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Model for improving Efficiency of Production Equipment Related to the OEE indicator through the Application of SMED, TPM and 5S in an SME in the Textile Sector

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Abstract

The Peruvian textile industry is one of the most relevant within the manufacturing sector, contributing significantly to the national GDP. However, it faces major productivity challenges, as the average OEE in the sector remains below the global standard of 80%. The company analyzed reflects this situation, with an OEE of 66.3%, 13.7% lower than the industry benchmark, highlighting a clear opportunity for improvement. This study aims to increase machine availability and production efficiency, currently limited by low equipment performance and delays in deliveries. To address these issues, Lean Manufacturing tools such as 5S, TPM, and SMED were implemented. The 5S methodology focused on improving organization and order in the raw materials warehouse, TPM established preventive and autonomous maintenance to minimize downtime, and SMED optimized changeover times to enhance productivity. A simulation with Arena Software and a 5S pilot test produced a 12.88% increase in OEE, surpassing expectations and confirming the effectiveness of the proposed model for SMEs in the textile and apparel sector.

Keywords
Overall Equipment Efficiency, SMED, TPM. 5S, Textile Industry.

1. Introduction
The textile sector in Peru is one of the most prominent within the manufacturing industry. According to Produce Empresarial (2025), in 2024, this industry contributed 7.3% to the Manufacturing GDP. Likewise, it contributed 0.9% to the National GDP. In 2024, textile and clothing production grew by +10.1% compared to the year 2023. This result is supported by the recovery of textile production (+8.0%) and clothing production (+11.4%), driven by the recovery of the external market (United States) as well as the local market (Produce Empresarial, 2025). Thus, by January 2025, according to Produce Empresarial (2025), the textile and clothing industry recorded an increase of 23.9% compared to the same month of the previous year, due to the increase in clothing (+27.2%) and textile products (+19.0%). Regarding companies, in 2023, the textile and clothing industry recorded a total of 46,693. Of these, 95.4% were represented by micro-enterprises, 4.0% by small ones, 0.1% by medium-sized, and 0.4% by large companies (Produce Empresarial, 2025).

The analysis of the sector indicates that the problems of the textile sector arise from the lack of models for the implementation of production processes and from the different technical failures in the equipment and personnel (Candelario Cordova et al., 2023). One of the main problems of the sector in Peru is productivity. The average efficiency worldwide is 80%, while in Peru it is 75%. Therefore, it is concluded that Peru is below average (Quispe-Roncal et al., 2020). Another of the common problems present in companies in the textile sector are unplanned stops caused by failures (the machine continues to work, but does not perform the function for which it was designed) and breakdowns (total inoperability of the equipment). Likewise, the duration of the preparation and adjustment times of the machines that are longer than necessary is considered lost time (Amiel-Reategui et al., 2022).

These problems have been addressed by various authors, who have proposed different approaches and solutions to improve the efficiency and productivity of companies. In a case study of a microenterprise dedicated to the manufacture of clothing, it was found that machine downtime and unexpected stops were the main obstacles to efficient production (Damian-García et al., 2023). Likewise, Bukhsh et al. (2021), in their study, indicate that in the textile industry a lot of time is lost during the changeover time of printing machines due to unnecessary activities (material flow and movement of workers) that decrease the production rate of the machines. In order to address this problem, according to Condeso et al. (2022), improvements in manufacturing processes must focus on waste or failures, which are the main causes of productivity in any production line. In the manufacturing sector, companies take advantage of the use of OEE (Overall Equipment Effectiveness) to obtain accurate data from their machines in a production line and thus be able to improve the times and quality of their products (Quiroz-Cueva et al., 2023). Therefore, this article proposes a model that is made up of a combination of SMED, 5S and TPM techniques focused on solving problems generated by the lack of standardization and optimization in changeover activities, poor organization, order and cleanliness in work areas and long waiting times due to machine breakdown.

1.1 Objectives

The objective of this research is to optimize the production process of a company dedicated to manufacturing backpacks through the combined application of SMED, TPM, and 5S methodologies, with the purpose of reducing changeover times, minimizing unplanned downtime, and improving overall equipment effectiveness (OEE). To achieve this, the current situation of the process is diagnosed, the main performance indicators are analyzed, and improvement actions are implemented aimed at standardizing changeover operations, promoting preventive and autonomous maintenance, and enhancing organization and order in the work areas. Finally, the impact of these tools on productivity is evaluated, and a sustainable continuous improvement model applicable to the textile sector is proposed.

