ISBN: 978-628-95207-4-3. ISSN: 2414-6390. Digital Object Identifier: https://dx.doi.org/10.18687/LACCEI2023.1.1.186

Increased Operational efficiency in an SME in the textile industry through a production model based on Lean, TPM, and SLP tools

Yasir Calderón-Ayala, BSc[1], Jeremy Vitor-Sanchez, BSc[1], Juan Carlos Quiroz-Flores, PhD[1], and Alberto Flores-Perez, PhD[1]
[1] Facultad de Ingeniería, Carrera de Ingeniería Industrial, Universidad de Lima, Perú.
20182370@aloe.ulima.edu.pe, 20182071@aloe.ulima.edu.pe, jcquiroz@ulima.edu.pe and aflores@ulima.edu.pe

Abstract– The textile sector is positioned as one of the industries that generate a great economic impact in Peru, in addition to being a generator of many sources of work. However, in recent years there has been a low production efficiency in companies related to downtime by operators and the machines used, high material flow, as well as high set up times. In this way, the aforementioned problems generate that the planned production cannot be fulfilled in the established times, causing new expenses due to a misuse of the available resources. In this sense, this article proposes an integrated model that uses Lean Manufacturing tools, including SMED and 5S, hand in hand with TPM and SLP methodologies to increase the operational efficiency. To verify the effectiveness of the of the proposed model, a pilot plan of 5S was carried out, giving positive results. In the same way, a simulation in Arena Software was done, finally reaching an improvement of 11.01% in the operational efficiency index. The contribution proposed in this study can help and guide other SMEs in the textile industry to counteract many of the main problems that afflict them, that the Lean Manufacturing Tools applied together with SLP and TPM methodologies can optimize process from both views of machines and operators, managing to increase efficiency in its operations and a better use of its available resources.

Keywords—Lean Manufacturing, Systematic Layout Planning, Total Productive Maintenance, Efficiency, Textile Sector.

I. INTRODUCTION

Nowadays, the textile sector worldwide is placed as one of the main industries, since it has a great relevance in the global economy and influence when establishing an international trade treaty or pact [1]. Currently, this industry is one of the most important sources of economic income and generators of work in developing countries. Thus, in the year 2019, China ranked first with 33% share and Bangladesh second place, with 9.7%. For Peru, the textile industry contributes about 2% of the national GDP [2]. In addition, the textile sector as an added value and contribution to the national economy is responsible for the contribution of 400 thousand direct jobs per year, which represents 26.2% of the manufacturing PEA and 2.3% of the PEA at the national level [3].

Digital Object Identifier: (only for full papers, inserted by LACCEI).
ISSN, ISBN: (to be inserted by LACCEI).
DO NOT REMOVE

In an analysis of the textile sector in SME companies, it is agreed that many of the problems encountered are related to low productivity and overall efficiency, due to a disorganization in processes and excessive flow of materials [4]. In the same way, another of the problems found are defective products, as they are one of the wastes with a greater negative impact on quality costs [5].

This is due to the characteristics of SMEs, which do not emphasize the care of the machines, which generates an accelerated wear and tear on them, exhibiting constant failures in the production process. Likewise, the absence of control of the spaces and activities within the production plant, evidence that tasks are incurred that do not add any value, generating that operational efficiency is impacted [6]. A case study was selected that shows the problem due to the high generation of unproductive times due to not having established procedures, machine failures and stops, high preparation times in the process and unnecessary movements, which generate monetary losses equivalent to 29.19% of the annual gross margin of the case study. It is worth mentioning that, in various parts of the world, techniques have been developed for the solution of low efficiency in companies in the textile sector or other areas with similar problems, and usually focus on a single factor, which may be the machine or the operator [7]. However, if you want to optimize a process its necessary to consider an integrated approach that takes a joint view of the two factors, machines and operators. Therefore, in this article, a model is proposed that is constituted by the combination of SLP techniques, TPM and Lean Manufacturing tools focused on solving problems generated due to an incorrect plant layout and misuse of machines and operator resources to improve operational efficiency in the Peruvian textile industry.

In order to analyse the proposal, this academic article has been divided into the following sections: State of the Art, presenting background from approaches of different authors; Contribution, explaining the theoretical basis of the model and describing the proposed model with its respective indicators; Validation, where the results are described before the intervention; simulation of the process and results after the intervention; Discussion; Conclusions and recommendations for future research.

II. State of the Art

A. Model to improve operational efficiency

The main problems within the textile sector during the last five years according to Sukwadi, Felicia and Muafi [8, pp. 327] mention that it has been low productivity, low efficiency index and a high waste rate. In addition, in [4] it is mentioned that many companies have a terrible use of physical space, excessive movement and unnecessary transport within the production plant. Therefore, it is of the utmost importance to solve the problem that most textile microenterprises are going through a model of improving productive efficiency in order to compete in the international market and increase the economy of the sector [7].

B. Lean Manufacturing (5S and SMED)

Lean tools in the manufacturing industry aim to reduce waste and increase the level of customer satisfaction [9] [10]. Studies agree that to reduce waste and optimize production processes, tools such as 5S and SMED are among the most effective [11].

