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Improvement proposal to increase the production efficiency of garment with lean manufacturing tools for the textile sector in Lima

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Abstract*– In Peru, the textile and clothing sector is considered the third activity with the highest market share and with the greatest contribution to the national economy.Much of this industry is made up of small and medium-sized businesses, which generate the largest number of jobs.However, most of these companies present problems in factors such as quality, high production times and low availability of machinery, which hinder better performance in the market and undoubtedly affect competitiveness. The present research work aims to increaseproduction efficiency in a garment line based on LeanManufacturing tools. Which proposes a model based on theuse of tools such as 6S, SLP, TPM (2 pillars), Study of methods, time, and motion study. The results of the application of the proposed model with each of the tools were taken periodically until an improvement of 13% was obtained in the indicator of Overall equipment efficiency (OEE).

***Keywords*— TPM, OEE, 6S methodology, SLP, Study of Methods**

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Abstract– In Peru, the textile and clothing sector is considered the third activity with the highest market share and with the greatest contribution to the national economy. Much of this industry is made up of small and medium-sized businesses, which generate the largest number of jobs. However, most of these companies present problems in factors such as quality, high production times and low availability of machinery, which hinder better performance in the market and undoubtedly affect competitiveness. The present research work aims to increaseproduction efficiency in a garment line based on LeanManufacturing tools. Which proposes a model based on theuse of tools such as 6S, SLP, TPM (2 pillars), Study of methods, time, and motion study. The results of the application of the proposed model with each of the tools were taken periodically until an improvement of 13% was obtained in the indicator of Overall equipment efficiency (OEE).

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I. Introduction

The textile and clothing manufacturing sector is made up of 30.6% at the Peruvian level for the group of micro and small enterprises (MSEs) [1]. Currently this industry has become very competitive internationally due to high quality standards. For the main problem identified in our research work which is the low production efficiency in the elaboration of garments, we have some concepts about the use of tools such as SLP, 6S, Studies of Methods, times and movements and 2 pillars of TPM.

The textile and clothing industry contributes 6.4% of the GDP of this sector generating 398 thousand jobs [1]. However, the decrease in production demonstrates the efficiency challenges. It is worth mentioning that, worldwide, the Overall equipment efficiency is 80% while the OEE of Latin America is 65% and Peru is 61.7% [2]. One of the most outstanding success stories tells us about a company that proposes to improve the OEE of its production line through the implementation of TPM and 6S from which results were obtained from a 62.2% increase in OEE [3].

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The following research work is motivated to improve revenue, process activities and overall team efficiency. This will detail the development of an improvement proposal to increase the production efficiency of the garment line based on Lean Manufacturing tools and study of times and movements in a company in the textile sector in Lima which is based on the diagnosis for the company *"Creaciones Simbron"* that produces garments for women.

Therefore, the following lines will detail the literature collected through the state of the art on the proposed tools to develop the model that is related to the main problem. Then the detail of the contribution for our research work is described with the visual aid of the model with the elements that are required for this research work to be successful.

II. Literature Review

A. *Overall equipment effectiveness (OEE)*

In the manufacturing sector, companies take advantage of the use of the OEE to obtain exact data from their machines in a production line and thus be able to improve the times and quality of their products.

For the aluminum extrusion company, they considered the SMED technique with the objective of reducing losses in the process and that can increase the reliability of the processes with the successful result of improving the OEE by 3.26% [4].

Having the participation of the people involved in the processes in order to facilitate the implementation of tools such as 5S, SMED, TPM and Jidoka made it possible to improve delivery to customers in a plastic producing company. It was possible to increase the OEE by 13% because there was a decrease in mold change times [5].