2. Literature Review

Lean manufacturing is defined as a philosophy that prioritizes the optimization of the production system by eliminating waste (mudas). In this sense, waste is understood as anything other than the absolutely minimum equipment, materials, space and effort necessary to add value to the product (Díaz & Rau, 2022).

Within the case studies developed by the different authors, it was found that one of the main problems present in SMEs in the textile and clothing sector in Peru is the low availability and efficiency of production equipment, usually measured with the indicator known as OEE (Overall Equipment Efficiency). The authors mention some related reasons that negatively affect the problem mentioned above. These reasons can be grouped into 3 major problems: long start-up and preparation times, poor equipment maintenance; and finally, lack of standardization, order and cleanliness in the work area. Under these contexts that need to be corrected, the three most relevant techniques found in the reviewed articles were SMED, TPM and 5S. The tools and techniques used provide productivity gains, encouraging continuous quality improvement while minimizing waste, reducing production time and defects by promoting effective communication, job satisfaction and team decision making (Baptista et al, 2021).

The authors propose a technique called Single Minute Exchange of Die (SMED) as a solution to the long start-up times of machines. This method seeks to reduce the time required to change the configuration and tools of a machine, thus allowing the production of a new batch of products to begin, which are usually different from the previous ones. In 1985, Shigeo Shingo proposed reducing this time by classifying and simplifying the activities necessary to increase efficiency in each machine in the process (Baptista et al., 2021).

The SMED methodology is divided into three stages. In the preliminary stage, the current execution of the preparation process is analyzed, observing and recording the times of all the activities involved. In the first stage, after collecting information on the activities, they are classified into two main groups: internal activities and external activities. Internal activities require stopping production and the machine to be carried out, while external activities are carried out while the machine continues to operate normally. After classifying the activities, the second stage works to convert as many internal activities as possible into external ones, so that they can be performed without interrupting the operation of the machine. Finally, in the third and final stage of the process, movements are simplified and reduced in all the preparation activities present (Braglia et al., 2023).

The introduction of this tool has generated positive results in the case studies presented by the authors. For example, in reference to (Torres- Mestanza et al., 2023), the implementation of SMED managed to reduce the preparation times of the sewing machine from 14 minutes before implementation to 9.97 minutes afterwards. This saving of 4.35 minutes in preparation time decreased the cycle time required to manufacture a garment, implying that monthly production could be increased by up to 294 additional garments. The application of SMED, in combination with other Lean tools, contributed to a 16.5% increase in the efficiency of the sewing process, raising the indicator to 80%.

On the other hand, speaking of poor equipment maintenance, this factor has been identified as one of the causes that influence the low efficiency of production equipment, since inefficient corrective maintenance causes unexpected machine stops that interrupt and delay the scheduled development of the process. Various authors highlight the success of implementing preventive maintenance to avoid machine failures, since if the equipment fails, it will paralyze the entire production process and processes that do not add value are generated (Sanchez et al., 2022).

The implementation of the TPM tool seeks to reduce defects to zero and minimize machine breakdowns in the production line; to considerably reduce the time, the product remains within the production line, thus increasing its quality (Quiroz-Cueva et al., 2023). The TPM technique uses the OEE indicator as a quantitative metric to measure the performance of a production system, with the general objective of increasing the overall effectiveness of the equipment (Anzualdo et al., 2023). In their same study, Anzualdo et al. (2023) verify the positive impact of the implementation of the TPM tool, resulting in an increase in the OEE of a SME in the textile sector in Peru, going from 74.54% to 81.20%.

Finally, regarding the lack of order and standardization and cleanliness, the authors propose the 5S tool. This tool helps to improve the company's work environment and product quality through five steps (Céspedes-Pino et al, 2020). The 5S tool is essential to improve the storage process as it improves the layout and order of the warehouse. It also stands out for its benefits, such as increased productivity without investing large amounts of money (Acevedo-Aybar et al., 2024).