Among the Lean tools, the 5S methodology adopts practices in the workplace focused on ensuring that the environment is kept clean, safe and efficient, which are classification (Seiri), set in order (Seiton), clean and check (Seiso), standardization (Seiketsu) and self-discipline (Shitzuke) [12], involving staff at all stages to support the implementation of improvements as part of the work [13].

In addition, 5S is a Lean Manufacturing methodology that provides a path for the implementation of other tools in organizations [14]. On the other hand, in relation to the high time of configuration changeover time of the machines, the application of the SMED tool is ideal; Changeover time is specified as the period of time between the last correctly produced item of the previous production order that left the equipment and the first good item of the next production batch [15]. This tool is used to reduce preparation and configuration times, which aims to reduce the time lost when performing the activities in the exchange of dies, allowing the elimination of waste and ensuring the availability of machines [16], [17].

C. Total Productive Maintenance (TPM)

Companies in the manufacturing industry continuously present a high percentage of downtime and low product quality, which cause limitations and losses within the production process [18] [19]; in addition, most organizations do not have a deliberate and convincing model to evaluate maintenance policies under uncertainty to cope with real-world conditions. That is why the application of the TPM methodology in the manufacturing industry aims to direct in a structured way the activities that must be carried out to achieve the reduction of unproductive times in the machines and thus improve production standards [20].

According to Xiang and Feng [21] The TPM is multifaceted and is best represented through a house that includes eight pillars of relevant maintenance activities, of which not all are implemented in organizations, they are usually individual, or pillars are selected. In autonomous maintenance they have the capacity, training, and daily responsibility for the maintenance of machines and equipment, increasing their skills to manage improvements [21]. On the other hand, planned maintenance is based on analysis of the actual situation and the establishment of a maintenance plan for the prevention of machine failures, considering inspection places and the frequency of performance [22].

D. Systematic Layout Planning (SLP)

Within the manufacturing industry, a series of very repetitive problems can be observed in the flow of materials, wrong distribution of plant, transit of materials, among others, which added to the unnecessary movement of operators causes productivity and efficiency losses [23]. Over the years, several authors have used plant distribution methods, considering as the most integrated and initial option the Systematic Layout Planning method, which, based on the production flow, performs the location of the workstations [24].

The aim of this tool is to reduce the distances of material transfer between processes [25]. The design of the facility layout involves a systematic physical arrangement of different workstations, machines, and common areas in a manufacturing company. The SLP method is as follows: the first stage is the analysis, that is, the analysis of the flow of materials, the analysis of activities, the considerations of space requirements. The second stage starts from the planning of the room relationship diagrams to the alternative layout designs. While the third stage is the selection process [26].

III. CONTRIBUTION

A. Model Basis

For the realization of the model of improvement of operational efficiency, the different proposals analysed in the literature and works based on waste management models and unproductive times were taken as a guide. These articles detail their models based on components such as those observed in the double-entry table. However, in many of these only a focus is incurred either towards the machine or the operator. Therefore, it seeks to establish an integrated model that allows to deal with operating problems through a global approach of the company, since these affect the operational efficiency of the same and this leads to unnecessary expenses due to a misuse of resources. In this way, all the aforementioned served as the basis for establishing an improvement model and the components that define it, unlike other models applied in the textile sector, the proposed model complements the tools of SLP and TPM with Lean Manufacturing, essentials for the solution of the problem of low operational efficiency of Peruvian SMEs.

TABLE I
COMPARATIVE MATRIX OF PROPOSED COMPONENTS VS STATE OF THE ART

Objective Causes / Scientific Papers	Management of work areas and material flow	Maintenance Management	Waste Management at workstations	Setup time management
S. Ruiz, A. Simón, F. Sotelo, C. Raymundo. [4]	SLP and 5S			
H. Quispe-Roncal, M. Takahashi-Gutierrez, E. Carvallo-Munar, I. Macassi-Jauregui, and L. Cardenas-Rengifo. [7]		SLP and TPM		
J. Cristobal, G. Quispe, F. Dominguez, G. Zapata, and C. Raymundo. [9]			5S	
P. Ribeiro et al. [12]			5S and SMED	
O. Dogan, U. Cebeci, and M. K. Oksuz. [16]				SMED
V. Ames, W. Vásquez, L. Macassi, and C. Raymundo. [17]				5S and SMED
B. Suhardi, E. Juwita, and R. D. Astuti. [25]	SLP			
Proposed Tools	SLP	TPM	5S	SMED

B. Proposed Model

Based on the research and review, an efficiency improvement model is proposed, which combines tools from Lean Manufacturing, Systematic Layout Planning and Total Productive Maintenance. This model seeks to reduce downtime, obstacles, material flow distances, as well as improve the amount produced. All the aforementioned indicators generate a low productive efficiency that triggers the waste of the company's resources. The components in question arise from an analysis of the current situation of SMEs and the search for a solution to the problem of low production efficiency. The model consists of 4 phases that are shown in Figure 1. The inputs and outputs of the process will be detailed in order to understand better the situation of the case study. The inputs of the model are low efficiency, unproductive times, machine shutdowns and an inefficient organization of areas. The results are increased efficiency, reduced downtime, simplified machine shutdowns and route optimization.

