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Model based on the Lean Manufacturing methodology to increase the OTIF of a MYPE company in the textile sector.

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Abstract*– Textile companies in Peru are currently facing problems of low productivity and exports, caused by the COVID-19 pandemic, generating a deficit in the trade balance and forcing producers to be more competitive. Reason why the national industry seeks to raise the standards of delivering products on time and fully delivering orders, increasing the level of service offered. For this reason, an improvement model is proposed for its application in the printing area of a Peruvian MYPE textile company, which will seek to improve production times and reduce reprocessing in order to increase the company's OTIF. Finally, the validation will be carried out through simulation to rein in the viability of the improvement model in the textile company and to validate the effectiveness of the proposed tools to solve the existing problems in the printing area.

***Keywords*-- Lean Manufacturing, OTIF, Method Study, Preventive Maintenance, SMED.**

I. INTRODUCTION

The textile industry plays a fundamental role in the economies of several countries. The textile industrycontributes 10% of the total employment in Peru and in the manufacturing sector it represents 1.9% of the Peruvian GDP. However, the textile manufacturing sector was affected by the COVID-19 pandemic, with a 43% decrease in exports in 2020,a percentage comparable to 2019. Therefore, during the pandemic, the Peruvian government sought to guarantee the permanence of the companies affected by COVID-19 through economic reactivation, granting loans to large companies and MYPES with economic sources of financing, in order to maintain the permanence of companies in the market.

As mentioned above, the textile industry is vital for many developing countries, since it generates employment and stable work. However, certain companies in the sector are experiencing problems with production delays and rework. Those problems generate decrease the OTIF indicator of a certain company, compared to other competitors. In the same way, it causes economic impact in payments for penalties and loss of dissatisfied customers [2]. Through literature reviews of the manufacturing sector, the authors made efforts to reduce the problems caused by production delays of companies in various sectors. Where several organizations mention they carry out bad practices and work methods, which fail to correctly optimize the processes, as well as an inefficient maintenance plan for the work machines and the high configuration times that must be carried out for each style and type of batch. Product for which companies do not have an approach to adequate management of certain factors that affect production time. In the same way, having bad processes and inefficient work methods cause an increase in production costs and an increase in the cycle time for each batch or unit produced [1]. Which, through several success stories in the manufacturing sector, the Lean Manufacturing tool helped to meet the expectations of improving processes with high success stories. In view of what is mentioned in this research article, the focus will be on reducing the problems that occur in the company's stamping area, that main bottleneck process of the production lead time [2].

This article has an organized content, starting with a summary, followed by the literary description of the methodology, existing tools and methods of proposals used for the development of the study. As a third point, it is described how the proposed improvement model resulting from the combination of a methodology to reduce production times, preventive maintenance of the machines and the application of the SMED has been structured, then the flow of the new proposed work method. Finally, the validation of the project is disclosed to show the viability of the project that is implemented, finally the discussion and the conclusions of the investigation in order to increase the OTIF of the company.

II. STATE OF THE ART

A. *Lean Manufacturing to increase the OTIF of the textile company.*

Textile manufacturing companies continually use the OTIF as an indicator that measures the number of shipments that are delivered to their destination according to the quantity and schedule specified for the order [1]. For this reason, many MYPES manufacturing companies currently calculate the OTIF in different ways, taking into account the gap that the production participants sit down to discuss the performance of the distribution of orders [2]. On the other hand, internal business processes often delay order fulfillment as many businesses prioritize improving performance based on inconsistent data and requirements. Also, the effort required to align with an OTIF definition and correct performance measurement distracts transacting parties from understanding and addressing the root causes of performance problems [3] [4]. OTIF generally refers to the right products in the right quantities delivered at the right time. Also, the most effective approach for companies to take is to opt for the producer and customer to agree on the target OTIF standards, as failure to adhere to OTIF standards can have real financial impacts in many industries, as many Companies lose and have a negative impact on their annual sales due to late and incomplete deliveries. Therefore, the company must find a solution to increase its OTIF to avoid severe sanctions from customers and companies for not complying with delivery on time and complete orders. For this reason, using Lean Manufacturing tools has the focus of improving production systems, based on the reduction and/or elimination of processes or activities that do not generate or add value to the production processes or to the customer. Those eliminations are called waste, processes that cause long waiting times or non-conformity in the products. Given this situation, it is extremely necessary and essential that companies have the initiative to incorporate Lean Manufacturing, given its approach to reducing costs and increasing billing through the systematic and continuous elimination of activities without added value. On the other hand, for the identification of process waste, the VSM (Value Stream Mapping) tool should be used to obtain a better overview of the current situation of the company, with the aim of identifying and eliminating activities that do not contribute and have value in production. Likewise, the importance of Lean Manufacturing optimizes process management through the integration of tools focused on solving problems related to optimization of production times and resource costs to reduce operating costs[5]. In the same way, it seeks a better efficiency of work processes and defines very useful tools andcan also be directed to the MYPE sector. However, many textile industries do not implement Lean Manufacturing, due to lack of knowledge in its implementation, resulting in losses of productive time, effort and money in reprocessing, in addition to the high levels of unproductive time that occur delaying the cycle time of production.