By eliminating activities that do not add value, combining some parts and changing the sequences of existing methods, the proposed work method can be optimized to meet customer requirements and improve overall productivity (Ewnetu & Gzate, 2023). In their study, after the improvement, the total distance to be traveled was reduced from 131.8 m to 99.3 m, with an average of 20 movements per operator per shift. This translates into a saving of 650 m per shift. In addition, non-value-adding activities decreased from 43% to 5% and bottlenecks were eliminated from 3 to 0. The actual daily production of flat sheets was 43.3% per shift, but after the improvement, it increased to 75.8% (Ewnetu & Gzate, 2023).

3. Methods

The tools and results presented in the literature review served as the foundation for developing a model aimed at increasing the efficiency of production equipment. In the case study, the main reasons and their root causes were identified using the 8D methodology, which involved conducting three key analyses: 5 Whys, Value Stream Mapping (VSM), and 5W1H. The three primary reasons for low efficiency were identified as the lack of standardization and optimization in changeover activities, poor organization, order, and cleanliness in work area, and high waiting time due to equipment failures. To measure the importance and weight of each main reason and its associated causes, Pareto diagrams were used, based on time data and historical production information from the company, as shown in Figure 1.

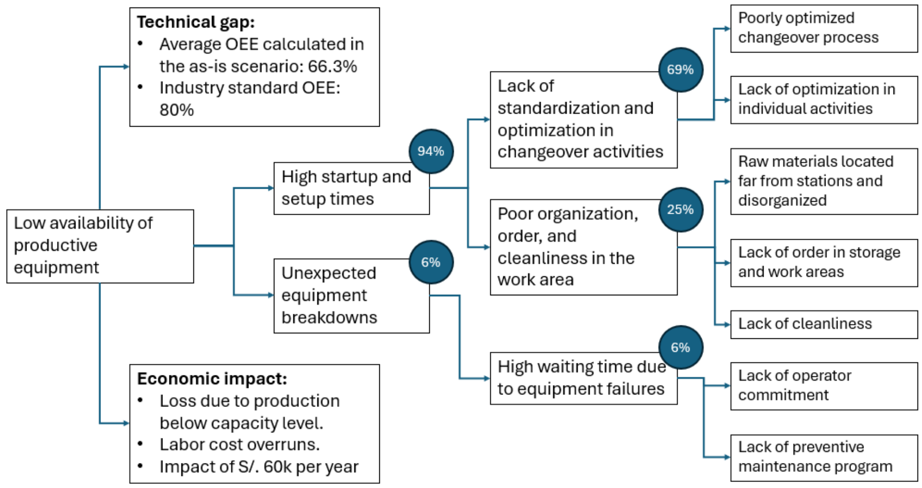

Figure 1. Problem tree

To address these issues, specific objectives were established to tackle the root causes associated with each of the identified reasons. These objectives were then aligned with various tools identified in the theoretical review, ensuring they supported the overall goal of improving the low availability of production equipment. The most suitable tools to address the identified reasons are 5S, Single Minute Exchange of Die (SMED), and Total Productive Maintenance (TPM). The proposed model aims to combine these three tools, which belong to the Lean methodology, with the objective of increasing the operational efficiency of the machines present in the textile plant. The development of efficiency will be measured using the indicator known as Overall Equipment Efficiency (OEE). This indicator consists of three components: availability, performance, and quality. The proposed model consists of three phases, one for each tool to be used.

Limitations were encountered in fully implementing the proposed actions on the production stage. Therefore, this model will be validated in a mixed manner through the integration of a simulation and a pilot program (Table 1).

Table 1. Matrix of Specific Objectives vs. Tools from Theoretical Review

Objectives/ Authors	**Organize and clean the work area**	**Optimize and standardize changeover activities**	**Encourage greater commitment from operators**	**Implement a preventive maintenance policy**
(Calderón-Ayala et al., 2023)	5S	SMED	5S and TPM	TPM
(Damian-Garcia et al., 2023)	Work Standarization			
(Roncal-Coronel et al., 2023)	5S and ABC			
(Braglia et al., 2023)		SMED		
(Baptista et al., 2021)	5S	SMED		
(Leon-Ludena et al., 2023)	5S		5S and TPM	TPM
(Sanchez et al., 2022)	Work Standardization	SMED	TPM	TPM
(Amiel-Reategui et al., 2022)		SMED	TPM	TPM
Tool Proposal	**5S**	**SMED**	**TPM**	**TPM**

The proposed model receives three inputs: theoretical review, the identified problem, and the data and information required for analyses and the creation of indicators. Through the three phases, sub-steps are outlined, and a specific tool is utilized in each phase to address specific objectives. The goal is to achieve an output that reflects an increase in efficiency by reducing setup times, minimizing unexpected downtime due to equipment failures, and improving order and cleanliness in the workspace.

