and economic growth, as the implementation of improvements such as Systematic Layout Planning (SLP) and work standardization increases production efficiency, leading to sustainable economic growth. By improving productivity, more employment opportunities can be created, and better working conditions can be guaranteed for workers. Additionally, operators received training, which will improve their skills, favouring professional development. The implementation of 5S improves the organization and safety of the work environment, reducing accidents and improving workers' occupational health. This creates a more dignified and safe work environment, aligned with the principles of decent work.

Additionally, the implementation of 5S also meets SDG 3, health and well-being, as it creates a cleaner and more organized work environment, contributing to the reduction of work stress and improving employee well-being. Moreover, a safer and more orderly environment reduces the risk of accidents, benefiting workers' health. Finally, improvements in the plant and production processes promote technological and organizational innovation, thus fulfilling SDG 9. The optimization of plant layout through SLP done with FlexSim, and simulations to evaluate improvements, create an environment conducive to continuous innovation, which is key to the growth of sustainable industries.

V. Conclusions

The implementation of Standardized Work achieved a reduction in the error rate, representing a substantial improvement in process quality and operational efficiency. This standardization not only systematized tasks but also reduced variability in execution, which is key to ensuring consistency and high quality in production, confirming this way the efficiency of the tool at line balancing in manufacturing companies.

As expected, the application of the 5S methodology reduced machinery maintenance times, as constant organization and cleanliness helped operators to be quicker and more efficient in cleaning after roll changes, further reinforcing the positive outcomes reported in previous implementations of this tool.

The reorganization applied through SLP significantly reduced the time it takes for operators to bring fabric rolls to the machinery. There was a reduction of nearly 50 seconds per roll, facilitating the process and reducing the physical burden on operators.

The use of these three tools resulted in an improvement in plant utilization, as it allowed for the laying of four additional fabric rolls per day, which in turn is an increase in the company's productivity. This outcome aligns with the initial expectations of the implementation, while also demonstrating how lean manufacturing tools can be effectively adapted to the company's particular operational realities.

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