The implementation of Lean Manufacturing tools in today's competitive market offers results in solving various problems related to textile manufacturing industries across thespectrum for survival and success. In the same way, it allows companies to increase the OTIF, minimize stocks of raw materials and finished products, minimize operator idleness through efficient work assignment and minimize production processing times.

B. Study of Methods in the textile sector to optimize cycle times and reduce reprocessing.

The study of methods in textile processes allows validating a method that achieves goals, objectives to improve processes and specific quality characteristics that are required [6]. However, currently these organizations allow operators to carry out and develop their own work method, this has a negative impact on the scope goals in improving processes. On the other hand, when there is a problem that has to do with reprocessing, it becomes very difficult to find the root cause, because it can be the product of different work methods that were carried out [7]. Given this situation, by not specifically. establishing the correct process, the reprocesses affect the income of the companies [8][9]. In many garment industries, method study is not strictly followed, resulting in higher cost of production and increased lead time of orders to the customer. Along with other work measurement techniques, method study can play a vital role in utilizing resources to improve profit margin and those influences improving company performance [10]. In the same way, various applications of the study of methods require a prior evaluation of the processes that generate production problems, through the techniques of sampling, data collection and analysis. Therefore, improving production through the study of methods and times increases the production and work process capacities in terms of production cycle time, number of processes and production rate, proposing an efficient work process to the company.

Implement improvements in the processes through the study of methods, directly influence an adequate production time [11]. Therefore, the garment industries are always trying to improve the production and quality of the garments to stay in the huge competitive market, since the manufacture of garments implies a series of operations carried out in different places by the operators, where these activities must be carried out in a synchronized, planned, and timely manner to achieve the desired on-time production [6][7]. Finally, the project carried out in the company based on the study of methods and times, has allowed an increase in production and a 60% reduction in rework in a textile area with production and reprocessing problems [8][9][10].

C. SMED and Preventive Maintenance of machines in the textile industry

In the current business scenario, each textile manufacturing company faces increasing competition, therefore, it tries to be an effective producer in the shortest possible time and at low cost of its product with high productivity. On the other hand, one of the improvements thatthe TPM has, is to allow a model with tools that can be complementary to improve the global efficiency of the machines at percentages that are competitive. In the same way, the strategic result of preventive maintenance implementations reduces the occurring failures and breakdowns of the machines that interrupt the production process, cause losses and increase production times, these problems cause losses that can exceed millions of dollars a year. TPM uses OEE as a quantitative metric to measure the performance of a production system, with the overall goal of increasing the overall effectiveness of the equipment. In studies carried out, the application of preventive maintenance as a work plan for periodic maintenance and improvement of the global efficiency of textile production machines, is an activity considered fundamental in a textile company, with theaim of avoiding unplanned machine stoppages in full production and increase machine availability [11][12]. Many times, it is not possible to achieve textile productivity in the shortest possible time and deliver customer orders on time, due to factors related to capacity problems and problems related to machine performance, such as breakdowns, failures, stops of machines that have not been planned and speeds in performance. Faced with this situation, companies make an unnecessary extra investment in the purchase of new equipment, increased shifts and working hours. Likewise, the problem of programming and adaptation in the machinery for each type of batch to produce, depend on the sequence, that is, the configuration time depends on the sequence of tasks / batches in the machine [13] [14]. Given the current trends in industrial manufacturing and requirements such as high variability, customization and reduction of product life cycles, organizations seek to implement new SMED methodologies to adapt and respond with greater flexibility to the new demands of global markets [15]. On the other hand, during external activities, the rest of the internal activities are simplified, thus standardizing the activities to carry out the elimination of unnecessary operations, as well as downtime or waste of other resources. By implementing preventive maintenance in an organization or work area, the increase in the availability of the machines reaches 13% by reducing the rate of unplanned stops and the cycle time in the production machines, to satisfythe demand in the right time. Implementing the SMED methodology in an industry made it possible to reduce changeover time and configurations in just 76 minutes, representing a significant reduction of 30% of the original changeover time. This reduction was made possible by modifying 14 different steps of the change process [11][12][3]. Likewise, the time for changing parts was reduced from 142 minutes to 117 minutes in a manufacturing company with highly complex machines. Therefore, considering the financial aspects, companies can save costs for each change. In the same way, the implementation of the production SMED for the process of changing activities, obtains considerable savings in time and significant savings in material, increasing the availability of production time and theproduction capacity of the machines and the increase in production capacity can be quantified through the additional income generated by the sale, imposing significant economic savings [14][15].