B. *SLP*

The System Layout Planning tool is validated through qualitative methods, its purpose is the distribution in the plant and the rearrangement of areas, for this first step the activities and movements are evaluated considering the ideal proximity in which the areas interact in the production process. to be related in addition to the arrangement of the machines[6]. These changes are proposed with the purpose of optimizing the flow of materials and reducing the distances of transfers and the route of the materials in the work stations [6]. In addition, greater efficiency is achieved by reducing space and total travel distances [7]. This reduces wait times caused by process delays by minimizing process and facility travel distances by providing standardized procedures and activities. With the implementation of this tool, it is possible to reduce waste by displacement by 40%, as achieved by a company in Indonesia [8]. On the other hand, a reduction in the cost of handling materials is achieved, obtaining reduction results of 23.88%. and 22.92% compared to the current design, in addition to the material transfer time which was reduced by 34.01% [6].

C. 6S

This 6s methodology is an extension of the 5s tool, which consists of the implementation of the Seiri, Seiton, Seiso, Seiketsu, Shitsuke stages and a new stage that is safety, which allows compliance with the hazard identification and risk assessment requirements. Potential risks in avoiding accidents in order to guarantee the safety of workers in a company in the construction sector[9]. It is proposed to integrate this sixth "s" as the fourth phase of the implementation of the methodology to meet the needs of safety and health at work [10].

The implementation of this methodology is developed through the Plan-Do-Check-Act cycle, thus providing better quality in the work area [9]. As was done by a company that developed an electrical line that allowed reducing the time of activities without added value, through the use of instructions and procedures that evaluate those activities that present greater risks and allow them to be carried out safely, as well as the training that is provides and the necessary protection equipment to guarantee the success of this methodology and an improvement in efficiency of 8% is achieved [11]. On the other hand, to evaluate the success of the implementation of this methodology, an audit is carried out, obtaining a score of 80%, which indicates the positive impact, since a score higher than 75% is considered a process that worked and therefore an increase. in the results. expected after a few months. [10]

D. Study of methods, times and movements

The study of methods, times and movements allows to provide a previous analysis that helps to balance the activities and therefore reduce the times in the work area through a redesign of workstations, to increase efficiency and improve the optimization of resources, likewise, it increases the productivity index in production line, so that after the implementation of the standardization of work unnecessary movements were reduced to 66%, and reported an increase in production per line by 3.28% [12]. A work distribution is proposed from the functional opinion, since this study focuses on obtaining efficiency by using the tools with which the activities can be divided, so the production report evidences the increase in a staggered manner and that the operators had adapted to the new assignments of the activities resulting in an increase in production of 5.49% [13]. Through the study of times and movements it was possible to reduce the cycle time by 26% per garment, Work in Process in the value flow was reduced by 0.59min to 0.46 min and the performance of the equipment increased by 35% [14]. In addition, the cycle time directly affects the productivity for this it is necessary to evaluate also the tack time of the line, this data allows to make a balance or equilibrium in detail of the whole process in the workstations so that all remain operational, it is important after this study I can notice that the productivity increased by a reduction of 8% of the total time worked [15]. It is suggested to compare the results with the objectives set. In the case that the new methods are effective, the production lines are adjusted with the new production methods and adjusted workstations are established, including visual aids and templates designed inefficient body movements and postures in operators decreased by 66%, and the standard time was reduced by 18.44% [16].

E. TPM

The implementation of TPM, seeks to reduce to zero the defects and minimize machine breakdowns in the production line, in order to reduce considerably the time of permanence of the product inside the production line, thus increasing the quality of these. The exercise of this tool focuses on social practices related to people as it seems to develop a key role for the successful implementation of concepts for continuous improvement to improve HR factors. Such as the role of top management and training methods [17]. The author proposes the implementation of this tool, based on one of the pillars of TPM, such as preventive maintenance, in a production line associated with failures by machines following a maintenance plan so it is required to have a frequency control for the verification of tasks by which is obtained as a result the decrease of machine failures [18]. Likewise, the author suggests that the areas of production and industrial maintenance require that the human factors that influence performance are continuously investigated and cannot focus exclusively on the reliability of equipment and systems [19].On the other hand, it is proposed lean manufacturing tools such as 5S and TPM, eliminate the lack of added value provide an efficient and effective practice, so that, "process improvement is used to develop the improvement of the quality of finished products based on customer needs" exposed by [20]. Similarly, the use of the tool to eliminate waste from the inventory maintenance area and subsequent to that the TPM tool is used to establish zero defects and zero breakdowns for the machines of a production line. Likewise, the author agrees with the improvement of the quality of the finished products. After starting the TPM, the waiting time between work units is reduced, therefore, the cycle time has been improved by 37.30% and the reduction of Work in Process is 49.04% in a textile company [21].

