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Production model based on Lean Manufacturing and TPM to increase efficiency in a company in the textile sector

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Abstract*– The textile industry has been a participant in a global transformation, where the use of new technologies and tools achieve greater effectiveness within the organization. However, the management of these tools in the MSEs, who represent 99% of textile clothing in Peru are scarce, which reveals the various problems that affect the production efficiency of this sector, where the main problems are waste and production cycle times. That is why the purpose of this paper is to develop an improvement system through Lean Manufacturing tools, such as SMED and Standardized work, and a TPM program, under the PDCA methodology, which increases the productive efficiency of a Peruvian textile company. Likewise, the execution of the improvement proposal will be validated through the Arena simulator software; where positive results were obtained, with an increase in productive efficiency by 42% and a positive economic impact due a reduction of 73.81% for unproductivity and shrinkage. To contribute to scientific knowledge, this study could be used as a methodological basis for future research on the topic in question.

***Keywords*- Lean Manufacturing, Deming cycle, Textile sector, TPM, Productive efficiency**

I. Introduction

Throughout the last decades, the textile sector worldwide has been involved in an unprecedented industrial and digital transformation, because this industry has been facing many challenges, where it is increasingly difficult to compete with the global market. due to strong competition in the business [1]. To address these problems, in the present investigation, waste or failures are highlighted as a point of improvement within the production processes, since these are the main causes of alteration in any production line [2]. Situating ourselves in the textile sector of Peru, where 99.9% of garment manufacturing were identified as MSEs and the rest (0.1%) as large and medium-sized companies [3], there is clearly an improvement and innovation initiative for the application of the good practices of lean manufacturing, since Peru has a notable recognition for its textile quality, which would allow greater ease of access to the international market and with high competitiveness [4]. That is why this sector turns out to be one of the most important in the Peruvian economy, having a performance with a significant impact on the growth of the country: the sector represents approximately 26.2% of the employed manufacturing population (2.3% to national level), close to 7% of industrial GDP, and employs close to 400 thousand people throughout the country. However, national statistical sources indicate that in 2020, the production level index had a drop in its performance of 32.1% [3]. This drop was due to imports of low-value products, as well as the undervaluation and smuggling of the informal sector due to the COVID-19 pandemic [5]. According to the literature, it can be found that the low efficiency present in the studied sector can be caused by inefficiencies such as poor-quality controls, low product quality or disorganized material flow [6], as well as waste of resources, whether expressed in money, time, or goods, which entail invisible cost overruns [4]. The problem appears in other international investigations, for example, in India, unnecessary activities such as the flow of material and the movement of workers reduced the production rate of the machines [7]. Likewise, low efficiency, lack of a defined flow of materials and operator activities, excessive movement of materials, supplies and people were identified; among others, such as problems involved in the production process of a textile company in the country of Rio de Janeiro [8]. In the Spanish-speaking region, non-compliance with orders is identified as the main problem identified in a textile company in Ecuador, with special emphasis on those activities that do not generate value, leading to problems with the efficiency and competitiveness of the company [9]. What has been previously indicated shows that companies in the textile-apparel sector present processes that do not meet the appropriate standards, so it is essential to continue researching and developing new alternatives to solve the problems presented. In this context, it is necessary to give a greater focus to the development and improvement of the national textile sector, for a greater ease of insertion and competitive development, which would benefit both MSEs and large companies.