III. INPUT

A. Rationale

The proposed model is developed based on the Lean Manufacturing model and the model will be applied in thearea of the stamping process, where the tools belonging to the Lean model are mentioned and implemented, such as preventive maintenance and SMED. In the same way, in the improvement model it was complemented with the study of methods and times, to optimize production times and avoid reprocessing. With the purpose that the orders are deliveredon time and are delivered complete to increase the OTIF ofthe company.

B. Proposed model.

The design of the proposed model mentions the tools to be used to improve the company's OTIF. It should be noted in Fig.1, the improvement model works as a component implementation cycle, starting with the implementation of the first component 1, where the preventive maintenance tool (Pillar of the TPM) will be used, to impose a maintenance plan for machines and equipment periodically and increase the availability of machines. Subsequently, component 2 will be implemented, which will apply the study of methods and times, to optimize current work methods, production times and reduce reprocessing and finally component 3 will use the implementation of the SMED tool in the stamping area to optimize setup times for automated screen-printing machines.

TABLE I
COMPONENT 1 ARTIFACT

Previous evaluation for the maintenance plan of the stamping area			
Issues	Critical	Regular	Good
Mean Time Between Failure Frequencies	✓		
Impact of machine stops on operations	✓		
Flexibility in failover operations		✓	
Maintenance staff safety	✓		

C. Model detail

For the implementation of preventive maintenance belonging to component 1 of the improvement model, the instrument in Table I was used for the evaluation and approach to be developed, to correctly implement the preventive maintenance plan in the stamping area. The proposed artifact is a Check List format, which will allow us to analyze and evaluate the information collected on the frequencies of failures and periodic existing breakdowns ofthe machines, as well as the impact caused by the failures of machine in full production and the flexibility of the stamping area, referring to its ability to cover production when there are faults in the machines and finally in what state the operators are currently performing, which can be analyzed using the

TABLE II
COMPONENT 2 ARTIFACT

Implementation analysis of the new working method			
Issues	Critical	Regular	Good
Cycle time in screen printing	✓		
Reprocesses in screen printing	✓		
Operator fatigue		✓	
Current working method	✓		