III. CONTRIBUTION

A. Foundation

After having carried out the research of the literature based on scientific papers, the most representative success stories were selected and with this a comparison of the tools was made, as well as the methodologies developed, the benefits and their contributions in each case that manage to solve the problem of low g Overall Equipment Effectiveness.

In order to achieve the increase on the production efficiency of the company through the OEE indicator (Overall Equipment Effectiveness), tools such as SL have been chosen, because it allows us to make a new relocation of the areas of the process, movements of machines and allows us to reduce the distances due to the long routes made that finally leads us to be able to reduce cycle times of production. The 6S tool was also chosen to considerably reduce excessive mess and dirt in the work areas that is inherent to the search time which will allow us to eliminate activities that do not add value. In addition, the tool for studying methods, times and movements that involves activities that, carried out in the manufacturing process, bottleneck process, improve inadequate working methods. As the basis of the solution proposal also involves autonomous maintenance and planned maintenance these belong to the Total Productive Maintenance (TPM) methodology, it is one of the most important when we want to provide a solution to a problem of low efficiency in a production line, that is why it's one of the important tools in our proposal model. This methodology is structured with 8 pillars; however, the development of all these adjusts the needs presented by an MSE company that is the sector. According to the above, it is proposed to use 2 pillars of the TPM: planned maintenance and Autonomous Maintenance since it allows us to easily implement improvement activities having notable changes in a short term, with ease of adaptation and with a lower investment.

B. Proposed Model

A proposed model was proposed that is shown in Figure 1 which is composed of the inputs that are the data of the company, analysis of the data and the selection of the methodology. The first component shown belongs to the main diagnosis of the company with the use of tools such as the problem tree, ABC and PQ diagram, AVA matrix, Value Stream Mapping (VSM) and thus be able to verify the current situation and obtain an initial diagnosis of the company.

The following component 2 describes the SLP and 6S tools that are tasked with reorganizing and cleaning areas to reduce production cycle time. The last component makes use of the study of methods, times, and movements to improve the working methods used in the clothing area currently with the 2 pillars of TPM that can solve problems such as failures such as constant machine stops by the hand of the 2 pillars: autonomous maintenance and preventive maintenance.

Finally, through the implementation of the tools, we achieve a standardization of the processes and help us to evaluate the scenario before and after the implementation. Likewise, to achieve a positive impact in the textile sector, a constant improvement based on an evaluation of results is required, for this reason the proposed model is focused on the use of the Lean Manufacturing methodology, the tools involved in this methodology will manage to generate large changes focused on the optimization of processes at any scale, as the second selected methodology is Kaizen, which aims at continuous and progressive improvement of all processes and seeks the participation and involvement of company personnel to achieve common goals.

In our proposed model it can be noted that the Lean Manufacturing philosophy and Kaizen interact in a complementary way so the advantage of this methodology is enhanced because, by implementing the tools help to reduce waste in the process, making it much more efficient; it also has an important and necessary continuous improvement approach, which makes this proposal applicable to companies as changing as they are the textile companies.

Through the implementation of the proposed methodology of the model, it was sought to generate solutions to a common problem in textile companies such as low efficiency, which was able to increase by 13%, which translates into greater production, which encourages growth in the company generating more jobs.

C. Model Components

The design of our model has three components: First component is the Initial diagnosis; the second component is the organization of the workstations and the production process, and the third component is the optimization of activities and times throughout the process and maintenance that are based on Lean Manufacturing tools and the Kaizen methodology with the purpose of increasing OEE.