That is why this research aims to present the problems faced by the textile sector in terms of efficiency in production, which are tied to high leisure times, excessive stops of the machines due to their misuse or by the lack of ideal preventive maintenance; Likewise, these inefficiencies can be caused by the poor quality of the raw material, which generates high amounts of waste within the process, negatively impacting

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production costs. Given the previously described problems, a combined model of improvement tools was developed, which were proposed and developed based on success stories with similar problems, to increase production efficiency. Among the implemented tools we have Total Productive Maintenance (TPM), which will work hand in hand with the SMED tool, through a standardized and systematized work system. To disseminate the proposal presented in this academic article, it has been organized into different sections: the State of the Art, which will provide relevant background information for the problem from different perspectives of previous authors. The Contribution of the investigation where the theoretical foundation of the proposed model will be detailed, as well as a description of the model and indicators. The Validation section will show the results obtained before, during and after the intervention, during the implementation of pilots and simulations, as well as the results after the intervention. Finally, in the Discussion and Conclusions sections, the reflections and recommendations derived from the study carried out will be presented, which may guide future research in this field.

II. STATE OF ART

A. *TPM*

Total Productive Management (TPM) is a continuous improvement methodology that focuses on maximizing the efficiency and effectiveness of equipment and industrial processes, with the aim of achieving zero breakdowns, zero accidents and zero defects in production, as well as positively influencing in the Overall Equipment Efficiency (OEE) of machines or production lines [10]. The effectiveness of the methodology is evidenced in studies where, after its application, it was possible to reduce the total production cycle time by 300 seconds, reduce the number of defective products by 5% [11], as well as increases in the OEE that vary from 11% [12] to 15% [13]. Authors choose to implement autonomous maintenance, one of the pillars of TPM, managing to reduce machine downtime by 20% and an improvement of 15% in the general efficiency of a textile company [14]. Emphasis is also placed on the importance of implementing a robust TPM framework, as productivity can be significantly improved, as well as staff training to sustain the effects of continuous improvement over time [15].

B. *Plant Distribution*

Total Productive Management (TPM) is a continuous improvement methodology that focuses on maximizing the efficiency and effectiveness of equipment and industrial processes, with the aim of achieving zero breakdowns, zero accidents and zero defects in production, as well as positively influencing in the Overall Equipment Efficiency (OEE) of machines or production lines [10]. The effectiveness of the methodology is evidenced in studies where, after its application, it was possible to reduce the total production cycle time by 300 seconds, reduce the number of defective products by 5% [11], as well as increases in the OEE that vary from 11% [12] to 15% [13]. Authors choose to implement autonomous maintenance, one of the pillars of TPM, managing to reduce machine downtime by 20% and an improvement of 15% in the general efficiency of a textile company [14]. Emphasis is also placed on the importance of implementing a robust TPM framework, as productivity can be significantly improved, as well as staff training to sustain the effects of continuous improvement over time [15]

C. *Lean Manufacturing*

The implementation of lean manufacturing tools aims to improve and control the productivity and sustainability of an organization [19], through a reduction or mitigation of waste, understood as anything that does not add value to the organization [20]. In addition, the companies that opt for the implementation of such methodology are large companies, and that the performance depends on the size of the manufacturer [21]. As part of the tools used to achieve the objective of implementing the lean philosophy, three tools were identified, which are standardized work, SMED and 5S.

As the first tool to consider, we find the standardization of work, which is based on operational excellence, due to the definition of a single and optimal criterion, within a register or process guide within the scope of the entire organization, for the execution of different processes that this same has, in order to improve the overall efficiency of the processes of the standard product [4]. Likewise, standardized work aims to increase planning and productivity, and reduce operating times, through clear activities, optimization of movement, reaching the balance of production [12]. Under this methodology, defects per year can be reduced with respect to poor material management by 68.84%; and with respect to defective products by 68.86% [22].

On the other hand, there is the Single Minute Exchange of Die (SMED), translated as "Die change in less than 10 minutes", it is a tool made up of a collection of techniques based on Lean Manufacturing designed to allow flexible production and minimize the times for both tool changes and preparations. The effects of the application of SMED can be seen reflected in reductions in the configuration time of the machines by approximately 73.1% [23]. Likewise, the authors opt for the union of SMED together with Lean Manufacturing tools in the elaboration of their improvement models, allowing improvements in process efficiency, cost reduction and productivity increases [22].