C. Model Components

The proposed model is divided into four phases mentioned below

1) Component 1: Focus on the operator

Phase 1: Reorganization of work areas

The SLP methodology incorporates the flow of the distribution materials, organizing the total planning process and establishing a series of phases that allow identifying, assessing and visualizing all the elements involved in the implementation and the relationships between them. For the application of this tool, these steps were followed: PQ-ABC analysis, route

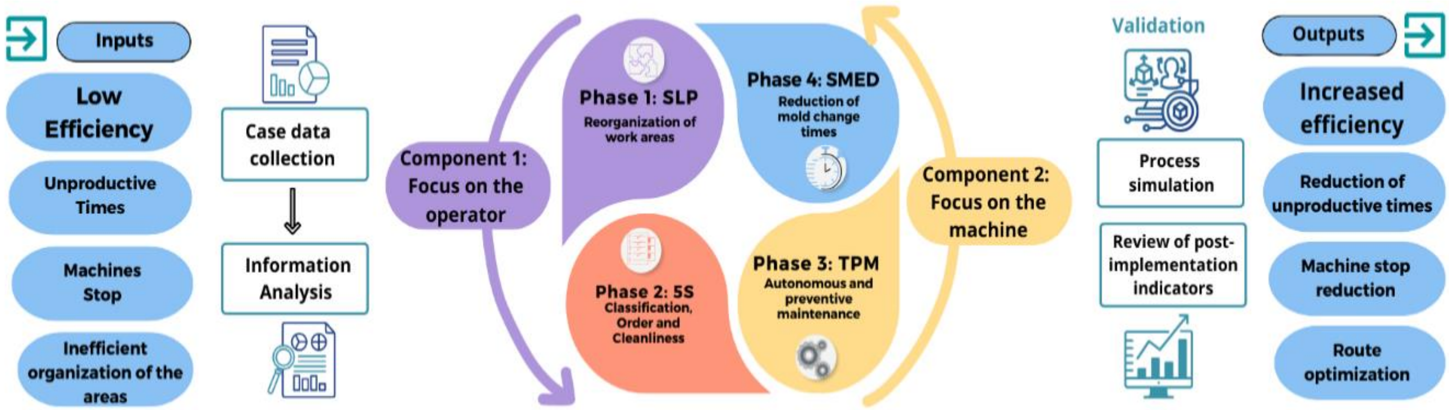

Fig. 1 Main figure of the proposed improvement model

diagram, activity relationship diagram, activity relationship graph and matrix table method.

Phase 2: Classification, Order and Cleanliness

The application of the methodology will be divided into 5 stages, the first stage Seiri (Classify), the necessary elements are separated from the unnecessary ones that are not constantly used; therefore, if the element is considered unnecessary, a red label is placed indicating its separation. The second stage Seiton (Set in Order), is organized according to the frequency of use and labelled for the identification of the location. In the third stage Seiso (Clean and Check), the cleaning conditions of the areas and equipment are verified, and a maintenance plan is made, reviewing compliance through a checklist. The fourth stage Seiketsu (Standardize), ensures that what has been implemented so far is maintained, for this the labels used for the identification of the elements are standardized and directions images are established. Finally, in the fifth stage Shitsuke (Self Discipline), 5S meetings are held periodically and progress made through implementation is evaluated through follow-up audits.

2) Component 2: Focus on the machine

Phase 3: Autonomous and Preventive Maintenance

Firstly, autonomous maintenance will increase the participation of operators in maintenance activities through regular inspections. In addition, a training plan was structured to help staff become aware of their equipment and how it works. Then, the planned maintenance corresponds to the incremental and sustainable improvement of the equipment, in order to achieve the goal of zero breakdowns. This second pillar will be carried out through activities to prevent and correct equipment breakdowns through periodic and predictive routines.

Phase 4: Reduction of mold change times

In the fourth phase, in order to solve the problem of high Setup times, the SMED methodology is applied. In the first stage: Preparation, the correct functioning of the tools and the established location are verified; with respect to the second stage, it separates the internal activities that are carried out with the machine turned off from those external activities carried out with the machine on. Continuing with the next stage, internal activities are outsourced, and finally, activities are optimized by minimizing times.

D. Flowchart of the proposed model

The following is the flowchart of the proposed model shown in figure 2, which details step by step the process from the collection of information to the development of what the implementation of the tools and validation of the results would look like. This begins with the collection of all kinds of information regarding the case study to analyze the information and identify the main problem, the reasons that generate it and its causes, in this way, the current indicators of the case study can be analyzed against the objectives.

In addition, to enrich the case study, the literature and success stories should be reviewed to finally establish the improvement tools to be used. The selected engineering tools were: SLP, 5S, TPM, SMED. After defining the process and how each of the tools would be applied, a pilot program of the 5s tool and a simulation of the rest of the tools of the integrated model are executed. Finally, the indicators obtained are reviewed and evaluated.

