A model to increase efficiency in a manufacturing S&ME in the cardboard sector applying SMED, TPM, 5S and JIDOKA

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Abstract*-The manufacturing sector in Peru, represented 7.9% of the economic activity and paper and cardboard industries among them, represents 11.3% of the manufacturing activity analyzed until 2018, reason why companies must seek adequate control of their processes, maintain qualitystandards, reduce waste in the time of production and achieve good employment of its machinery. For this reason, based on the analysis of the Real Production Efficiency, 85% worldwide has been achieved and the company under study is below the aforementioned. The main purpose of this researchis to increase the efficiency in the production line of a small manufacturing company in the paper and/or cardboard sector, through the reduction of unproductive times that occur in one of the manufacturing processes and defective products. The contribution is focused on increasing efficiency, profitability and reducing the observed economic impact on the company. Developing the solution to this problem, the tools of the Lean Manufacturing methodology will be taken into account, which are the pillars of Total Productive Maintenance (TPM) that are Corrective, Preventive Maintenance and SMED. Additionally, the Jidoka and 5S tools will be used. In that sense, the main reason of this proposal was chosen is to maximize the resources of the paper and/or cardboard sector in this case of study; and that can be improved and become big, recognized and competitive in this field.

Keywords-SMED, TPM, 5S, Jidoka, cardboard sector, manufacturing sector, SMEs.

I. INTRODUCTION.

Currently, the manufacturing companies develop in a context where they are required to constantly increase their competitiveness, which is related to optimization and efficiency in production processes; For this reason, it is of the utmost importance to propose improvements where concepts are understood about the application of the tools ofthe Lean Manufacturing methodology that allow increasing its performance, effectively reducing the economic impact.

According to the INEI in 2018, it has been observed that SMEs have contrived an important source of development for the economy in Peru because they generate jobs for 60% of the working population [1].

The economic sectors and subsectors in Peru, such as micro, small and medium-sized companies, generate 20% of total sales, where it is necessary to improve the competition, productivity and efficiency of companies. This is because MSMEs face many challenges, where tax and labor policy is needed to generate their development and to increase these aspects. Some companies work under the conditions of productive capacities, technologies, new innovations and in different environments [2]. For the last months of 2018, the production of paper and/or cardboard products increased by 29.26%. In the BCRP study, in the lastmonth of 2019 the paper and cardboard sector increased by 0.2% in the contribution to growth and paper and/or cardboard packaging in the first months of 2020 increased by0.7% [3]. In this study, a case of manufacturing SMEs with low efficiency in one of their cardboard tube production lineswill be analyzed. The World Economic Forum published a report on productive efficiency in the different Latin American countries based on the results in an indicator wherethe components are measured to determine this efficiency. Peru has a productive efficiency of 61. 7% that places it as one of the countries with the lowest percentage, for this reason it is considered a country with low competitiveness [4]. New trends in the paper and cardboard market indicate that new opportunities are approaching in the sector due to the consumption of eco-friendly products [5]. ManufacturingSMEs endure and bear severe problems that do not allow economic development, impede the growth of the market with a high level and lack of competitiveness due to the fact that their operations or processes are not efficient and effective. In this sector, it is necessary to promote a good organizational climate where the staff works happily and in this way they will be more productive. In addition, it is extremely important to update processes and automate activities due to customer requirements [6].

According to the web portal Semana SA in the year 2021, productivity and efficiency problems are being witnessed in companies due to losses in production time and misuse of equipment, non-compliance with market requirements,losses in production time, production, lack of planning and defective products and all this affects the growth of the organization, in costs, profits and even failure to meet delivery dates [7].

Lately, manufacturing SMEs endure and bear severe problems that do not allow economic development and prevent the growth of the market with a high level and lack of competitiveness due to the fact that their processes are not efficient and effective [8]. A case was examined for the evaluation of the delays in the waiting time of the manufacture of scaffolding, which caused a low efficiency in its production process, where Lean tools such as SMED, 5s were implemented to eradicate the main problem and it was achieved with successful reduction of these unproductive times [9]. The publisher of the SME sector of [10], shows a low efficiency and optimization of resources in a printing company that performs manual and mechanical tasks due to the preparation time of its machines that is generated in the production line.

For this reason, it is important to propose improvements where concepts about the integration of the tools of the Lean Manufacturing methodology are understood, since there only are few previous studies showing the use of these as such, most of the analyzes are applied in a textile environment or mechanical. In addition, this project is motivated to reduce

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unproductive times in the manufacturing process anddefective products that generate low efficiency in the company.