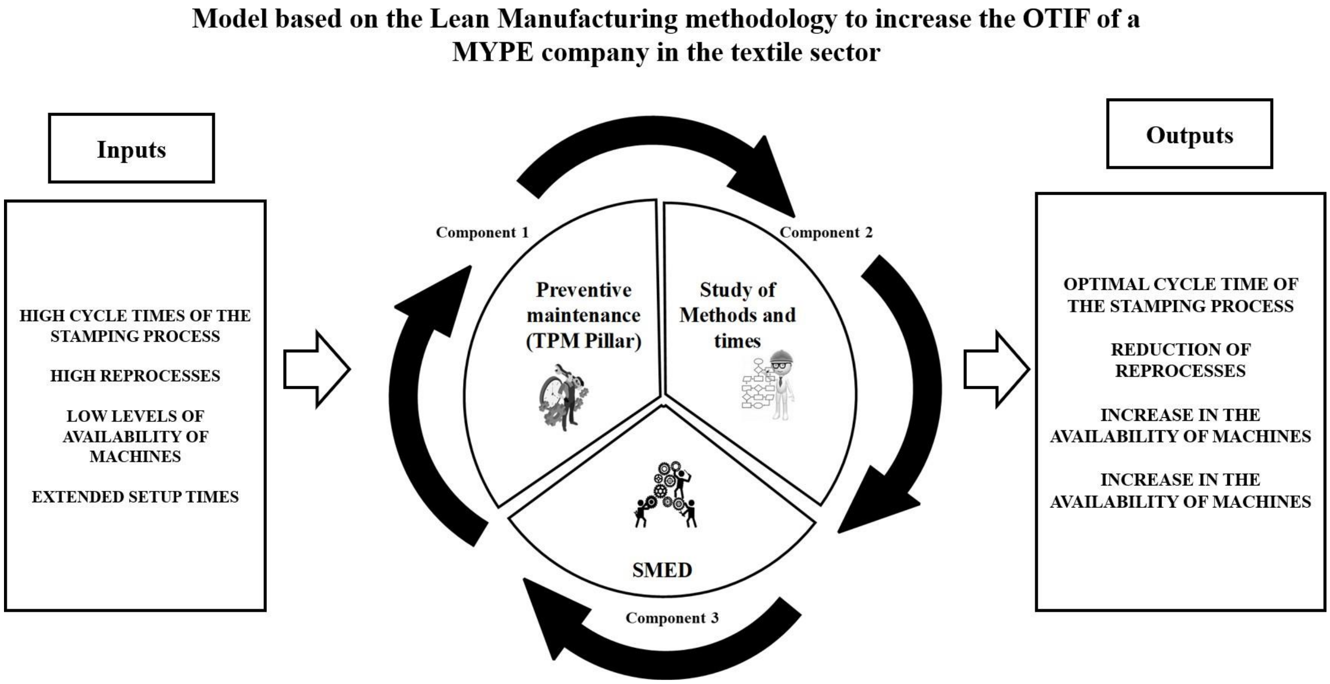


Fig. 1 Improvement model to increase the OTIF.

table if it counts with the necessary safety equipment to carry out maintenance work on machines and/or work equipment.

On the other hand, for the implementation of the study of methods and time of the stamping processes, to analyze the implementation of the new work method that is to be developed. Table II is an artifact proposed in a Check List format, which can define that the existing problems start from the critical to good level, allowing to analyze and evaluate the problems that cause production delays and rework. Therefore, in that artifact, the 4 main problems evidenced in the visits made in the stamping area were considered and in addition to being collected by the information provided by the company.

Finally, for the implementation of the SMED, Table III is displayed, which will use the artifact in table format for the analysis of the conversion of internal activities into external activities for the automated screen printing machine, this format was adapted and I add the times of each activity to find the main focus of focusing the tasks related to the handling of products and materials, information gathering, cleaning, maintenance, adjustment and control with their respective time it would take to carry out that activity and analyze the new times obtained by the changes of activities..

D. Proposed Process

The main contribution of this research is the model of the new method of the screen printing and stamping process, which will be applied in the stamping area. In Fig.2 shows the processes, beginning with the intervention of the inspection operators, who will have a Check List format, so that they can follow up on the verification according to the requirements of the quality of the fabric that the inspections must present pieces from the cutting area, so that they are accepted in the verification. Subsequently, the operators in charge of stamping will monitor the placement and removal of poles from the machines, in addition to monitoring the entire production to avoid inconveniences caused by the machines. Finally, once the stamping process is finished, those in charge of the stamping system output inspection will verify the quality of the stamping made on the newly stamped part, verifying its resistance and other requirements found in the Check list format, which they must comply with certain production standards so that they are accepted and can go on to the next process.

TABLA III
COMPONENT 3 ARTIFACT

Conversion of internal activities to external ones	Time (min)
Move the screen printing frames to the cleaning area	1.25
Clean and wash screen printing frames	36
Move mechanical screen-printing brushes to cleaning area	1.25
Washing of mechanical brushes in the cleaning area	8.9
Transfer the screen-printing compressor ink tubes to the cleaning area	1.36
Clean and wash the compressor ink tubes	3.87
Assemble all washed parts to carrier	2.48
Transport all carriage-mounted parts to stamping area	1.25
Clean and maintain compressor air in the power supply area of the plant	9.45
Total, minutes of external activity	65.81 min

E. Indicators

- **OTIF indicator**

It allows to measure the On Time and the In Full to identify the OTIF of the company.