1. Initial diagnostic

The first component involves diagnostic tools used to obtain data and perform analysis based on it to generate a substantial impact regarding the problems presented by the company under study. The development of an ABC and PQ analysis to determine the identification of the most demanded products of the company. The Visual Stream Mapping will allow us to evaluate the current situation of all the areas of the company with data such as the cycle time of the processes, and lead time of the production process, etc. In addition to having the AVA matrix to be able to identify the activities that do not generate value throughout the production process. The tack time graph was made and compared with the times of each process. Through this calculation it was possible to identify which are the processes that cause delays within the process called bottleneck. It was determined that the bottleneck process is the confection process. Table 1.

Available time: 17.9700 seconds / week

Average weekly demand: 149.63 coats/week

Tack time: 20.02 min/coat

Tack time: 1,200.01 seconds/coat

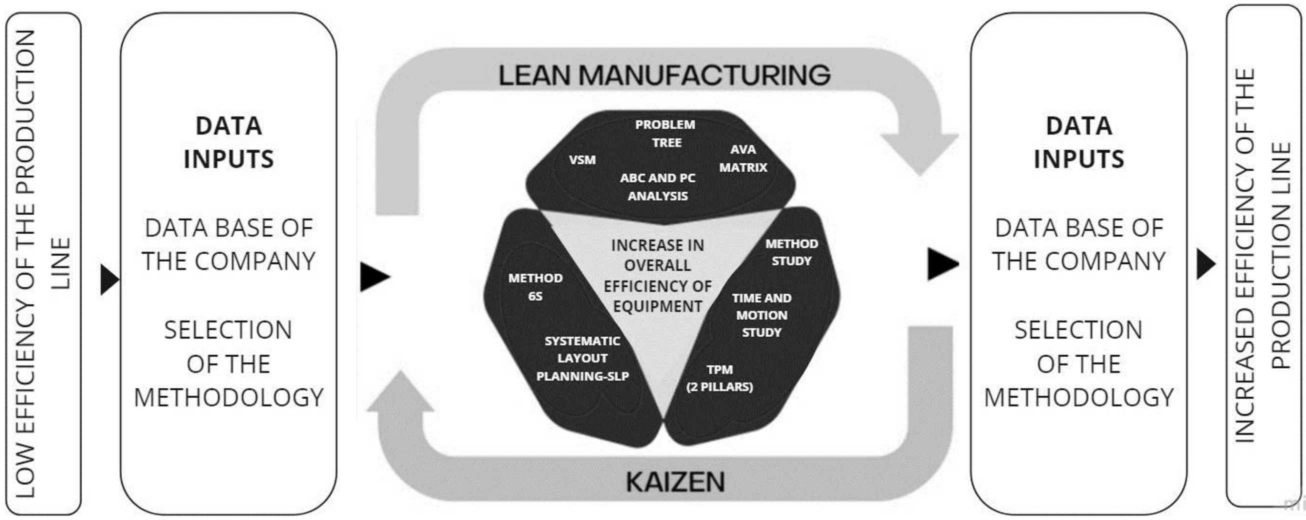


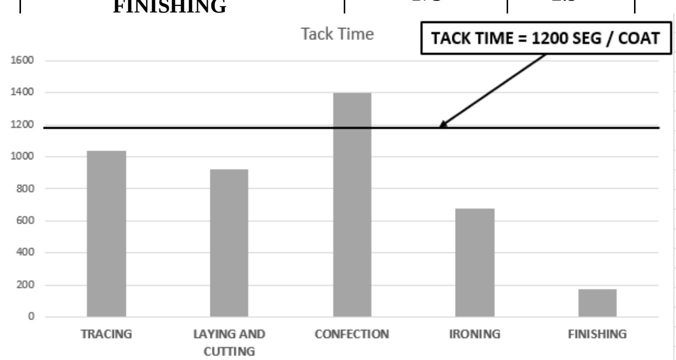
Figure 1 Proposed model design

TABLE I

CYCLE TIME OF THE PRODUCTION PROCESSES OF A COAT

Figure 1 Time bar chart by areas

Cycle Time		
Processes	**Seconds**	**Minutes**
TRACING	1,035	17.3
LAYING AND CUTTING	924	15.4
CONFECTION	1,400	23.3
IRONING	675	11.3
FINISHING	173	2.9



It can be concluded that for our research work we prioritized the manufacturing process, being the process with the longest time before tack. Figure 2.