II. State of the art.

This section was elaborated with the previous investigation of different articles with aspects that contribute with information for the solution of the problem that is under study. Regarding the search for information, it was of the utmost importance to continue with a methodology that helped with this search for the most outstanding scientific articles that meet the purpose of this research.

From the review of several scientific articles for the elaboration of the State of the Art, the information was grouped by typologies.

A. Analysis of productivity and efficiency in a manufacturing company.

Of the articles chosen for this category, the research of [11] and [12] agree that in the face of the globalization of competition in companies, it is essential not only to apply the Lean Manufacturing philosophy, but also that this tool be the most efficient. and convenient, since applying it is reflected in low costs and productivity improvements. For [13], he developed this research due to low productivity in a pre-assembly line of a gearbox manufacturing company. Lean manufacturing was used, which will generate a reduction in cycle time and waiting time. The contribution of the authors is to design and study the implementation of an intelligent and sustainable materials handling system for the distribution of materials using an algorithm based on agents as a control architecture to increase productivity in SMEs [14]. It is noted that, starting from the high level of competitiveness of organizations, the implementation of Lean Manufacturing tools is important, but also that it be efficient and the most appropriate, that at the time of implementation it is reflected in the results such as lower production costs and increased productivity.

B. Use of Lean tools.

[15] lies in the adoption of lean practices in manufacturing companies as an aid for success in the face of intense market competition. In addition, it directly influences the improvement of yield and production performance. In the study of [16], the low performance and low capacity of units of SMEs in India were evaluated, when implementing the different Lean tools such as 5S, Kaizen, where productivity and competitiveness were increased, improving efficiency, reducing internal rejections. On the other hand, [17] proposed quantitative strategy based on Lean tools that can be used in manufacturing SMEs and positive results are obtained, andfor [18] Lean Manufacturing tools help companies reach benefits and also act as hard competitors satisfying their customers. It was rescued that implement the different Lean tools such in the companies it is possible to increase productivity and competitiveness by improving OEE and increasing profit. It was rescued that implement the different Lean tools such as 5S, JIDOKA, TPM, SMED, KAIZEN among others in SMEs, it is possible to increase productivityand competitiveness by increasing the overall effectiveness of the equipment (OEE) and increasing profit.

C. Development of the SMED methodology.

For [19] and [20] they carried out an investigation on a strategy to make their processes more flexible and efficient. For this, the SMED methodology was applied to reduce Setup times. In addition, they examined fields of engineering, the results of this application being the effective reduction of times and a lower cost of the companies studied. [21] when implementing SMED shows a significant improvement in equipment availability, increasing the average OEE of 10.8%. In the study of [22], the high times for preparation, low availability of machinery and lack of order in the work area were evaluated. It seeks to improve the quality and performance of a production process by applying TQM and Lean Production principles and tools. The contribution is based on the implementation of the SMED methodology, visual management and the 5Stechnique, with this application it was possible to reduce the total configuration time of the machines with which the manufacturing process is carried out. . The application of the SMED methodology was reviewed in order to corroborate the effectiveness of the model in different situations. In addition,the application of this tool was carried out with the purpose of reducing Setup times and it proved to be the most appropriate. The application of the SMED methodology was reviewed in order to corroborate the effectiveness of the model in different situations. In addition, the application of this tool was also carried out with the purpose of reducing setup times and it was shown that this tool is the most suitable.

D. Development of the TPM methodology.

[23] applied the Total Productive Maintenance tool as a systematic means to prevent waste and increase productivityin a mechanical production line. Through theimplementation, it improved 10.7% in terms of production capacity and increasing the efficiency of the machine. In [24] and [25] , it is desired to reduce the total delivery time and the hours of breakdown that occur in the industries. In order to achieve this goal on the high hours ofbreakdowns using Lean tools such as the TPM and its pillars such as autonomous maintenance and planned maintenance,achieving positive results. In the development of [26], the reason for unscheduled downtime and unproductive time due to industry averages was examined, where TPM was implemented to reduce them,and involved greater use of time and reduced downtime. It is concluded that with the TPM implementation, the reduction of delivery times, downtime due to breakdowns that are caused by machine failures, and reduction of human errors are achieved.