At present, the 5S improvement tool is a very widespread improvement proposal and applied in research cases, since it not only optimizes the organization's production, it also reduces the amount of waste and creates an orderly environment in order to reduce waiting and delay times, and non-compliance with orders [11]. Just as the implementation of this tool is a potential means for the elimination of waste, this in turn provides the organization with a more effective workplace, where the handling of tools or materials will be easy to handle and access [24], due to the delimitations assigned by each of the resources that the company presents, this to simplify the work environment. This is how the impact of this tool is reflected in a decrease of 25% and 26% for the number of defective products and unfulfilled orders, respectively [25].

D. Supply Management

As is well known, supply management is the efficient management of the production flow, to maximize delivery time, quality, and customer service, as well as the profitability of any company. A fundamental factor that mainly affects the productivity of the company is the control of production, where it is observed that, after having greater control of its resources, productivity can increase by up to 100% of its current value [6]. Given the existence of factors that affect the effectiveness of the production processes of an organization, tools of various kinds are used, among the most frequent, we observe the tools MRP-1, MRP-2, Kanban and JIT, which complement each other. Regarding one of the most frequented tools, we have the MRP-1, which converts the master production schedule (MPS) into a detailed schedule to guarantee the availability of raw materials and components at the right time, with the necessary quantities [26]. One of the impacts implied by the absence of this handling of materials and components, in turn, affects the operators, generating unnecessary waiting times due to the lack of said materials [27].

Regarding the Kanban tool, the function of this tool is to be able to indicate and monitor the progress of production flows in a visual and practical way, with the least allocation of resources [28]. Likewise, given the waste due to waiting and overproduction, the Kanban tool is a very effective solution [29], as well as reducing the level of inventory in transit [30]. This can be seen reflected in an improvement of 31% with respect to inventory in process [31], and 11% with respect to the number of orders fulfilled.

On the other hand, there are other tools that optimize supply management, such as Lean Warehouse and JIT [32]. This can be seen in production capacity increased by 22%, line target was 95% met, line efficiency increased by 17% and overall throughput increased by 20% [33].

III. CONTRIBUTION

A. Model Justification

This research, based on the tools explored in the state of the art, will develop an integrated model as a value proposition, to improve the current situation of productive efficiency in a company in the textile sector. For the construction of the model, a previous search of studies was carried out where proposals based on a context or problem like that of the present study were generated.

B. Proposed model

The following model is based on the Deming cycle, or also known as the PDCA cycle (Plan, Do, Check and Action), which seeks to make constant improvement within any organization, which in this case, will be carried out based on the tools previously mentioned. The current proposal consists of 4 components. As the first component we have "Planning", this stage consists of collecting data to identify the specific problems that can be found in the execution of a process. As main tools we find the lane diagram, the Pareto diagram, and the Ishikawa diagram. As a second component we have "Do", with the information obtained in stage one about the problems encountered and their possible solutions, the start-up is given for the implementation of the proposed improvement. For this stage, the proposed tools are work standardization, the SMED method, and the TPM tool. Once the execution of the improvement project is finished, we proceed with the "Check" stage, which seeks to measure and evaluate the results and compare them with the previously raised expectations. For this stage, the processes to be carried out are audits, a simulation of the entire process after having implemented the improvement and finally an evaluation of the indicators that were determined. Finally, we have the "Action" stage, which seeks to correct if there is a problem within the implementation of the improvement, or to make improvements in case an opportunity is detected. Figure 1 shows the design of the proposed model as stated above.