2. Organization of workstations and the production process

The second component to make do with the tools of SLP and 6S. The systematic design planning (SLP) tool is worked on based on the relationships of the areas of the productive process with the aim of reducing distances and consequently reducing the times of the process involved. To carry out the redesign of the plant, the reorganization of the areas is required.

That will allow an optimal flow of materials and seeks to eliminate those processes or activities that do not generate value within the productive process on the organization of the workstations.

The 6S tool seeks to eliminate elements to keep workspaces tidy and clean that allow greater productivity in productive activities. Traditionally they are Seiri, Seiton, Seiso, Seiketsu, Shitsuke and the sixth is the operator's occupational safety through OHSAS 45001. It begins with an initial audit to obtain a score regarding the current situation of each S. Then we proceed to the development of the first S, which is to classify, where unnecessary tools and machines are identified. In addition to separating useful and unnecessary materials. The second S is to clean and eliminate the sources of dirt and keep the supports in perfect condition. The third S is to sort and locate manufacturing tools giving them a strategic location for work in progress. The fourth S is Security where the IPERC of the work areas must be carried out and the necessary personal protective equipment is determined. The fifth S is for standardizing and recording manufacturing activities where changes must be maintained through visual control. Finally, the sixth S is discipline, in which the corresponding meetings and training are held, evaluating compliance with standardized procedures.

3. Optimization of activities and times throughout the process and maintenance

For the third component, the optimization of activities and times throughout the process and maintenance is detailed. A restructuring of the activities that are carried out in the current production process must be elaborated with the study tool of methods, times, and movements. It begins by selecting the manufacturing area for the study of methods, then the timing of the manufacturing process of the main product is recorded. Then, a process activity diagram must be made to identify the activities that generate value and those that do not generate value within the entire manufacturing process. The construction of the new method proposed for the manufacture of coats is carried out. We continue with the realization of a proposed bimanual of clothing activities. Then the procedures of the manufacturing process must be documented. To then implement the new work method and clothing activities. Finally, maintain the new procedure proposed by means of an activity control.

In addition, the two pillars of TPM are implemented, making use of its two pillars which are autonomous and preventive maintenance in which a single monthly maintenance plan can be created, training for operators based on knowledge of machine maintenance.

D. Indicators

To measure the development of the proposed model and each of its components, indicators are used to validate the results. Below are the indicators expressed in percentages that measure the improvement of the company under study.

1. Percentage reduction in the transfer time of the entire production process of the garment. It will indicate the degree of reduction of the transfer time for the entire production of the garment. The result obtained measures the initial transfer time, with respect to the measurement of the time clocked before and after the implementation of the improvement.

$$\%_{ROUTE} = \frac{Route_{before} - Route_{after}}{Route_{before}} \times 100\ \%$$

2. Percentage reduction in the time spent searching for materials, tools and parts used by operators during the manufacture of the garment. It will provide us with the degree of reduction in search time for the tools. The result obtained measures the total search time, compared to the total search time before and after the implementation of the improvement.

$$T_{Search} = \frac{Tc_{before} - Tc_{after}}{Tc_{before}} \times 100\ \%$$

3. Percentage reduction in manufacturing activity time: Indicates the degree of reduction of time in carrying out the manufacturing activity. The result obtained measures the activity time in which the activities are carried out, expressed as a percentage, with respect to the measurement of time before and after implementation.

$$\%T_c = \frac{Tc_{before} - Tc_{after}}{Tc_{before}}$$

4. Overall Equipment Efficiency (OEE):

This indicator measures the manufacturing efficiency in a production line with zero defects, it is an integral tool that measures 3 component factors which are availability, efficiency, and quality, which evaluate the production process. The formula for calculating this indicator is as follows.

$$OEE = Availability \times Performance \times Quality$$

IV. VALIDATION

A. *Foundation*

After having carried out the research of the literature based on scientific papers, the most representative success stories were selected and with this a comparison of the tools was made, as well as the methodologies developed, the benefits and their contributions in each case that manage to solve the problem of low g Overall Equipment Effectiveness.