$$On\ Time\ (\%) = \frac{Number\ of\ deliveries\ made\ on\ time}{Total\ number\ of\ deliveries} \times 100$$

$$In\ Full\ (\%) = \frac{Number\ of\ complete\ deliveries}{Total\ number\ of\ deliveries} \times 100$$

$$OTIF = One\ Time \times In\ Full$$

Scenery:

- Optimal: >=85%
- Normal: 50% > x < 85%
- Pessimistic: <= 40%

- **Stamping cycle time indicator**

Allows to measure the production cycle time per batch in the stamping area

$$Cycle\ time = \frac{Total\ production\ cycle\ time\ per\ batch}{Number\ of\ units}$$

Scenery:

- Optimal: <= 210 hours
- Normal: 250 hours > x < 210 hours
- Pessimistic: > 290 hours

- **Screen printing reprocessing indicator**

It allows to measure the percentage of screen printing reprocesses of the basic pieces in the stamping area.

$$Reprocesses\ (\%) = \frac{Non\ reprocessed\ poles}{reprocessed\ poles} \times 100$$

Scenery:

- Optimal: <= 8 %
- Normal: 15% > x < = 8%
- Pessimistic: > = 40%

- **OEE indicator for stamping machines**

It allows to measure the percentage of the global effectiveness of productive equipment (OEE)

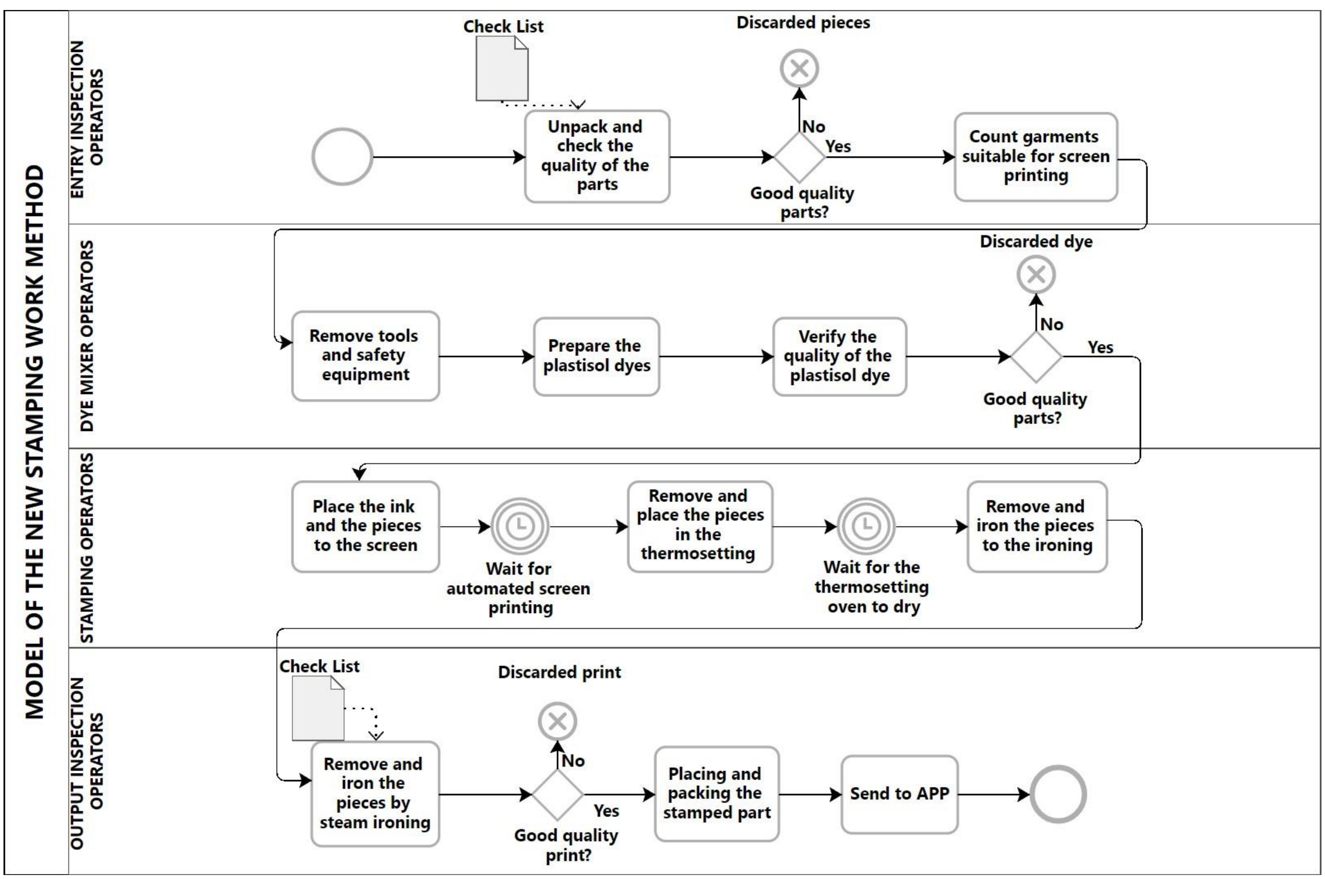
$$OEE\ (\%) = Availability\ x\ Performance\ x\ Quality$$