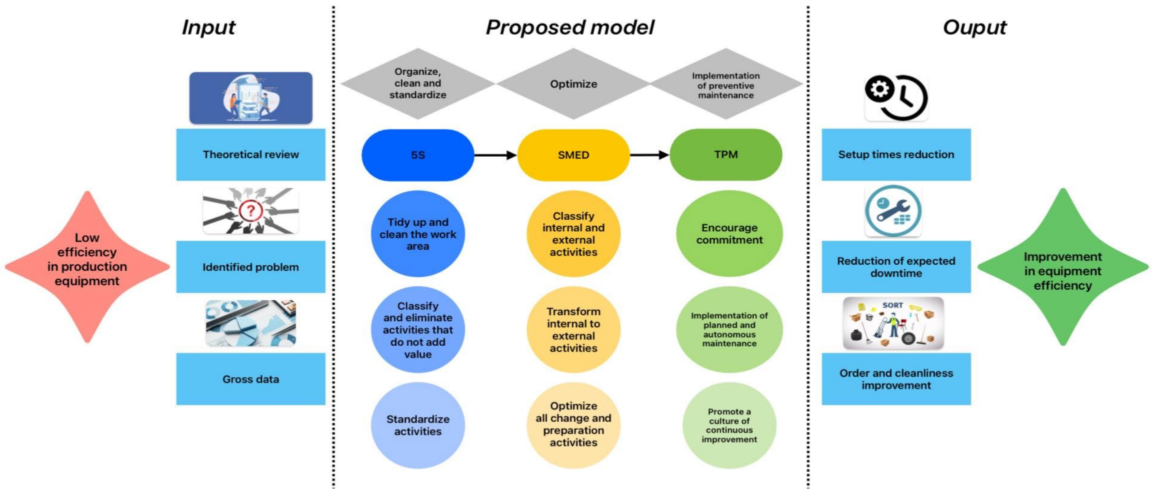

Figure 2. Macro model of the proposed solution

Phase 1: Organize, clean, and standardize

Within the current state of the company, it was observed that there is a disorder of materials and tools in two different instances: in the storage of raw materials and in the arrangement of products in process. This causes significant delays as operators take more time than necessary to find and bring the required materials. The validation of this component will be through a pilot program, where the goal is to reorganize both the workspaces and storage areas. Additionally, activities will be standardized, and non-value-adding activities will be eliminated. To achieve this, shelves will be organized and labeled for easier material retrieval. For work areas, signs will be placed with the names of each station and will be color-coded according to the type of activity being carried out, as shown in Figure 2. Finally, operators will be trained for at least two months to instruct them in the correct way to collect, organize, and search for materials whenever needed (Figure 3).

Black	Work in progress
Blue	Raw materials and tools
Green	Finished product
Orange	Inspection area
Red	Retention of defective materials
Yellow	Aisles, walkways, and traffic zones

Figure 3. Color code guide for plant signage

Phase 2: Optimize

For the development and validation of phases 2 and 3, Arena software will be used to simulate the process. It was observed that operators were performing machine setup activities without following a standardized sequence, resulting in increased time to start the operation at each station. To address this, the SMED methodology will be applied. The sequence of setup activities at the sewing stations will be identified and timed, as these stations involve the use of machines. Next, all activities will be categorized as internal or external, with internal activities being those that require stopping the machine. Finally, efforts will be made to convert internal activities into external ones, and a structured sequence for the changeover process will be established. The aim of this methodology is to reduce the total time spent at each workstation that uses a machine resource.

Phase 3: Implementation of preventive maintenance

The company was mainly performing corrective maintenance on its machinery, which led to highly variable repair times and negatively affected planned production. To address this issue, a planned and autonomous maintenance policy is proposed under the Total Productive Maintenance (TPM) framework. The first step involves raising awareness and motivating operators about TPM's core principles, benefits, and pillars. Three key pillars were prioritized: total participation, planned maintenance, and autonomous maintenance. For planned maintenance, a policy based on regularly produced units is established, while for autonomous maintenance, a flowchart defining the correct maintenance sequence is created, as shown in Figure 4. Finally, operators will be trained to promote a culture of continuous improvement, ensuring the sustainability of the new policy. The goal of this methodology is to reduce unexpected equipment downtime and standardize repair times.