E. Solution tools to reduce defective products.

In the articles [27], [28] and [29]developed the 5S methodology and from it the manufacturing organizations accumulate benefits significant as the improvement in the general organization, reduction of defective products such as productivity, quality, safety, and cost optimization. For [30] he implemented the Jidoka tool which is a principle with an automation approach as well as a learning system capable of simultaneously improving the efficiency of the production process. From the implementation of the 5S technique, it was made easier for organizations to improve efficiency, quality, safety and cost optimization. Also, Jidoka was highlighted as an automated approach as well as a capable learning system. The implementation of the 5S technique, it facilitates manufacturing organizations to accumulate significant benefits such as improvement in the general organization such as efficiency, quality, safety and cost optimization.

III. Input.

Based on the background, it was possible to infer that the manufacturing SME sector is in continuous growth but also has some drawbacks, as can be seen in figure 1; one of themis the low efficiency in the production process, and among them is in the production line of cardboard tubes due to unproductive times and defective products that they present,so it is important to establish a model that allows reducing and improving low efficiency in this sector. In this way, thisresearch is based on proposing a new proposal on this inefficiency with the objective of ensuring that the percentage of affectation will be reduced and therefore will avoid the economic impact it generates.

According to the section on linking the causes, the proposed model involves the integration of four tools of the Lean Manufacturing philosophy, of which are the 5s methodology, SMED , TPM and finally, Jidoka. In the same way, based on the review of the literature, there are few previous studies that show the use of the four tools in the SME manufacturing sector of cardboard tubes as such, since most of the analyzes are applied in a textile environment. ormechanical.

The proposed model considers four components mentioned in the previous paragraph that will be made up of two phases:the first phase that is integrated by the Jidoka tool and 5S, will be used to reduce the defective products that are being witnessed in the company. And the second phase: made up of the SMED tool and two pillars of the TPM that will be in charge of reducing unproductive times due to machine downtime and breakdown frequency. The implementation to be carried out with each tool proposed in the solution model will be specifically explained.

improvements will be recorded andthe manufacturing process will continue.

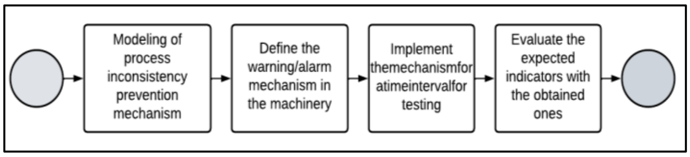

Fig.2. Jidoka Lane Diagram

As a first step, the operator will have a visual inspection of the defective cardboard tubes through the axis located at the end of the winding machine. If the cardboard tube meets the correct weight and dimension, the flow will continue to the drying area. Otherwise, if it does not meet the required weight and dimension, the alert mechanism will warn about the inconvenience that is happening, then the machine will be stopped and the axis will be calibrated correctly.Through the Jidoka tool, the operator instantly detects faults in tube measurements in such a way that the number of defective products is reduced.

It has two cylindrical pieces that are placed vertically around the tube being made. These pieces will fulfill the limit function for the thickness of the tube; If it has not been glued correctly, the tube will not be able to advance and a circular blade will fall (this being the last component) that will cut the tube to stop the winding and stop the machine in order to correctly calibrate the axis and continue with the flow. of production.