C. Model Components

1. Planning

In this first phase, the objective is to determine the specific problems found within the organization, for this a lane diagram was made to identify the main problems faced by the organization. After the identification of the main problems, the Pareto diagram is used to filter and order the problems according to their level of criticality. Finally, the problem tree

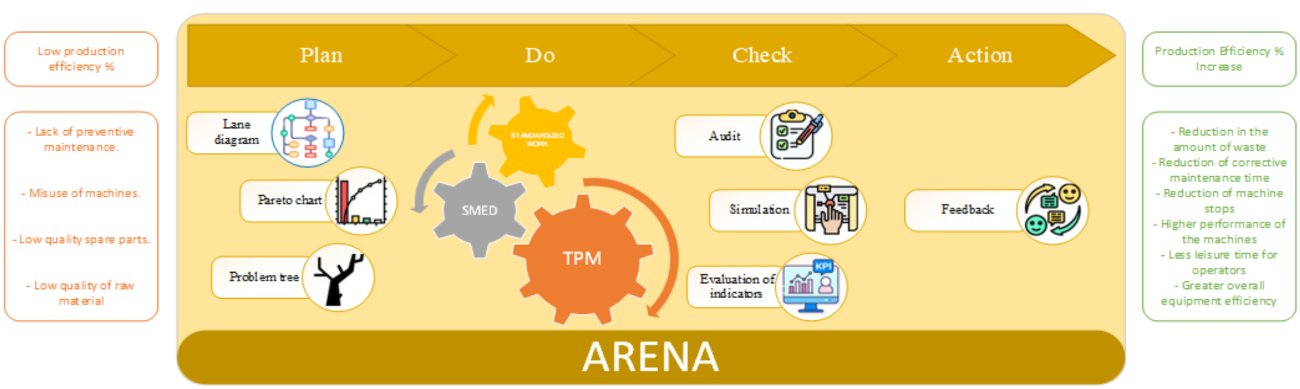

Fig. 1. Model Proposed

is used to determine the most critical root causes according to the specific problems determined.

2. Do

The second stage is based on the implementation of the improvement to solve the problems found previously. As the first tool implemented, we have the standardized work, where it seeks to find the best practices for the various activities carried out within the organization, achieving greater efficiency and quality of these. To do this, the activities carried out within the organization will be monitored, the process of which will be reflected in a lane diagram, which will then be measured and evaluated in the company of the operators to establish a standard application for each activity.

Once the first tool has been defined and implemented, the SMED tool will be executed for greater control and better use of setup and product preparation times. For this, use will be made of the information of the process and its elements obtained in the previous tool, for the conversion of internal elements to external ones, to be able to carry out the greatest number of change processes with little or no modification. Finally, as the final part of the implementation of the improvement, we find the TPM tool, a tool based on the elimination of losses, reduction of stops, quality assurance and cost reduction. For the execution of this tool, we have as a first step the cleaning and inspection of the machines, for its subsequent elimination of the sources of the problem and inaccessible areas. Likewise, together with the correction of the sources of the problem, we proceed to create cleaning and lubrication standards. For everyone to carry out their activities in the same way, general inspection training is carried out and autonomous periodic inspections are organized for the standard review. Finally, all work processes are standardized and visually managed, to conclude with the implementation of the improvement through the implementation of autonomous team management.

3. Check

As part of the third stage, we find verification, where possible problems that have arisen during the execution of the improvement are identified. As the first point to be developed, an audit will be carried out, in order to be able to collect the information and verify if the established standardized activities are complied with. Subsequently, with the information obtained and with the help of the ARENA software, a simulation of the processes will be carried out, to measure each of their respective activities. Finally, the previously established indicators will be used to compare the processes before and after the implementation of the improvement, and the objective that was set at the beginning.

4. Action

Finally, in the act stage, corrective maintenance measures are applied to improve some opportunities that may arise. This stage seeks mostly to provide feedback in order to maintain good practices for continuous improvement.

D. Proposed process

Figure 2 shows a flowchart that graphically represents the process of the proposed model using the Bizagi tool.