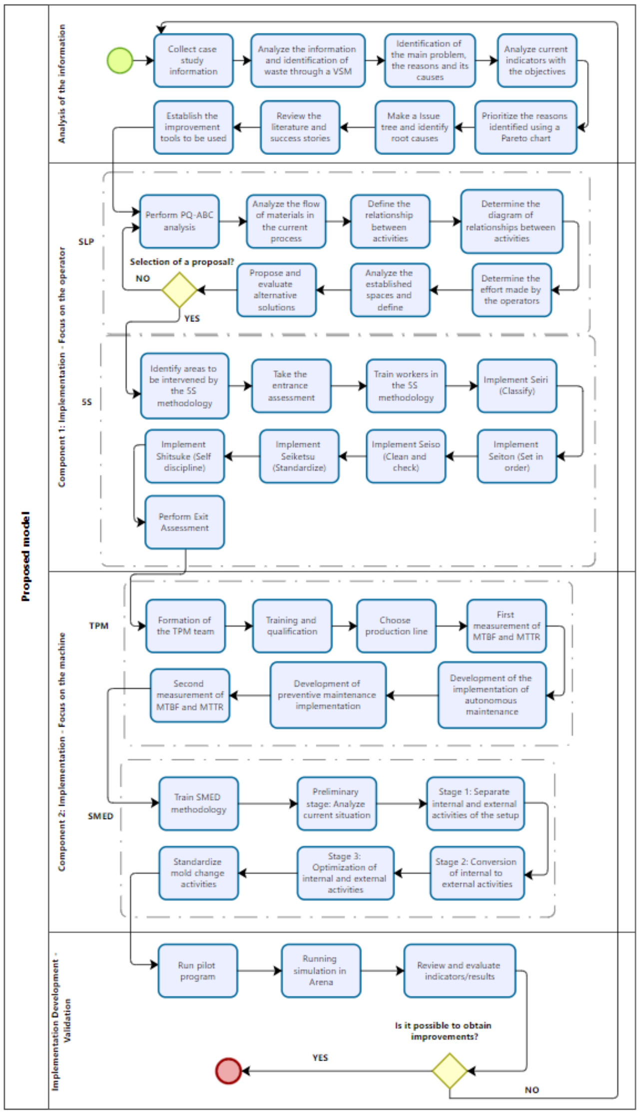

Fig. 2 Flowchart of the model

E. Indicators

The execution process and results will be controlled by proposed indicators, with the aim of evidencing the improvements achieved with the tools proposed in the model.

- Efficiency: This indicator allows to measure the level of execution of the process and the performance of the resources used in it.

$$\text{Efficiency} = \frac{\text{Actual quantity produced}}{\text{Planned quantity}} \text{x100}$$

- Total Time Mold Change (TTMC): This indicator measures the total time in the mold change in the setup of the machines., it is measure using the next formula:

$$\text{TTMC} = \text{Internal Activities Time} + \text{External Activities Time}$$

- Mean Time to Repair (MTTR): It is the actual average time used to machine restoration, this indicator includes times to analyze and diagnose the problem, fix time, etc. This indicator is measured as follows:

$$\text{MTTR} = \frac{\text{Total Maintenance Time}}{\text{Number of Repairs}} \text{x100}$$

- 5S Audit: Measures the level of compliance of the 5S implementation audit in the organization.

$$\text{5S Audit} = \frac{\text{Score Obtained}}{\text{Total Score}} \text{x100}$$

- Distance of Route: This indicator allows to evaluate the variation of the transfer distance for the development of the examined activity.

$$\text{Distance of route} = \frac{\text{Actual Distance} - \text{Proposed Distance}}{\text{Actual Distance}} \text{x100}$$

- Total Transfer Time: The indicator allows to evaluate the variation of the transport time used in the development of activities.

$$\text{Transfer Time} = \frac{\text{Actual Transfer Time} - \text{Proposed Transfer Time}}{\text{Actual Transfer Time}} \text{x100}$$

In the following table, it can be seen the initial values of the indicators selected for the measurement and the improvement objectives to be achieved for each of them.

TABLA II
ACTUAL INDICATORS VS EXPECTATIONS

Indicators	**As Is**	**To be**
Efficiency (%)	69.48%	80.00%
Total Time Mold Change (minutes)	51.47	29.702
Mean Time to Repair (minutes/failure)	121.32	100.99
5S Audit (%)	32%	80%
Distance of Route (meters)	87.25	66.40
Total Transfer Time (hours)	31.17	23.8

IV. VALIDATION

In this paper, validation is carried out in an SME of the textile industry, dedicated to the manufacture of garment products. Among the products of greater production and rentability are the round neck t-shirts and jackets, which represent 74.15% of the quantity produced. For the present study, the production process of round neck t-shirt is selected. The sources of information to evaluate come from there. Previously, a diagnosis has been made and the causes from the main problem has been found, then the techniques to be applied have been defined and finally an integrated model has been proposed, so that it can fill the knowledge gap and reach the objectives of the case of study.