Scenery:

- Optimal: > = 85 %
- Normal: 65% > x < = 75%
- Pessimistic: < = 65%

- **Set Up time indicator for each machine.**

It allows to measure the reduction time of the Set Up of the automated screen-printing machine.



$$Set\ Up\ Reduction = (Current\ time - Reduced\ time)$$

Scenery:

- Optimal: < 3 horas
- Normal: 3 < = hours > x < 25 = hours
- Pessimistic: > = 10 horas

IV. VALIDATION

A. Validation Scenario

The validation of the improvement model proposed in the research was carried out using the Arena simulator, the simulation will start from the lead time of polo shirt production, from the process of enabling the raw fabrics to the management of the packing list and boxed. However, the mainenvironment of the validation scenario will be in Stamping.

The stamping process because it is the main bottleneck of the company, and it is the scenario where the components of the improvement model will be implemented. Therefore, Figure 3 shows the validation scenario of the stamping area, currently made up of manual screen-printing workstations, automatic and semi-automatic machines, those machines carry out the stamping process from the entry of the batch of pole pieces. from the cutting area. Therefore, the Arena software will allow us to understand the behavior of the stamping area when applying the artifacts proposed in the contribution and thetools proposed for its application. The company's infrastructure is located in Lima-Peru, it has 5 areas of production processes, such as the process of dyeing fabric, cutting parts, printing parts, clothing and polo shirt finishes. Finally, the historical information of the orders delivered was collected, to calculate the OTIF of the company.

B. Initial diagnostic

According to the problem of the investigation, a series of indicators was established to determine the feasibility of the investigation. For this reason, Table IV started with the initial values by means of current indicators of the company. Regarding the objective value, those indicators were based on the research of authors focused on the textile sector. Therefore, obtaining the average OTIF indicator is based on research carried out in the MYPE manufacturing sector, the rest of the objective value indicators were also obtained through the investigation of scientific articles related to the applications of the proposed tools. for the improvement model, which process times were recommended, configuration of equipment in the adequate time of the textile sector and the number of reprocesses that a textile production company must reduce, to have adequate optimal production processes with the textile sector. Finally, in the table of indicators of the initial diagnosis, there is a differential column for each indicator to be improved, in order to have knowledge of what is expected to reduce or increase theresults of the indicators.

TABLE IV
INITIAL INDICATORS

Indicator	Initial value	Result	Gets better	Gap
OTIF	OTIF	41.08%	90 %	48.92%
% Reprocesses	% Reprocesses	36%	10 %	- 26%
% OEE	% OEE	74.54%	85%	10%
Stamping cycle time (hours)	Tiempo de ciclo de estampado (horas)	291.55	210	-81.55
Set Up Time (hours)	Tiempo de Set Up (horas)	3.55	2.25	-1.30

C. Validation Design

To carry out the validation through simulation in theArena software, we opted to obtain information from data belonging to the company, thanks to the fact that one of our research team performs his engineering practices in the company. The company, being a private entity, having as limits that the information was of a private nature, the requestand use of the company's data, the company manager was informed about the use of the company's information in sum research. The information obtained from the company falls from the last years of operation, for this reason in Table V theinformation of the records of the arrival time of each batch from the enabled parts to the stamping area is observed. Likewise, information on manual screen printing and automated screen printing. In the same way of the machines, such as the thermosetting oven, the steam iron and finally the packaging machine. These steps were carried out to obtain theaverage activity times for each batch arrival to the system andtheir distributions equally to each stamping machine.