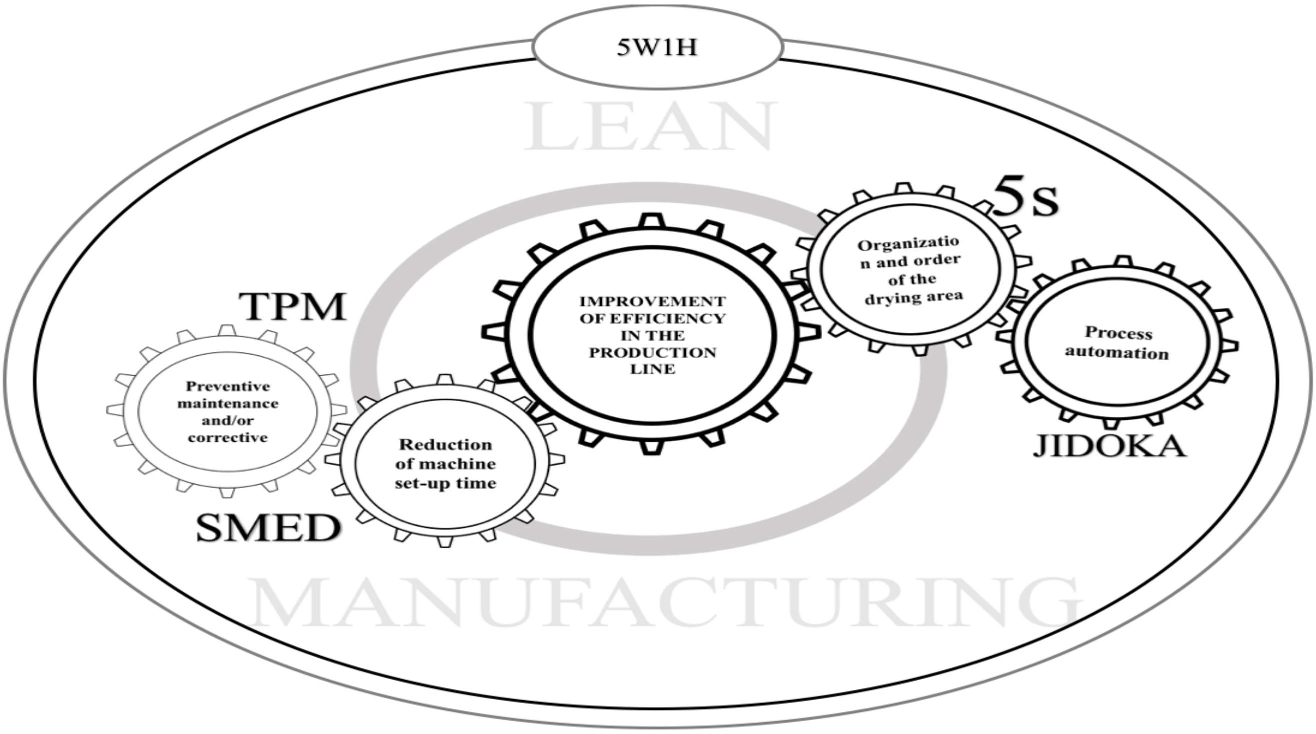

Fig.1. Proposed Innovative Model

PHASE I.

A. Component 1: Jidoka Tool

As can be seen in figure 2, component 1 will beginwith the identification of the errors that are present in the defective products, then an analysis of the faults will be carried out and the machine will be stopped, emitting an alert signal for the error, then the causes will be validated and prioritized and finally the implementation of the Jidoka system where

The indicator for this component is as follows:

%poorly glued cardboard tubes=

$$\frac{cardboard\ tubes\ with\ defects}{elaborate\ cardboard\ tubes} x\ 100\%$$

B. Component 2: 5S Tool.

The components to follow for the implementation of the 5S methodology in the process were formed. Figure 3 shows the 5s lane diagram starting with the classification of what is necessary with what is unnecessary in the drying area, then with the order of the area where everything is going to be organized in its place and proceed to clean the entire area where the cardboard tubes will be dried.

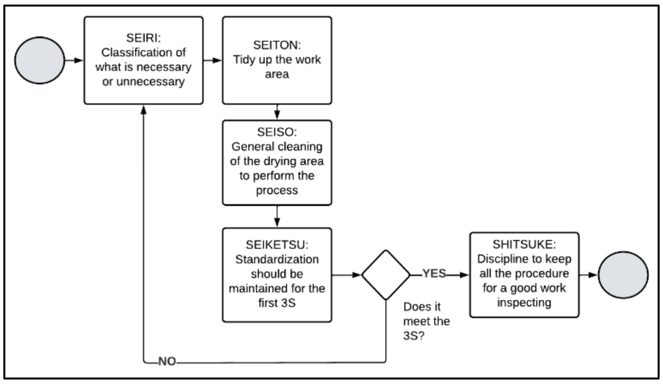

Fig.3. 5S Track Diagram

According to the result obtained through the audit before the 5s implementation, it can be seen that the TUBOCART company has a score of 1.67, a score less than 3. For this reason, it is deduced that it is in poor condition according to the order factors, cleanliness and discipline in the drying area and urgent corrective action is needed. In figure 4 the radial diagram will be shown.