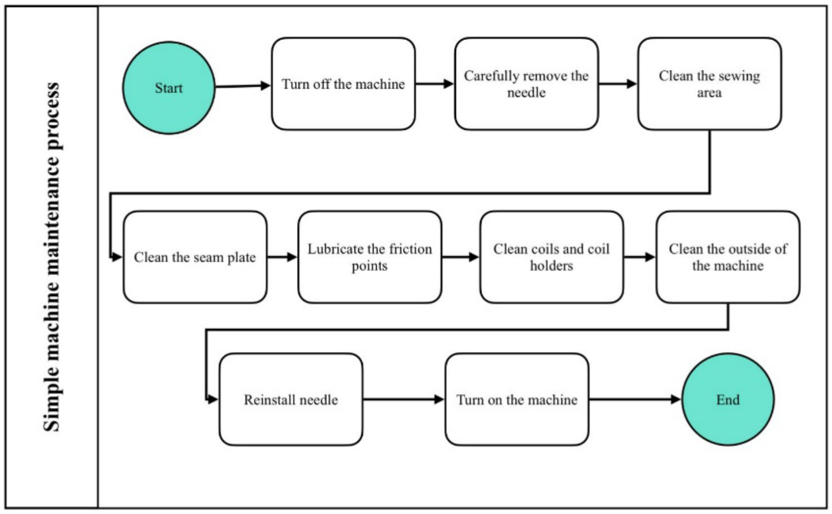

Figure 4. Simple Maintenance Process Flowchart

The implementation and monitoring of the proposed model will be carried out through four indicators. The indicators for the previous state were calculated, and specific objectives for each have been established, as shown in Table 2. It is important to note that the quality component of the OEE is not considered, since the company consistently maintains a 100% quality rate. This result is achieved because all waste and defective products are reused to create other product lines. Although quality is not an indicator targeted for improvement, it is still included in the OEE calculation.

- Overall Equiment Efiiciency: It is used to measure the effectiveness of production machines.

$$OEE = Availability\ x\ Performance\ x\ Quality$$

- Machine Availability: Allows to measure the time the equipment is available to operate, compared to the expected or planned time allocated for production.

$$Machine\ Availability = \frac{Actual\ Operating\ Time}{Planned\ \ Production\ Time}$$

- Performance: This indicator allows to measure the difference between actual production and the expected or ideal production capacity based on the machine's capability.

$$Performance = \frac{Actual\ Production}{Ideal\ Production}$$

- Unproductive time: No specific formula is used; it is measured by summing all the recorded unproductive times daily, including delays due to breakdowns and changeover times.

Table 2. Proposed indicators

Indicator	Measure Unit	As Is	To be	Expected Improvement
OEE	%	66.3	71.25	4.95%
Availability	%	72.50	75	2.5%
Performance	%	91.43	95	4.95%
Unproductive time	min/day	131.95	90	-31.17%

The textile plant produces various fabric-based bags, including kangaroo bags, backpacks, and different-sized backpacks. Among these, the “Gran Ruta” backpack is the most popular and influential product in terms of sales. To enhance the accuracy of this study, the "Gran Ruta" backpack has been chosen for implementing the proposed model.

The average OEE within the plant over the past six months was calculated to be 66.3%. Theoretical research indicates that the standard for this indicator in the textile sector is 80% (Quiroz-Cueva et al., 2023). Therefore, from a technical perspective, this model, despite setting a conservative target indicator, shows a technical gap of 13.7%.

From an economic perspective, efficiency problems result in two major financial challenges for the company. Firstly, the installed capacity of the company’s machinery allows to produce up to 408 backpacks per month. However, the initial diagnosis revealed that the plant produces 16 backpacks daily. Adjusted to the 24 regular working days per month, the plant produces 384 backpacks monthly. This shortfall of 24 "Gran Ruta" backpacks represents a loss in potential sales due to insufficient stock. Considering that the profit margin per backpack, accounting for the selling price and total production cost, is 164.70 PEN, the inability to sell these 24 backpacks every month translates to an annual potential economic loss of 47,424 PEN.