A. Initial Diagnostic

Given the difficulties observed in the selected case study that directly affect the production system, it is defined as the main problem: the current low efficiency that arises. It is worth mentioning that the level of efficiency identified in the case study is at an average of 69. 48%. In a study on the efficiency and productivity of SME companies in the textile sector in [7] it is identified that the efficiency of the sector worldwide is on average 80%. The low efficiency in the case study with respect to the optimal standard generates a considerable economic impact of 92,744 PEN per year, equivalent to 29.19% of the gross margin of the period under study. This loss is due to an inefficient use of labour and machinery resources directly harming profits. In the same way, the causes of the problem of low efficiency were identified as unproductive times, made up of the time used in the change of mold, the time lost due to the failures of the machines and the times used in the search for materials and tools by the operators, as well as transportation and movements between areas.

B. Validation Scenario

To validate the proposed improvement model from the present research, two types of validation will be used, the application of a pilot plan of the 5S methodology and a simulation with the Arena software for the implementation of the SMED, SLP and TPM tools. First, for the development of the pilot plan, the results obtained in the pilot plan correspond to an operation time of two months in execution and analysis. In this way, the effectiveness of the 5S methodology will be verified. In addition, it is proposed to simulate the implementation of SMED, SLP and TPM tools by evaluating the production process of round neck t-shirts; observing the cutting process, followed by the embroidery part, then sewing process, and ending in the finished and bagged process. In this way, it will be possible to study and analyse the progress of the complete process with the improvements executed.

C. Validation Design Improvement

- 5S pilot plan:

For the execution of the first validation through the pilot plan for the 5S methodology. It was applied after carrying out an entry evaluation, which obtained as results that the production areas of the company do not have an adequate level of organization, due to a large number of useless and damaged elements, a lack of classification and there are no defined locations for each of the elements used, which causes the increase in search time.

Fig.3 Sewing area before the pilot plan

Fig.4 Embroidery area before application of 5S methodology

Figures 3 and 4 shows the conditions of the sewing and embroidery production area prior to the implementation of the pilot plan. It shows the disorder and lack of cleanliness that was generated in the areas under study. The floors were full of waste of papers, threads and fabrics resulting from the activities, the cones of the threads were not stored in an orderly and practical way according to colors, slowing down the search for these when it is required to use them, as well as other elements and equipment that were placed in any position, creating an uncomfortable work atmosphere. Based on the above, in the input evaluation a value of 16 out of 50 points was obtained, indicating a level of compliance of 32% of the 5S methodology, which represents a low level.

Figures 5 and 6 shows the implementation of the pilot on the 5S methodology. Red cards were used to classify the necessary elements in each of the areas and identify those that are unnecessary which hinder the work of the operators generating delays and downtime in production. Among these unnecessary elements were identified bags and waste, broken cardboard boxes, containers from other areas, equipment and tools in poor condition, among others. In addition, organizers are placed near the worktables to facilitate access to threads. In the same way, the shelf of the threads cones is organized considering a sequence by colors.

Fig. 5 Pilot 5S fully implemented in Sewing area

Fig. 6 Ordered thread cones and Embroidery area

The results indicated a considerable reduction in the time spent searching for materials and tools, due to the newly established organization. For its part, a cleaning policy was established for each area, in which maintenance corresponds to each of the operators who work in it. In addition, waste containers and cleaning supplies such as broom and dustpan were assigned. On the other hand, to solve the lack of identification of elements and areas, which generates a significant impact on the time of search and transport, standardized signs and management figures were used. in addition, the implementation process continues with the delimitation of areas, tables and machines with the use of reflective tape on the floors. As a result of the implementation, operators will be able to work in a more comfortable, clean and orderly environment.

At the end of the pilot implementation, a 5S output evaluation is carried out, which obtained results that indicated a final compliance on the 5S methodology of 76%. Achieving a significant increase compared to the initial one.

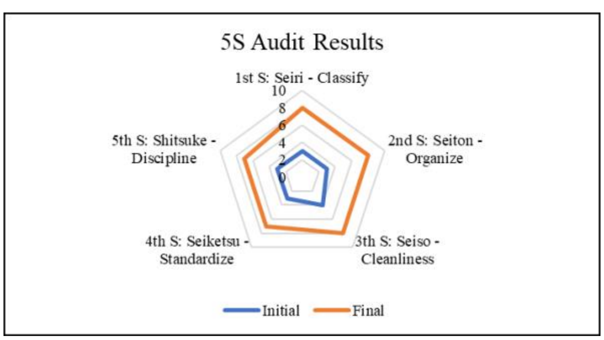

Fig. 7 Results from the output 5S evaluation

- Simulation of improvement proposal:

As a validation tool, a simulation was carried out in the Arena software, to validate the viability of the aforementioned tools in the integrated model, in order to verify the efficiency of their operation.

In this section, the simulation conditions were defined, such as: system scope, variables, sample size, entities, implementation areas, resources, failures, frequencies, as well as the orders involved in the test period analyzed.