TABLE IV
INPUT DATA FOR EACH WORKSTATION

Activities	Time	Distribution Type	Sample
Inter arrival time	TELL	EXPO (6.73)	529
Manual screen printing	TSSM	TRIA (47,52.5,59)	150
Automated Screen Printing	TSSA	6.44 + 2.96 * BETA (1.55, 1.68)	119
Thermo Set	TSTF	1.58 + 1.28 * BETA (4.17, 4.57)	210
Steam Ironing	TSPV	TRIA (1.71, 2.73, 3)	164
Packaging	TSE	NORM (1.32, 0.108)	106
Automated Screen Printed Set Up	SETSA	TRIA (3,3.36,4.27)	250

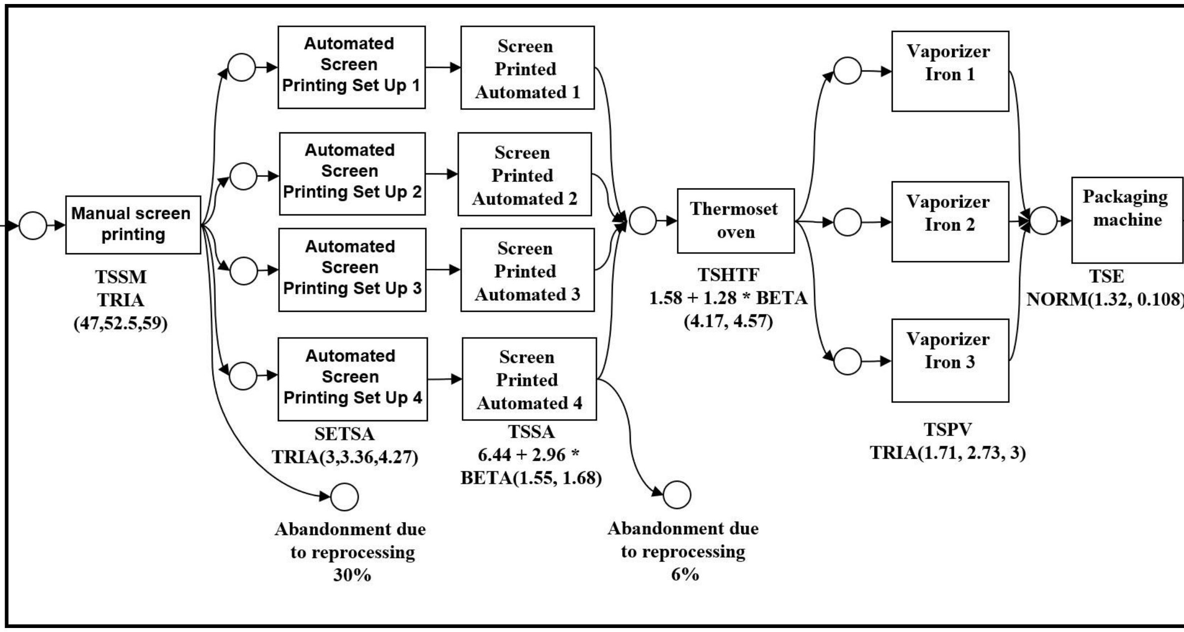


Fig. 3. Graphic representation of the simulation model in Arena

TABLE VII
MTBF AND MTTR INPUT DATA FROM STAMPING MACHINES

Machine	Mean Time Between Failures (MTBF)	Mean time to repair. (MTTR)	Samples
Packing	34.5 + 4 * BETA (0.893, 0.959)	TRIA (1.19, 1.78, 2.09)	106
Automatic screen printing	9.5 + WEIB (2.29, 1.39)	3.12 + 1.51 * BETA (2.83, 2.14)	199
Thermoset oven	11.5 + 3 * BETA (1.26, 1.04)	0.9 + 0.67 * BETA (1.56, 1.43)	210
Vaporizer Iron	16.5 + 9 * BETA (1.44, 0.917)	0.85 + 1.15 * BETA (1.68, 1.56)	164

In the same way, in Table VI, the simulator entered the data of the mean times between failures (MTBF), the mean time between repairs (MTTR), and the Set-Up time for each automated screen-printing machine. The sample amount of time between each repair of each machine, the number of failures in a period and the Set-Up times that were carried out for each arrival of orders, were variable between each machine.