Additionally, it was identified that the company has been scheduling two extra shifts per month to meet planned production. These extra shifts are typically unbudgeted and considered an emergency measure that has unfortunately become a regular occurrence in recent months. Each extra shift costs the company approximately 533.30 PEN. With at least two extra shifts per month, the annual additional cost amounts to 12,800 PEN. Combined, the losses from unproduced backpacks and the extra shift costs result in an annual economic impact of 60,225 PEN.

The proposed model, through the 5S pilot program and the simulation of SMED and TPM methodologies, aims to reduce the company’s economic impact and close the technical gap associated with the OEE indicator.

3.1 Implementation and Simulation

5S Pilot Program:

For the implementation of the 5S methodology in the plant, the various areas were organized and cleaned. Additionally, signage was added, and time tracking was introduced at stations that only require operator resources to measure optimization after the implementation. The main warehouse for raw materials and components needed for backpack production was disorganized and lacked proper signage, making it difficult for operators to efficiently identify the materials required at each stage of the production process. Similarly, the areas of the plant housing the sewing machines lacked signage, further hindering the operator’s ability to locate workstations efficiently. Images of the production plant prior to the tool’s implementation are shown in Figures 5 and 6.

Figure 5. Material shelf

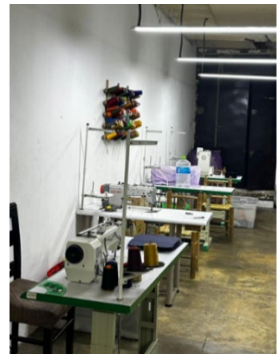

Figure 6. Sewing area

For the implementation of signage in the different areas of the production plant, laminated A4 sheets were used, displaying the workstation name and an icon in the upper corner in the shape of a circle with the corresponding color for each specific area according to the figure rule, as shown in Figure 7. In addition to the laminated sheets, labels were printed with the respective names of the different materials, which were placed on each section of the accessories warehouse stand, as shown in Figure 8. For the raw material and accessories warehouse stand, the first step was to clean and organize the different materials, grouping each type of material, tool, or accessory in a single block of the stand for subsequent labeling, thus reducing the time spent searching for materials during the production process.

Figure 7. Tag block

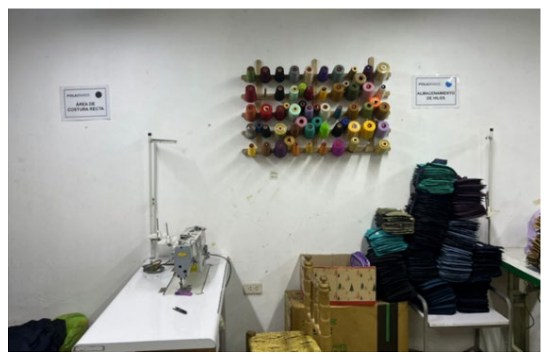

Figure 8. Straight stitching and thread storage

After the implementation of the signage, times were recorded for tool changes and material searches at the cutting, packaging, and dispatch workstations. Additionally, operators were trained in the proper organization and retrieval of materials to maintain the established order.

The results show a decrease in times at the cutting station due to a reduction in time spent searching for zippers, sponges, and molds, which are now properly organized on the stand. At the packaging station, a decrease of 0.12 minutes was observed, attributed to the central storage of bags in a single location in the warehouse, eliminating the need to search in multiple places. Finally, the dispatch station recorded a reduction of 0.16 minutes.

SMED and TPM Simulation:
To obtain the most accurate representation of the real scenario, a sample size of 28 backpacks was established for time measurement at each workstation. This sample was determined using a sampling formula for finite populations. Considering that 80 backpacks are produced weekly over five working days (an average of 16 per day), two time-measurement shifts will be required. Furthermore, to analyze the effects of fatigue, each daily shift will be divided into two stages: one in the morning and one in the afternoon.

Next, the time inputs obtained will be processed and analyzed for each workstation using Arena’s Input Analyzer. This will allow for determining an expression that best represents the behavior of the times. The criteria for the most suitable expression will be guided by the distribution with the smallest quadratic error and that meets the rule of having a p-value greater than 0.15 under the Kolmogorov-Smirnov Test. Below, in Table 3, the expressions obtained for each identified workstation are presented.