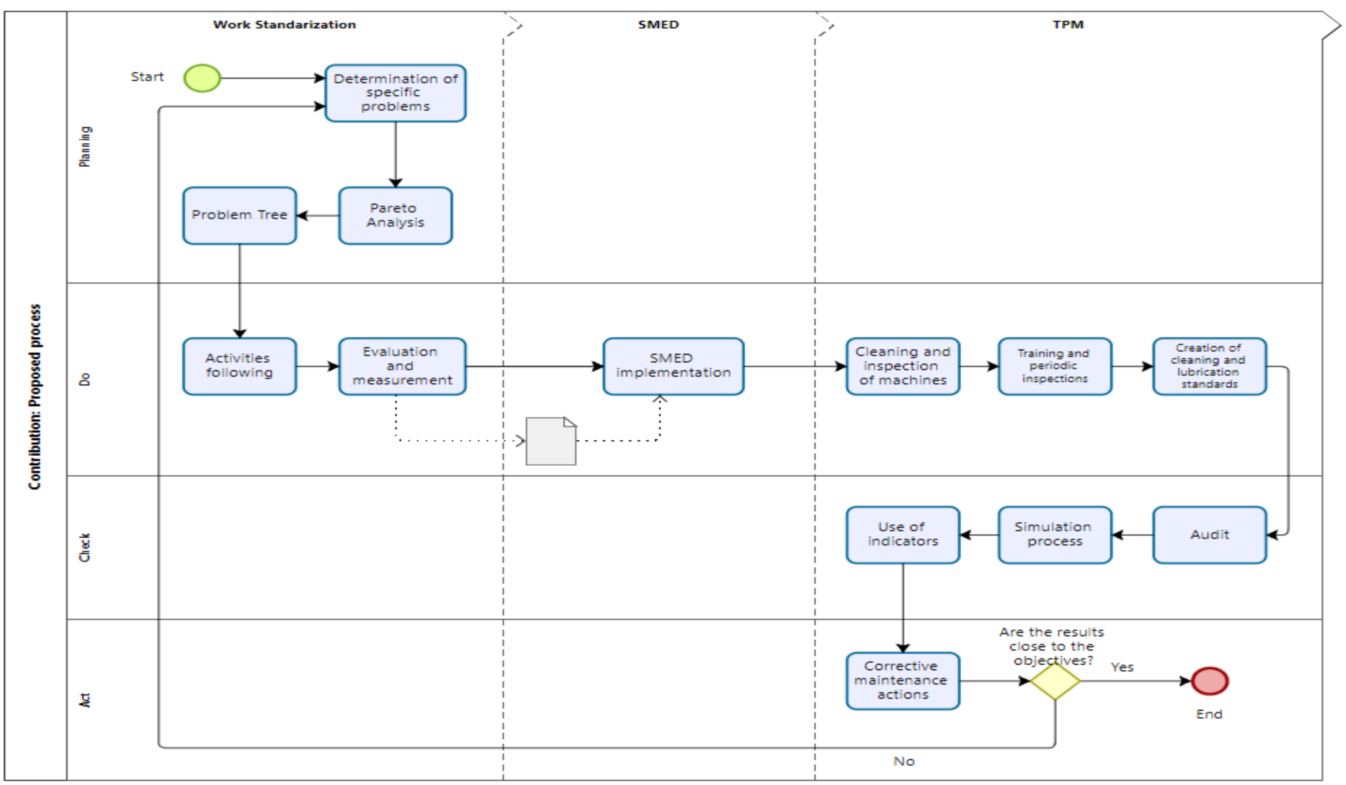

Fig. 2. Proposed Process

TABLE I
INDICATORS

Indicators	Formula
Production efficiency	(actual production rate/standard production rate) *100
Leisure time	(1 - actual operating time/planned time) *100
Machine performance	(actual speed/planned speed)*100
Waste	(1 - valid units/total units produced) *100
OEE	(actual operating time/planned time) + (actual speed/planned speed) + (valid units/total units produced)

E. Model Indicators

For this research, the considered indicators are shown in Table I.