D. Result of the validation and indicators obtained.

TABLE VIII
INDICATORS OF RESULTS OBTAINED

Indicator	Initial value	Result	Gets better
OTIF	41.08%	71.70 %	30.62%
% Reprocesses	36%	6 %	30%
% OEE	74.54%	81.20%	6.66%
Stamping cycle time (hours)	291.55	206.71	84.84
Set Up Time (hours)	3.55	1.52	2.03

To obtain the results, the simulation time was stipulated in 1 year, to visualize the panorama of the company after implementing the 3 proposed components. The results obtained are that 38 orders presented an average of 6% reprocessing, a percentage lower than the maximum allowed 10% of the client, which would become complete deliveries. Likewise, the total production lead time was reduced to 828.69 hours. For this reason, passing to workdays, it was considered that each day 14.33 hours are worked for 2 work shifts, a total of 57.82 days was obtained, which are within the allowed days, which are from 57 to 58 days. average.

$$Production\ lead\ time = \frac{828.69\ hours}{14.33\ hours} = 57.82\ days$$

However, of the total of 53 orders that were delivered to the client during the first year, an average of 38 complete orders were delivered, because the simulator took into account the variability of the reprocesses, which some orders exceeded 10 %, but they would not be so much higher than the allowed limit. Therefore, the calculations of the new OTIF% indicator will be made after the simulation in one year.

$$On\ Time\ (\%) = \frac{53\ orders\ delivered\ on\ time}{53\ total\ orders\ delivered} = 100\ \%$$

$$In\ Full\ (\%) = \frac{38\ orders\ delivered\ complete}{53\ total\ orders\ delivered} = 71.70\ \%$$

$$OTIF = 100\%\ (One\ Time) \times 71.70\%\ (In\ Full):$$

$$OTIF = 71.70\ \%$$

On the other hand, after the results obtained in the simulation, the Set-Up time was reduced, going from 3.64 hours for each machine to 1.52 hours. Likewise, the reduction of the cycle time of the stamping area was identified, thanks to the implementation of the new screen-printing method in the simulation, which would be the fully automated screen- printing process. On the other hand, the stoppages and breakdowns of the machines after a period of 1 year, theautomatic screen-printed octopus machine failed only 7 times, the times between repairs of each machine was an average of 48 minutes. In the same way with the other stamping machines,they have failed very few times during a year and their times between repairs were optimal. Therefore, to identify the new percentage of OEE, the new total of 36 unplanned hours was taken into account in the simulation, obtaining an increase in the availability of the machines to 81.33% and in the performance and quality of the machines. The OEE calculationwas made, obtaining a percentage of 81.2%, passing the acceptable percentage level.

$$OEE\ (\%) = Availability\ x\ Performance\ x\ Quality$$

$$OEE\ (\%) = 81.33\%\ x\ 99.94\%\ x\ 99.89$$

$$OEE\ (\%) = 81.2\%$$

In addition, the stamping cycle time was reduced from. 291.55 hours to 206.71 hours, reducing it by 84.84 hours when applying the 3 components proposed in the improvement model, in order to increase the % OTIF of the company. Finally, Table VIII can compare the results of the indicators obtained with the initial values.

V. CONCLUSIONS

- The implementation of the proposed solution regarding the new work method and new Set Up activities and the preventive maintenance plan in the stamping process, allowed to increase the OTIF indicator to 71.70% in the first year, after the implementation of the improvement model in the stamping area.

- Reason for changing from manual screen-printing method to fully automated screen-printing method, rework could be reduced to 6%. Said percentage of reprocesses, being less than 10%, validates the degree of customer acceptance, which in turn also increased the number of complete deliveries to 39% in the first year.

- The application of preventive maintenance tools resulted in a decrease in the unplanned time of the machines due to failures and breakdowns. What increases the percentage of availability of the machines and increases the working time so that the company can cover the specific demand.

- The application of the SMED component in the stamping area, allowed to reduce the Set-Up time for each automated screen-printing machine, reducing the cycle time of the stamping area for each batch of parts that enters the system.

- The profitability on the savings for payment of penalties to the client, in the first year after the implementation of the tools, an increase in savings of 82.8% was obtained compared to the annual economic impact that the company lost, having a saving of $ 45,024.00 in reduction of the payment of penalties for late deliveries and incomplete deliveries.

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