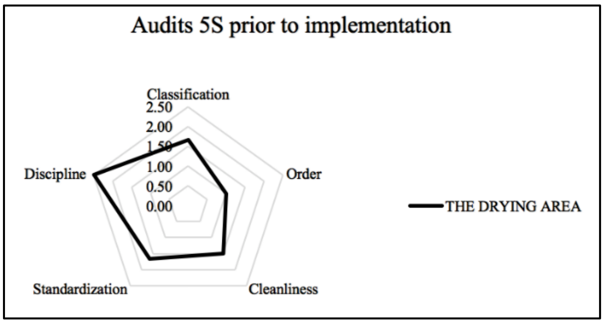

Fig.4. 5s audit before implementation

The components to follow for the implementation of the 5S methodology in the process were formed. Starting with the classification of what is necessary with what is unnecessary in the drying area through the well-known red card, as can be seen in figure 5.

RED CARD			
AREA: DRYING		DATE:	
NAME OBJECT			
CATEGORY		REASON	
	SHELVES		DEFECTIVE
	MATERIALS		WASTE
	RESIDUE		NOT USED
	PAPERS		USE UNKNOWN
	OTHER:		OTHER:
FINAL ACTION			
	RELOCATE		THROW
	DESTROY		WAREHOUSE
	RECYCLE		OTHER:

Fig.5 . Red card

Then, with the order of the area, where everything will be organized in its place and the entire area will be cleaned where the cardboard tubes will be dried. A garbage can will be implemented and in addition to this a heater for the efficient drying of the cardboard tubes. Standardizedcleaning is continued; this condition is applied when the firstthree "S" are maintained. Finally, the last step is to disciplinethe habit of preserving the procedures that were established.

The indicator for this component is as follows:

%damp cardboard pipes =

$$\frac{damp\ cardboard\ pipes}{total\ tubes\ produced} x\ 100\%$$

PHASE II.

C. Component 3: SMED Tool.

The implementation of the improvement proposal, it is planned to reduce the times of machine stops by Setup in the production process. Next, figure 6 will show the flowchart of the procedure that will be carried out with this tool.

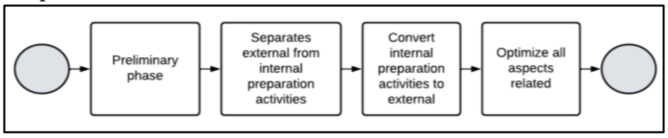

Fig.6. SMED Swimlane Diagram

As a second component of the application of the proposal, it is planned to reduce machine downtime due to setup in the production process. Beginning with the preparation known as the preliminary phase. Next, with the separation of external preparation activities from internal (Phase I). In phase II, the internal preparation activities are converted into external. As a last phase, the optimization of all aspects related to Setup. The indicator for this componentis as follows:

% of preparation and machinery adjustment by turn =

$$\frac{\sum T_{machinery\ preparation}}{T_{total\ of\ machinery\ operation}} x\ 100$$

D. Component 4: TPM Tool

It is proposed to minimize downtime due to breakdowns in the rolling and gluing process, it will be developed in three phases which are, which can be seen in figure 7: the preliminary phase where the training of the personnel will be carried out, explaining what is wants to achieve with maintenance; then the phase of the autonomous maintenance application, where the maintenance tasks of the machine will be carried out by the operators and finally the phase of the application of the preventive maintenance, which is developed in order to prevent the occurrence of breakdowns in the machine.

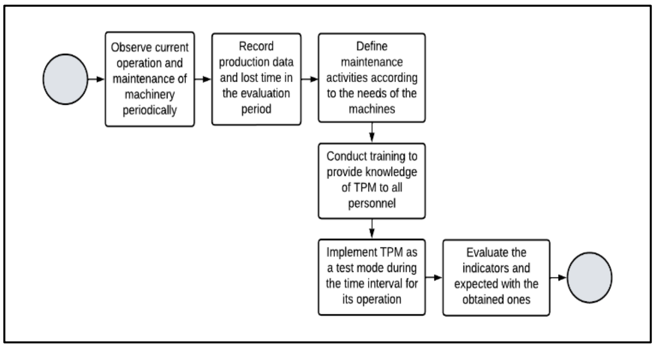

Fig.7. TPM Lane Diagram

Preventive Maintenance Pillar:

Currently, the company does not have its own documentation specifying the frequency of breakdowns and errors that occur in the machines located along the production line. Likewise, it is not possible to analyze or compare possible results of the different maintenance activities that are carried out. The organization performs some corrective maintenance activities; whose workers are responsible for repairing the machine every time there are breakdowns during production.