IV. VALIDATION

A. Initial Diagnostic

Low efficiency has a notable presence in the bulk of the MSEs in the textile-apparel sector in the country, due to factors such as the negative effects of Covid 19 [34], time of leisure, among others. Other researchers point out: "the production efficiency at the national level in Peru in this sector is on average 75.2%, while globally it is on average 80%, so we can deduce that Peru is below average" [35].

With this in mind, we proceeded to calculate the production efficiency of the company over 6 weeks to compare the results with the industry standard, obtaining 42.18%, ranking significantly below the sector with a percentage difference of 33.02%.

The company currently has a net profit margin of 43.9%, this due to the high production waste and unproductiveness of the operators. Waste represents 13.14% of the company's net profit.

Likewise, the waste is sold per kilogram to third parties, obtaining a decrease in profit of 89.86% if the company maintains a waste equivalent to 5.77% with respect to the total finished product. In the same way, the unproductivity of the operators is equivalent to 4.39% with respect to the net profit of the company. In a period of 6 weeks, at the general level of the company, there was a monetary loss due to unproductivity and losses, for a total value of S/.1,010.28, which is equivalent to 10.05% of the net profit obtained.

Along the same lines, figure 3 shows a lane diagram of the process to be investigated was made to identify the main problems, where it is observed that the production chain has 6 main operations, which are spinning, overlocking, inspection, labeling, bagging, and boxing.

Figure 4 shows the main problems of the organization, together with the causes that cause it, the stops of the machines have a significant impact, since this problem corresponds to 78.57% of the low production efficiency, while the lack of raw materials corresponds to 21.43%.

Based on the initial diagnosis, Table II shows a summary of the selected KPIs, along with the expected goal after implementing the improvement.