In order to achieve the increase on the production efficiency of the company through the OEE indicator (Overall Equipment Effectiveness), Therefore, the SLP (system layout planning) tool is proposed, which focuses on the efficient use of resources, work areas and equipment in the plant [22]. The productive activities and the layout of the garment machines using the relational table where the areas are redesigned based on the previous analysis, reducing the transfer time. The 6S tool was also chosen to considerably reduce excessive mess and dirt in the work areas that is inherent to the search time which will allow us to eliminate activities that do not add value [11], with the purpose of reducing the time of activities that do not generate added value, such as the time spent searching for materials, the reduction of accidents and the reduction of costs of items that are not used. In addition, the author in this study suggests integrating an additional "s" based on safety as the fourth phase of the methodology [10].

In addition, the tool for studying methods, times and movements that involves activities to be able to restructure their current activities and use other techniques that are within the standard for the textile and apparel sector. The standardization of work through a study of times and movements that allows balancing the times of the activities in the work areas in order to reduce unnecessary movements and increase production efficiency [12]

As a previous step, the 6s tool is used as a prerequisite and previous step to the application of TPM [3]. Likewise, the operators are trained in the proper handling of their machines and a monthly maintenance plan is created, which the personnel must exercise by applying in a structured [23].

Finally, after implementing the tools that help to improve the production process, the aim is to maintain these improvements over time to improve the production of the company, through continuous data analysis and standardization of processes [24].

B. *Company*

The company's main problem is low overall efficiency (OEE). To solve the problem, it was determined thatthe root cause of unnecessary transfer time was identified as the second activity the second activity that occupies the most time represented by 35% the delay due to the search for materials on the worktable with 11.6% of the manufacturing. activities, unnecessary movements represent 14% of the activities that do not generate value in the manufacturing process. Finally, repairs due to failures due to downtime due to breakdowns with the MTBF (mean operating time) and MTTR (mean time to repair) indicators, for which an initial availability of 85.65% is obtained.

C. *Validation design*

1. *SLP*

After detailing the composition of the SLP tool, it must be validated through the pilot plan and show the evidence that the tool is valid in order to reduce the transfer time, for this a relational table of activities was used to relocate the areas that were find a close relationship according to the flowof materials. As a current situation, time was taken and a timeof 105 minutes of transfer time resulted. The pilot development plan explained in chapter three in component number two was carried out, following the steps of the implementation of the pilot plan and with the new rearrangement of the workshop layout, which proposal number two was chosen. Which gave us a total of 88 minutes of transfer time. A reduction of 15% is evident with respect to the time it took with the current layout. Table II. The current indicator, the expected indicator and the result of the validation of the SLP tool are shown below.

TABLE II
RESULT OF THE SLP METRICS

Tools	Indicator	As Is	To Be	Validation Results
SLP	Transfer time	105 min	89,25 min	88 min

2. *6S*

For the validation of the 6S tool, an internal audit was carriedout which allows us to support our results. This audit evaluates each "S". We obtained the result of the audit with an average of 0.9 on a 5-point scale, below what was expected. This is why we apply what was developed in the second component in order to validate it in the same workshop. After having applied the 6s tool, we find a favorable average of 4.5 on a 5-point scale. Said indicator goes hand in hand with taking the time for the indicator, which is the search time for materials, tools, and parts, whichwent from 125 minutes to 47 minutes, so we can validate that said method is efficient for our research work. Table III.