The simulation ranges from the arrival of the fabric from the material warehouse that conforms to a normal distribution with an average of 13.6 minutes. This fabric is directed to the cutting area in which for each fabric 4 t-shirts will be obtained, this activity is comprised by a triangular distribution in minutes with a minimum value of 6.47, mode of 9.6 and maximum of 13.45. Likewise, these pieces will be transferred to the embroidery area where prior to entering the embroidery machine the poles must be prepared in racks and grouped into packs of 8. The embroidery time is adjusted to a triangular distribution of 20.3, 21.8 and 24 minutes, when leaving the embroidery machine of 8 heads these must go individually through a cleaning activity in which the threads generated by the machine will be removed. Next, the entities (t-shirts) are taken to the seam process, which is adjusted to a uniform distribution between 7.17 and 12.5 minutes, and then move to the finishing and bagging process that is incurred in a time with triangular distribution in minutes of 0.85, 1.34 and 2.95. It should be noted that, to finalize all the poles are transferred to the finished products warehouse. In figure 8, it is shown the proposed model simulated and configured in Arena Software with the parameters mentioned.

After the aplication of the pilot plan on 5S methodology and the simulation through Arena Simulator, a new measurement of the indicators war carried out. The results are shown in Table III.

TABLE III
INDICATOR RESULTS

Problem/ Cause	Indicator	Initial situation	Improved	Variation
Main Problem	**Low level of operational efficiency**	**69.48%**	**80.49%**	**+11.01%**
Pilot plan on 5s methodology results				
Unproductive downtime of operators	5S Audit	32%	76%	+44%
Arena software simulator results				
Machine stops	Total Time Mold Change	51.47 minutes	24.21 minutes	-52.96%
	Mean Time to Repair	121.32 minutes	100.15 minutes	-17.45%
Plant layout	Distance of route	87.25 meters	53 meters	-32.96%
	Total Transfer time	31.17 hours	17.8 hours	-42.89%

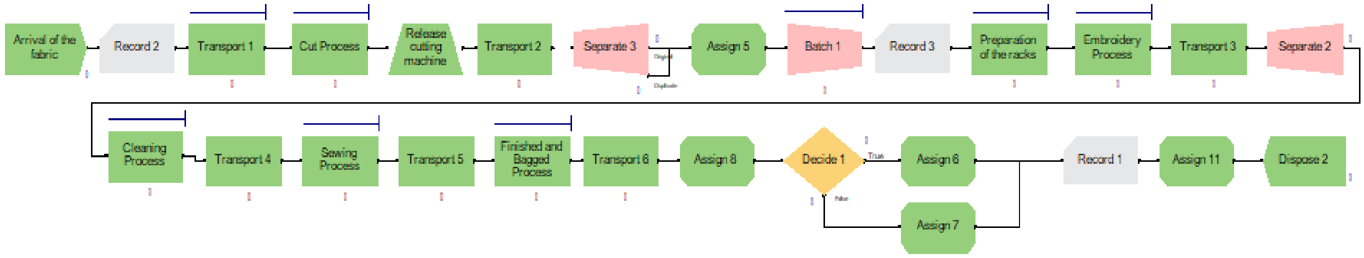

Fig.8 Simulation of the improvement T-Shirt production process

V. DISCUSSION

The proposed model that seeks to increase the operational efficiency of an SME in the textile industry using Lean Manufacturing, SLP and TPM tools can be adapted to other companies that provide a similar service or that are having the same problems previously identified in this research, such as: low productivity, low efficiency index, high setup times, unnecessary movements, machine downtime and unproductive downtime of operators. The results of applying the model are shown in Table III.

As can be seen in the results obtained, the indicator with the greatest variation was the total time of mold change with a variation of 52.96% with respect to the initial scenario, and exceeding by 18.49% those proposed by the authors Ames et al. [17] and in 10.96% from those obtained in Dogan et al.[16], it should be noted that through the SMED tool it was possible to convert as many activities as possible into external, managing to go from 51.47 to 24.21 minutes. Likewise, the 5S audit indicator presented a variation of 44% thanks to the classification of elements, release of areas, creation of cleaning policies and implementation of organizers; however, results showed a value 4% below what was proposed by the authors Cristobal et al. [9], who managed to reach 80% in the final audit of 5s. In addition, with regard to the indicators of SLP, transfer time, it was possible to reduce from 31.17 to 17.8 hours, decreasing by 42.89%, surpassing Suhardi, Juwita and Astuti. [25], who managed to decrease only by 23.64%; distance of route, it was possible to decrease from 87.25 to 53 meters, decreasing by 39.26%, surpassing Suhardi, Juwita and Astuti. [25], who could reduce this indicator by 23.89%. Also, an improvement can be observed in the MTTR indicator, which presents a variation of 17.45% with respect to the initial situation, going from 121.32 to 100.15 minutes, exceeding by 0.83% what was proposed by Quispe-Roncal et al. [7] with a main time to repair of 100.99 minutes. Finally, the operational efficiency indicator exceeded the 80% proposed by the authors Quispe.Roncal et al. [7], with a percentual increment of 11.01% from 69.48% to 80.49%, which was achieved thanks to the proposed integrated model.

VI. CONCLUSION

The application of the proposed model to increase the efficiency of a textile production plant obtained satisfactory results. The research provides a new alternative solution to a problem that afflicts many companies in the sector.

In that sense, related to the operational efficiency identified in the analysis as the main problem, it was possible to reach a final value of 80.49%, validating and solving the causes identified. In the same way, it was possible to significantly reduce the economic impact by 44,477 PEN for the year under study, achieving a 14% improvement in profit for that year, by reducing costs for overtime and downtime of operators.