Fig. 4. Problem tree

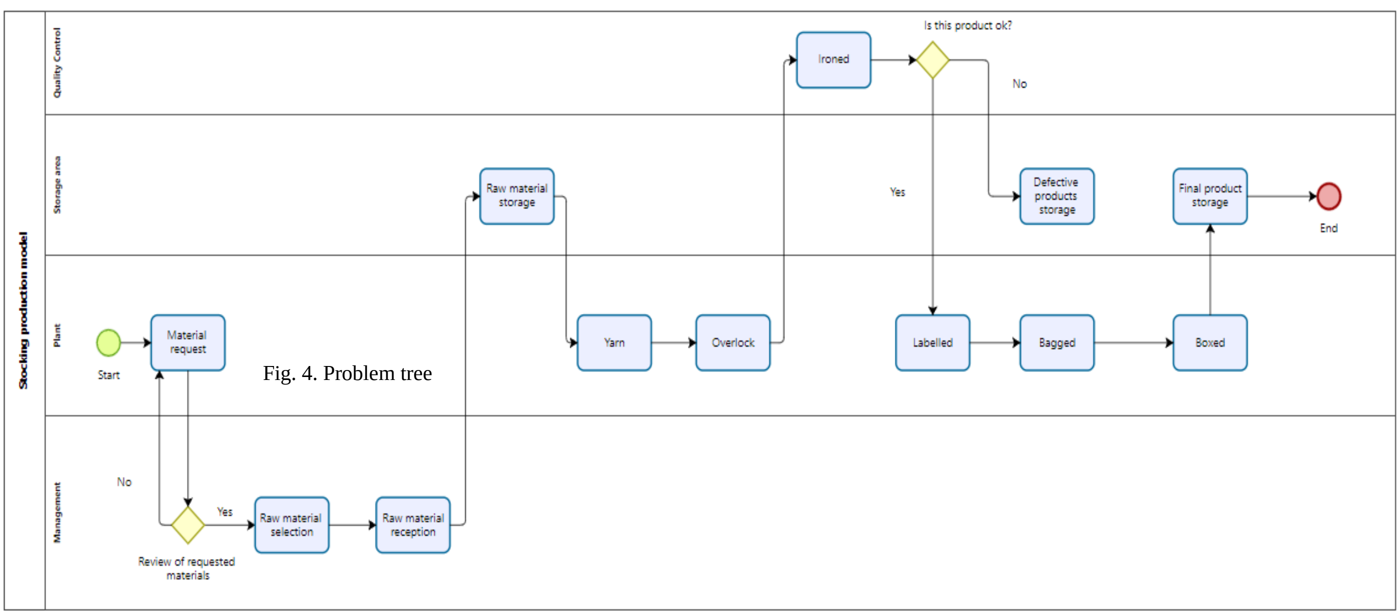

Fig. 3. Main Process

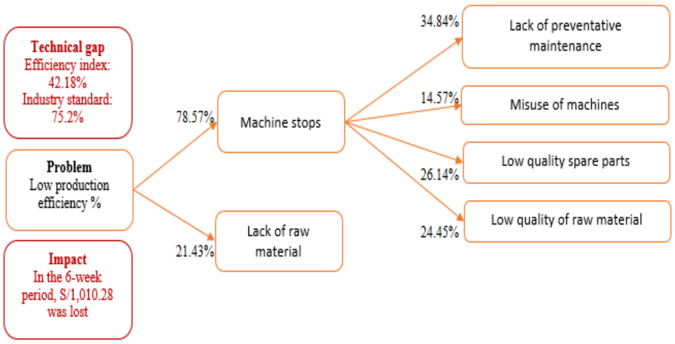

Fig. 4. Problem tree

TABLE II
CURRENT SITUATION - INDICATORS

Indicators	Current	Objective	Variation
Productivity efficiency	42,18%	75,20%	43,90%
Waste	5,77%	3%	47,98%
Machine performance	72,70%	95,00%	23,48%
Leisure time	38,27%	10%	73,87%
Overall equipment efficiency	42,29%	75%	43,62%

B. *Validation Design*

Figure 5 shows the simulation model of the process through the Arena software, to demonstrate and validate the contribution offered by the proposed model with respect to the efficiency of the different operations that our flow has.

The indicators of productive efficiency, waste, machine performance, leisure time and overall equipment efficiency were selected to evaluate the effectiveness of the proposed model.

As the first stage of the execution of the proposed tools, we have the work standardization tool, which was developed for the overlock and ironing operations, impacting positively with respect to the current situation, allowing to shorten the cycle times of the operations. In the same line, the SMED allowed to shorten the configuration time for the change of threads of the spinning machine, leading to an improvement of 21%. In the same way, the application of the TPM was able to reduce the waste by 25% and the number of 6 average daily stops to 4 average stops per day.

Likewise, just as there was an increase in the proposed indicators, there was also an economic impact, which with an increase in the net profit margin of 10.03%, this is due to an increase in income due to the reduction of losses. Likewise, the unproductivity of the operator had a reduction from 4.39% to 0.87%, with respect to the net profit of the company. Finally, in view of the monetary loss caused by unproductivity and shrinkage, it had a reduction in its value, to a final amount of S/. 291.91, which is equivalent to 2.63% of the net profit obtained, thus having a reduction of 73.81% compared to the initial situation.

The Input Analyzer software was used to process data from 30 observations, generating the appropriate distribution for inclusion in the model. To determine the necessary number of replications for the simulation, an initial sample of 30 replications was taken. A target half-width of 10% was set, leading to a total of 180 replications. A confidence level of 95% and a 10% margin of error were considered in the evaluation process.

Table III shows the results of the simulation of the proposed model applied.