TABLE III
6S METRICS RESULTS

Tools	Indicator	As Is	To Be	Validation Results
6S	Time to search for materials	125 min	50 min	47 min

3. *Method study*

The method study tool is used to reduce the time of the preparation activities, the chosen validation method is the pilot. In order to reduce the preparation times of the operators, the following improvements are implemented: the first one is the tables that are available for each machine. the second is the new distribution to reduce the flow time of materials in process, the third is the standardization of manufacturing processes through bimanual diagrams. Achieving as a result a reduction in the preparation time from 1200 seconds to 1089 seconds. Table IV. Therefore, the study of methods and movements is validated in this way.

TABLE IV
SUMMARY OF THE TIME OF THE MANUFACTURING ACTIVITIES AFTER THE PILOT VALIDATION

Station	Time VA	Time NVA	Time Total Time
Confection	1061.76	27.24	1089
	97.5%	2.5%	100%

4. *TPM*

The 2 pillars of the TPM proposed for the bottleneck area were applied, that is, for the garment machines (straight and overlock) progressive training was made, autonomous maintenance was introduced with instructions for activities that can be carried out by the operators providing them with independence, list of resources necessary for maintenance, breakdown format and fault registration that allows us to reduce the breakdowns of the machines. The indicators of mean time to repair (MTTR) and mean time of failure (MTBF) are evaluated in the simulation software, proposes the author [25]. Therefore, availability increased by 5.99%. Table V.

TABLE V
RESULTS OF THE TPM METRICS

Tools	Indicator	As Is	To Be	Validation Results
TPM	% OEE	62 %	83 %	75 %

According to the results of the software there was an average increase of 83% in the use of the machines. A greater use in the machines of each of the denotes a greater availability of the equipment, factor which contributes to the increase of the indicator of the overall efficiency of equipment. In table IV shows a 13% increase in OEE. Table VI.

TABLE VI
RESULTS OF THE TPM METRICS

	Name	Type	Up Time	Up Time Units	Down Time	Down time
1	Machine A Failure 1	Time	NORM(150.25 , 12.4)	Hours	NORM(1.36 , 0.3)	Hours
2	Machine A Failure 2	Time	NORM(165 , 11.33)	Hours	NORM(2.13 , 0.25)	Hours
3	Machine B Failure 1	Time	NORM(113.90, 9.28)	Hours	NORM(6.17 , 2)	Hours
4	Machine B Failure 2	Time	NORM(115.05 , 15.4)	Hours	NORM(4.75 , 1)	Hours
5	Machine B Failure 3	Time	NORM(115.85 , 11.5)	Hours	NORM(4.02 , 0.8)	Hours
6	Machine B Failure 4	Time	NORM(115 , 10.5)	Hours	NORM(4.35 , 1.4)	Hours
7	Machine B Failure 5	Time	NORM(116.60 , 9.4)	Hours	NORM(4.62 , 0.9)	Hours

V. CONCLUSIONS

After the application of the corresponding solution tools of the Lean Manufacturing tools and the Kaizen philosophy, an increase of 13% was achieved in the Overall Equipment Effectiveness (OEE) indicator for the garment manufacturing process, which leads us to classify the company in an acceptable competitiveness range, taking into account the short time that the application of these tools was carried out, it can be seen that the results point to growth.

Through the implementation of the 2 pillars of TPM and the training provided, a commitment on the part of the operators was observed, which resulted in a greater responsibility in the care of the machines and a better order in their workplaces. After the simulation the indicator that was evaluated in these results is the percentage of machines utilization, the percentage of availability was increased by 7 % which indicates a higher utilization of the machines of the workstations.

The company in the case study had a cycle time of 20 min/garment, so after the implementation of the solution tools, a reduction in cycle time of 18 min/garment was noted in the production line. By using an inadequate manufacturing method, there were more activities that did not generate value within the production process, which represented 14% of the total, but by eliminating them, the manufacturing time was reduced.

The economic evaluation demonstrates the impact of the solution tools, which shows us results of the economic flow, obtaining a NPV of $3,367 and an internal rate of return (IRR) of 86.43%, demonstrating the feasibility of the project.

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