Table 3. Determination of distribution by workstation

Workstation	**Min value (min)**	**Max value (min)**	**Mean (min)**	**Standard deviation (min)**	**Distribution**	**Squared error**	**p-value**	**Expression**
Cutting	3.52	5.47	4.39	0.590	Normal	0.012716	>0.15	*NORM(4.39, 0.578)*
Flat sewing	3.58	4.95	4.26	0.420	Uniform	0.004082	>0.15	*UNIF(3.44, 5)*
Detail stitching	2.63	4.12	3.46	0.449	Beta	0.007291	>0.15	*2.48 + 1.79 * BETA(1.61, 1.32)*
Reinforcement stitching	1.63	3.09	2.32	0.415	Beta	0.001601	>0.15	*1.48 + 1.76 * BETA(1.66, 1.82)*
Volumetric stitching	6.13	7.93	7.07	0.501	Beta	0.016425	>0.15	*6 + 2 * BETA(1.59, 1.37)*
Quality inspection and correction	2.11	3.66	3	0.462	Beta	0.004395	>0.15	*2 + 1.82 * BETA(1.55, 1.28)*
Packaging	1.54	3.5	2.55	0.653	Uniform	0.021939	>0.15	*UNIF(1.34, 3.7)*
Dispatch	2.66	3.64	3.02	0.278	Gamma	0.011218	>0.15	*2.56 + GAMM(0.166, 2.75)*

Subsequently, the process was modeled in Arena, with an entry entity defined as "Fabric." Different machine and operator resources were assigned to each workstation as appropriate. The machine resources included two straight sewing machines, one overlock machine, and one volumetric machine. Regarding human resources, eight operators were distributed across the various workstations. To capture resource utilization, a Seize–Delay–Release logic was implemented, linked to the expressions previously defined in Table 3.

Due to time constraints and the random nature of machine failures, a four-week record of unexpected breakdowns was collected with operator support. Although repair times vary by case, operators typically take 10 to 15 minutes to complete a repair. Based on the data, the straight sewing machine averages a failure every 1,645.7 minutes, adjusted to 592.45 minutes considering backpack production (36% of total output). The overlock and volumetric machines were similarly adjusted to 1,382.4 and 296.24 minutes between failures, respectively.

Accordingly, an exponential distribution was selected for Uptime to represent the random occurrence of failures, and a uniform distribution (10–15 minutes) for Downtime, capturing the variable repair duration. These configurations were implemented in the Failure modules within Arena to reflect real production conditions. Finally, an exit termination rule was established for 16 fabric entities, and to enhance the reliability and clarity of the results, the simulation was run for 10 iterations. The model design is shown in Figure 9.

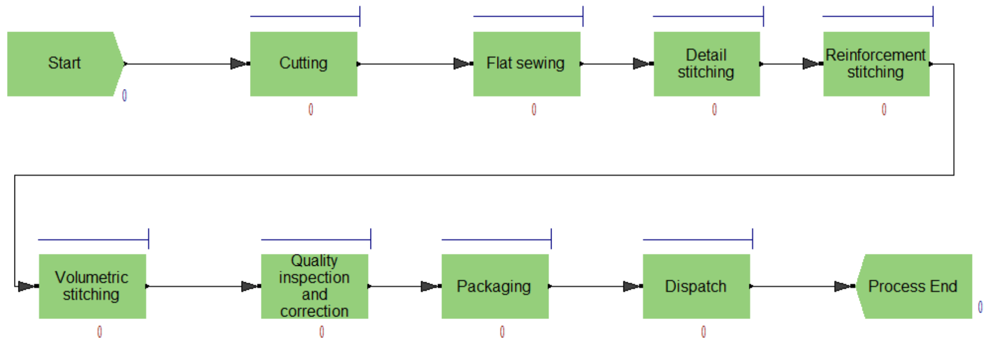

Figure 9. Simulation of "Gran Ruta" backpack production process

Improved scenario:
The deployed pilot program had a significant impact on reducing the processing times at stations that required an operator resource. To represent the influence of SMED, the corrections and optimizations implemented at each station resulted in a reduction of times for all stations utilizing a machine resource. Finally, the representation of TPM in the model was developed through the use of a Failure module, with an updated Uptime expression that now follows a counting logic for every nine produced entities, followed by a regular downtime of five minutes. This represents a preventive maintenance activity with a standard duration occurring after a specific number of produced units.