Corrective Maintenance Pillar:

Next, the corrective maintenance steps are delimited, which is carried out after having recognized the fault in the equipment. The aim is to implement the guidelines that allow the equipment to be restored to operating conditions in order to maintain the flow of the production line, the main objective being not to directly affect the efficiency of the tube production process.

The indicator for this component is as follows:

$$Avaliability = \frac{Toperation - T\ lost}{Toperation} x\ 100\%$$

IV. VALIDATION MODEL

The validation method to be carried out will be the simulationthrough the Arena Simulator Software since all the information required for the representation over time is available in said software. In addition, due to the current global situation, it is important that it be carried out with this method so as not to expose ourselves or the company's workers to a potential situation of contagion. But, we have a great opportunity to visit the plant with all the security protocols to use the pilot method with one of our tools. Once justified by which these validation methods will be developed, we proceed to perform the representation of the system considering the nature of the simulation, which is a system with the production process of cardboard tubes, observed in picture 8, and the description of the entities, attributes and activities of the process can be seen in picture 9.

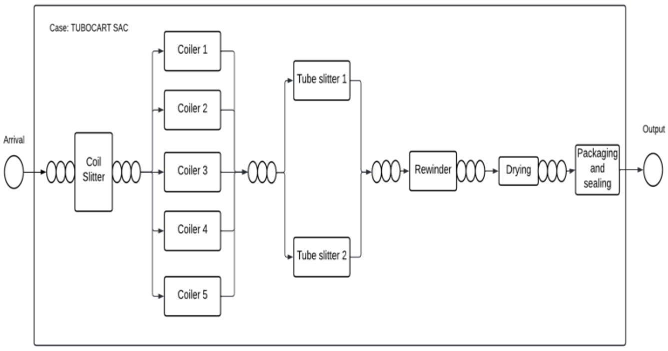

Fig.8. System Representation

Entities	Attributes	Activities
Work order	TLL	-Arrive at system. -Form coil slitter queue. -Occupy coil slitter. -Form coiler queue. - Occupy coiler i; i=1,2,3,4,5 -Form tube slitter queue. -Occupy tube slitter j; j=1,2 -Form rewinder. -Form dryer queue. -Occupy dryer. - Form packaging and sealing queue. -Occupy packaging and sealing. -Exit system.
Coil Slitter	TCB	-Expect for work order. -Attend work order.
Colier i=1,2,3,4,5	TE_i	-Expect for cardboard strips. -Attend cardboard strips.
Tube Slitter j=1,2	TCT_j	-Expect for cardboard tubes. -Attend cardboard tubes.
Rewinder	TR	-Expect for cardboard tubes. -Attend cardboard tubes.
Drying	TS	-Expect for cardboard tubes. -Attend cardboard tubes.
Packaging drying sealing	TES	-Expect for cardboard tubes. -Attend cardboard tubes.

Fig.9. Entities, attributes and activities

1. Validation Design

The proposed method of validation will be carried outthrough two phases:

1.1. Phase I:

In this phase, as mentioned above, it is the integration between the JIDOKA tool and the 5S tool for the reduction of defective products that will be analyzed through a simulation model and a pilot model, respectively.

1.1.1. Implementation of Simulation Plans with the Jidoka tool:

Previous analysis and diagnosis of the number of poorly wound tubes were carried out. The design focuses on reducing the level of defective products due to moisture, which with the support of the implementation of cylindrical mechanical parts, errors will be recognized and production will automatically stop. This implementation was applied bypersonnel external to the company, in hand with the training of operators in the area developed virtually due to the context of the pandemic, which concluded satisfactorily. Thefunctions of the operators are presented in table 1:

Process	Operator	Function
Rolled and glued	OP1	Position the junction point of paper tapes in the winding machine
Rolled and glued	OP2	Adjust belts and rollers
Rolled and glued	OP3	Perform calibration of the winding machine

Table 1. Operator Functions

These activities allowed the timely detection of the defects presented in the tubes, in such a way that the quality is improved and they are reduced in the process, observed in table 2.

Concept	Week 5	Week 6	Week 7	Week 8
Poorly glued cardboard tubes	162	120	83	57
% of badly glue tubes	1.88	1.39	0.97	0.66

Table 2. Percentage of poorly bonded tubes.