Furthermore, the reduction in 52.96% of the time spent in the mold change applying SMED and in 17.45% of the repair time by the TPM demonstrated the effectiveness of the application of the engineering techniques in the case of study, by improving availability and the quantity produced in the estimated time.

In addition, movements generated by the workers measured by the distance and the travel time and for which an improvement of 39.26% and 42.89% respectively was obtained. This was obtained thanks to the joint application of the 5S and SLP methodologies, aimed at the operator's work.

This allowed to verify the viability of the proposed model and the high level of complementarity between the engineering methodologies used.

It is also important to mention that the model is designed for SMEs in the textile sector that do not have a high economic power, and that with a small investment a significant profit can be achieved.

REFERENCES

[1] Cámara de Comercio de Lima, "Industria textil peruana cerraría en positivo en 2019", *La Cámara*, 2019. [Online]. Available: https://lacamara.pe/confecciones-peruanas-cerrarian-en-positivo-en-2019/#:~:text=Camisas%3A%20Para%20el%20caso%20de,exportado%20que%20impulsar%C3%A1n%20los%20env%C3%ADos. [Accessed: Apr 18, 2022]

[2] ADEX, "ADEX organizará el XVI foro textil 2020 en el marco de moda de Perú," 2020. [Online]. Available: https://www.adexperu.org.pe/. [Accessed: Apr 19,2022]

[3] Sociedad Nacional de Industrias. "Reporte Sectorial Industria Textil y Confecciones," 2021. [Online]. Available: https://sni.org.pe/27-industria-textil-y-confecciones/. [Accessed: Apr 19, 2022]

[4] S. Ruiz, A. Simón, F. Sotelo, C. Raymundo, "Optimized plant distribution and 5S model that allows SMEs to increase productivity in textiles", in *Proceedings of the LACCEI international Multi-conference for*

Engineering, Education and Technology, 2019, [Online]. Available: http://www.laccei.org/LACCEI2019-MontegoBay/full_papers/FP59.pdf. [Accessed: May 1, 2022]

[5] Y. Andrade, L. Cardenas, G. Viacava, C. Raymundo, and F. Dominguez, “Lean manufacturing model for the reduction of production times and reduction of the returns of defective items in textile industry”, in *Proceedings of the AHFE 2019 International Conference on Human Factors for Apparel and Textile Engineering*, 2019, pp. 387-398. [Online]. Available: https://link.springer.com/chapter/10.1007/978-3-030-20444-0_39. [Accessed: May 1, 2022]

[6] J.C. Quiroz, D.M. Aquino, E.A. Rodriguez, and M.F. Montoya. “Redesign of Workspace Through an Ergo-Lean Model to Reduce Musculoskeletal Disorders in SMEs In the Clothing Accessories Sector”, *International Journal of Engineering Trends and Technology*, vol. 69, no. 12, pp. 163- 174, 2021. https://doi.org/10.14445/22315381/IJETT-V69I12P219.

[7] H. Quispe-Roncal, M. Takahashi-Gutierrez, E. Carvallo-Munar, I. Macassi-Jauregui, and L. Cardenas-Rengifo, “Combined model of SLP and TPM for the improvement of production efficiency in a MYPE of the Peruvian textile sector”, in *Proceedings of the LACCEI international Multi-conference for Engineering, Education and Technology*, 2020, [Online]. Available: http://laccei.org/LACCEI2020-VirtualEdition/full_papers/FP322.pdf. [Accessed: May 2, 2022]

[8] R. Sukwadi, Y. Felicia, and Muafi, “TOC, lean, and six sigma: An integrated model to increase the productivity of the textile industry”, *Journal of Mechanical Engineering Research and Developments.*, vol. 44, no. 1, pp. 327-336, 2021

[9] J. Cristobal, G. Quispe, F. Dominguez, G. Zapata, and C. Raymundo, “Waste Reduction with Lean Manufacturing Model in an Alpaca Wool Workshop”, in *IOP Conference Series: Materials Science and Engineering*, 2020, [Online]. Available: https://iopscience.iop.org/article/10.1088/1757-899X/999/1/012014/pdf. [Accessed: May 6, 2022].2

[10] I. Carranza-Inga, E. Villayzan-Palomino, E. Altamirano and C. Del Carpio, “Improvement Model Based on Four Lean Manufacturing Techniques to Increase Productivity in a Metalworking Company, in *ACM International Conference Proceeding Series*, 2021, [Online]. Available: https://dl.acm.org/doi/pdf/10.1145/3447432.3447442.

[11] N. Barrientos-Ramos, L. Tapia-Cayetano, F. Maradiegue-Tuesta and C. Raymundo, “Lean Manufacturing Model of Waste Reduction Using Standardized Work to Reduce the Defect Rate in Textile MSEs”, in *Proceedings of the 18th LACCEI International Multi-Conference for Engineering, Education, and Technology: Engineering, Integration, And Alliances for A Sustainable Development” “Hemispheric Cooperation for Competitiveness and Prosperity on A Knowledge-Bas*, 2020, Available: http://laccei.org/LACCEI2020-VirtualEdition/full_papers/FP356.pdf

[12] P. Ribeiro *et al.*, “The Impact of the Application of Lean Tools for Improvement of Process in a Plastic Company: a case study”, *Procedia Manufacturing*, vol. 38, pp. 765-775, jun. 2019.