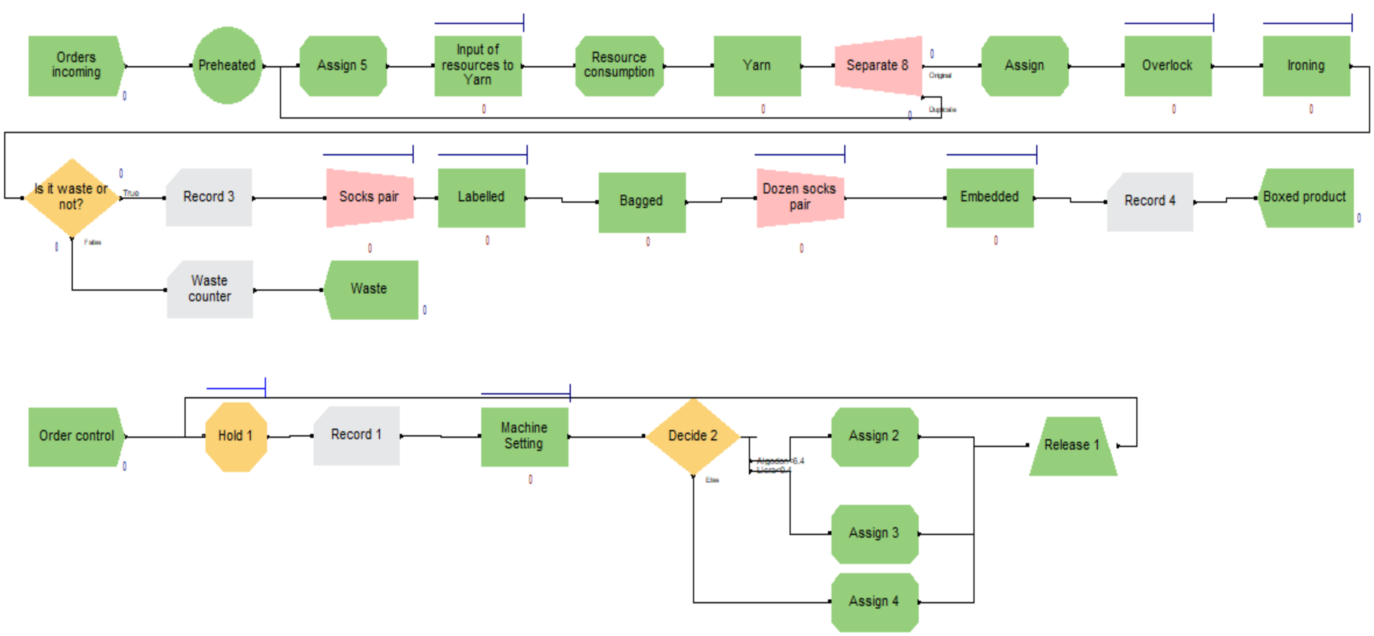

Fig. 5. Simulation of the process

TABLE III
INDICATOR RESULTS

Measurement of the proyect							
Main problem	As is	Objective	Results	Indicator	As is	Objective	Improved
Low productive efficiency	42 %	75,20 %	59,63 %	Waste	5,77%	3%	4,33%
				Machine performance	72.70%	95%	79,45%
				Leisure time	38,27%	10%	19,97%
				OEE	42.29%	75%	61.53%

V. CONCLUSION

After carrying out this investigation, it can be concluded that the implementation of the work standardization tools, SMED and TPM, through simulation in Arena, can result in significant improvements in the productive efficiency of the production line of a small company in the textile sector. Through the analysis of the causes that explain the low productive efficiency of the company, carried out using the Pareto diagram, it was possible to determine that 78.19% of the causes are explained by the stops of the machine. To contribute to scientific knowledge, this study could be used as a methodological basis for future research on the topic in question.

However, current factors, such as the Covid19 pandemic and its consequences, must be considered when collecting information from the company, since factors such as the number of personnel or demand may be affected, affecting entries and exits views in the simulation.

Likewise, according to the literature found, it is advisable to use additional tools such as 5's and Visual Management, as this promotes organization and cleanliness, as well as the understanding of methods and tools by operators, highlighting their simplicity and flexibility in the application of these.

Finally, constant training and supervision of operators is vital to sustain good results over time, as well as transversal commitment to all areas of the company, making it important to permeate continuous improvement into the organizational culture.

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