4. Results and Discussion

After the implementation of the pilot program and validation through simulation, the results obtained in the Arena software are presented in Table 4.

Table 4. Comparison of results for "as is" and corrected scenario

Scenario	**As is**			**Corrected**		
Iteration	**VA Time(min)**	**Wait Time (min)**	**Total Time (min)**	**VA Time (min)**	**Wait Time (min)**	**Total time (min)**
1	30.52	13.12	43,64	25.77	6.56	32.33
2	30.21	10.74	40,9	25.69	7.06	32.76
3	30.2	16.17	46,4	25.4	4.39	29.78
4	30.26	8.33	38,59	25.5	6.54	32.04
5	29.29	5.16	34,46	24.80	5.90	30.79
6	30.17	8.16	38,32	25.60	7.12	32.72
7	30.37	20.5	50,92	25.63	6.67	32.29
8	30.35	11.48	41,84	26.03	5.56	31.59
9	30.08	7.85	37,93	25.68	7.81	33.5
10	29.80	6.55	36,36	25.08	5.34	30.35
Mean	**30.13**	**10.81**	**40.94**	**25.52**	**6.30**	**31.82**

A reduction in wait time was observed across all iterations. Overall, the cycle time decreased by 9.12 minutes. The wait time and total time values were used to calculate availability in the improved scenario. The Arena simulation results indicate a total reduction of 13.48 minutes for the production of 16 units. When extrapolated to a monthly scale of 24 work shifts, this represents a time saving of 323 minutes per month.

In the corrected scenario, given that the production time per backpack is 31.82 minutes, the 323 minutes saved allow for the production of approximately 10 additional backpacks per month, increasing total output from 384 to 394 units.

For the calculation of unproductive time in the simulation scenarios, the average wait time per cycle shown in Table 5 was adjusted to the total time corresponding to the 16 simulated cycles. Based on these results and the established indicators, a comparison table is presented below, illustrating the differences between the real situation, the simulation scenarios, and the defined objectives.

Table 5. Indicator Results

Indicador	Real	Arena As is	To be	Corrected scenario
Availability	72.50%	73.6%	75%	80.2%
Performance	91.43%	91.43%	95%	96.56%
OEE	66.30%	67.29%	71.25%	79.18%
Unproductive times	131.95 min/day	172.96 min/day	90 min/day	100.8 min/day

The results indicate an increase in machine availability, meeting the established target and exceeding it by 5.2%. The performance indicator also surpasses its target by 1.56%, while the Overall Equipment Effectiveness (OEE) shows an improvement of 12.88% compared to the current scenario. Finally, although unproductive time is reduced by 31.15 minutes, the target set for the “to-be” scenario is not fully achieved. Overall, the implementation of the proposed model demonstrates a positive impact across the evaluated performance indicators.

5. Conclusion

The implementation of the simulation and pilot program together, as proposed in the macro model of the solution, shows positive results in increasing operational efficiency in the production equipment. This model combines Lean methodology tools such as TPM, 5S, and SMED to improve the OEE (Overall Equipment Efficiency) indicator. Its initial value was 66.30%, and despite having a conservative target of 71.25%, it was successfully raised to 79.18%, bringing it very close to the industry standard of 80%.

Thanks to the implementation of the pilot program for 5S, a significant reduction in the plant's unproductive times was achieved. These times were associated with the lack of organization in the warehouse and work areas, the absence of cleanliness, and raw materials being located far from the workstations. In total, unproductive times decreased by 31.15 minutes per day.

The implementation of SMED and TPM through simulation led to an increase in machine performance and availability, from 91.43% to 96.56% and from 72.50% to 80.2%, respectively. This was achieved through the standardization of machine setup and the integration of autonomous preventive maintenance. The results in the Arena software show a reduction in simulation time of 13.48 minutes between the two modeled scenarios.

To sustain the results and present a stable scenario in the months following implementation, training in the 5S, SMED, and TPM methodologies was proposed. The goal of this training is to maintain best practices and encourage operators to follow the newly established standards.

In terms of economic impact, while a potential impact of 60,224 PEN was estimated, the development of the solution allowed for an increase in monthly backpack production by 10 units and a reduction in extra shifts to one per month. With these improvements, 43% of the potential impact was covered, resulting in an annual savings of 26,160.60 PEN.

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