[13] R. Cespede-pino, J. Hurtado-Laguna, I. Macassi-Jauregui, C. Raymundo-Ibañez and F. Dominguez, “LEAN Production Management Model based on Organizational Culture to Improve Cutting Process Efficiency in a Textile and Clothing SME in Peru”, in *IOP Conference Series: Materials Science and Engineering*, *796*(1), 2020, [Online]. Available: https://iopscience.iop.org/article/10.1088/1757-899X/796/1/012004/pdf.

[14] D.V. Kumar, G.M. Mohan and K.M. Mohanasundaram, “Lean tool implementation in the garment industry”, in *Fibres and Textiles in Eastern Europe*, vol 27, no. 2, pp. 19-23, 2019. https://doi.org/10.5604/01.3001.0012.9982

[15] M. Bukhsh *et al.*, “Productivity improvement in textile industry using lean manufacturing practices of 5s & single minute die exchange (Smed)”, in *Proc of the International Conference on Industrial Engineering and Operations Management*, pp. 7374-7385, 2021. [Online]. Available: http://www.ieomsociety.org/singapore2021/papers/1282.pdf. [Accessed: May 5, 2022].

[16] O. Dogan, U. Cebeci, and M. K. Oksuz. “An intelligent decision support system for SMED and its application in textile industry”, in *Proc. of the International Conference on Industrial Engineering and Operations Management, 2018, pp. 933-942.* [Online]. Available: http://www.ieomsociety.org/paris2018/papers/169.pdf. [Accessed: Apr 20, 2022].

[17] V. Ames, W. Vásquez, L. Macassi, and C. Raymundo. “Maintenance management model based on Lean Manufacturing to increase the productivity of a company in the Plastic sector”, in *Proc. of the LACCEI international Multi-conference for Engineering, Education and Technology,* 2019, [Online]. Available: http://laccei.org/LACCEI2019-MontegoBay/full_papers/FP33.pdf. [Accessed:Apr 24,2022].

[18] M. Sayuti, Juliananda, Syarifuddin, and Fatimah, “Analysis of the Overall Equipment Effectiveness (OEE) to Minimize Six Big Losses of Pulp machine: A Case Study in Pulp and Paper Industries”, in *IOP Conference Series: Materials Science and Engineering*, 2019, [Online]. Available: https://iopscience.iop.org/article/10.1088/1757-899X/536/1/012136/pdf. [Accessed: Apr 25, 2022]

[19] S. U. Rehman, M. Asif, and A. A. Zaidi, “Implementation of total productive maintenance methodologies on a textile industry”, *Journal of Advances in Technology and Engineering Research*, vol. 7, no. 2, pp. 27-38, 2021. https://doi.org/10.20474/jater-7.2.2.

[20] J. Reyes, K. Alvarez, A. Martínez, and J. Guamán, “Total Productive Maintenance for the Sewing Process in Footwear”, *Journal of Industrial Engineering and Managemen*., vol. 11, no. 4, pp. 814-822, 2018.

[21] Z.T. Xiang and C. J. Feng, “Implementing Total Productive Maintenance in a Manufacturing Small or Medium-Sized Enterprise”, *Journal of Industrial Engineering and Management*, vol. 14, no. 2, pp. 152-175, 2021. http://dx.doi.org/10.3926/jiem.3286.

[22] J.C. Quiroz-Flores and M.L. Vega-Alvites, «Review lean manufacturing model of production management under the preventive maintenance approach to improve efficiency in plastics industry SMEs: a case study», South African Journal of Industrial Engineering, 2022, https://doi.org/10.7166/33-2-2711.

[23] A. P. Lista, G. L. Tortorella, M. Bouzona, S. Mostafad, and D. Romeroe, “Lean layout design: a case study applied to the textile industry”, *Production*, vol. 31, pp. 1-16, 2021.

[24] Kawakami-Arevalo, S., Veliz-Torres, M. S., Quiroz-Flores, J. C., & Noriega-Aranibar, M. T. (2022). Increased Productivity through a Production Model Based on Lean Manufacturing and SLP Tools in Small Furniture Manufacturing Workshops. In ACM International Conference Proceeding Series (Vol. 1, Issue 1). Association for Computing Machinery. https://doi.org/10.1145/3568834.3568873.

[25] B. Suhardi, E. Juwita, and R. D. Astuti. “Facility layout improvement in sewing department with Systematic Layout planning and ergonomics approach”, *Cogent Engineering*, vol .6, pp. 1-31, 2019. https://doi.org/10.1080/23311916.2019.1597412.

[26] A. T. Haryanto, M. Hisjam, and W. K. Yew, “Redesign of Facilities Layout Using Systematic Layout Planning (SLP) on Manufacturing Company: A Case Study”, in *IOP Conference Series: Materials Science and Engineering*, 2021, [Online]. Available: https://iopscience.iop.org/article/10.1088/1757-899X/1096/1/012026/pdf. [Accessed: May 10, 2022].