The results of the second month during the execution of the tool are shown, in which it was possible to reduce up to 0.66% of defects, seen in table 3:

Indicator	AS IS-diagnosis	TO BE-diagnosis	Implementation Month 2
% of blady glued tubes	5.62	0.6	0.66

Table 3. Final result of the Jidoka tool

1.1.2. Implementation of Pilot Plans with the 5S tool:

First, the Layout of the redistribution of the drying area was developed and from this the evaluation of the validation method began, observed in figure 11.

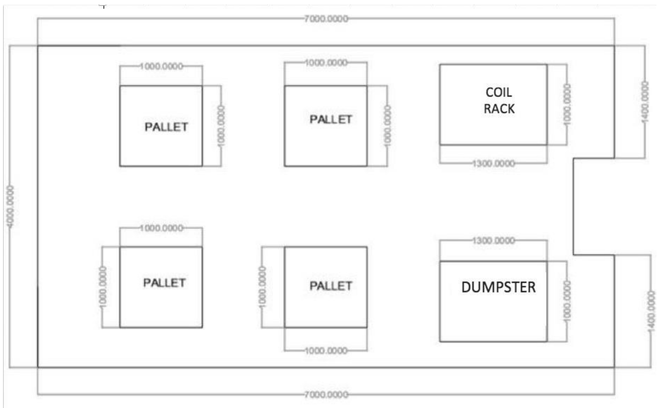

Fig 11. Layout of the proposed drying area

The pilot method developed with the 5S tool was developed with the help and participation of all the company's collaborators, which included operators and supervisors who are in the plant. This tool is applied in a production area where the cardboard tubes are dried, whose impact will be reflected in the satisfaction of the plant manager, operators, machinists and production related to factors of performance, safety and efficiency in their work.

It will begin with the classification and optimized organization within the drying area based on the identification of each material, waste or component that must be in the station. To do this, the red cards were used to make a list of the elements that must be removed or relocated from the station during the three months of action. It was obtained that 8 elements must be eliminated from the area, either due to lackof use or an object that should not be found in the drying area.Likewise, 2 elements were relocated within the area.

After carrying out the classification of the elements in the area, it was proposed and accepted the elaboration of the signaling of the floors for the ease of transport for the operators and additionally, a garbage container was purchased to have an order in the area with the accumulation of debris or rubbish found there.

Regarding cleaning, a planning was carried out where the personnel in charge have specific shifts to carry out this cleaning activity in the area. To finish with this pilot simulation, we proceeded to evaluate the application of the tool within the TUBOCART company carried out in the drying area during the first month of pilot validation to see the evolution of the method if it is viable or not, observed in the figure 13.

Audit Result			
5S	AS IS: Diagnostic		Pilot
	Drying Area	To Be Object	Drying Area
Classification	1.67	>=3	4.67
Order	1	>=3	2.5
Cleanliness	1.5	>=3	4.25
Standardization	1.67	>=3	4.33
Discipline	2.5	>=3	4.5

Fig.13 .Audit result.

From the development of pilot validation with the 5s tool and with the help of the viability of the tool through the audit carried out previously, the second month was evaluated, observed in table 5.

Concept	Week 5	Week 6	Week 7	Week 8
Poorly glued cardboard tubes	285	185	84	57
%of poorly dried tubes	3.24	2.14	0.97	0.66

Table 5. Percentage of poorly dried tubes

The results of poorly dried cardboard tubes during the execution of the tool are shown, in which it was possible to reduce up to 0.66% of defects, visualized in table 6:

Indicator	AS IS-diagnosis	TO BE-diagnosis	Implementation Month 2
% of blady glued tubes	3.24	0.49	0.66

Table 6. Final result of the 5S tool

1.2. Phase II:

In Phase II, the integration between the SMED tools and TPM pillars will be developed, where the unproductive times found in the company will be reduced. These tools will be carried out through the simulation validation model with the Software Arena.

1.2.1. Implementation of the Simulation Plan with theSMED tool:

Regarding the SMED tool, it is focused on the optimization of the times of the preparation activities and the adjustments in the machinery. This implementation will be carried out with the simulation method, obtaining information for two months September - October 2021. Additionally, it is intended to analyze the results obtained during that short period and thensimulate it for the next few months, verifying the viability ofthe case. Continuing with the implementation of the tool, from the detail of the setup activities and settings attributed within each machine where each setup task was recorded, With the objective of achieving the reduction of the stops of the machinery with said implementation of the tool, the final results of the development of the SMED were obtained, where the activities that were the data collection are shown according to the readjustment obtained with the activities from internal to external. to avoid downtime with the machines and obtain greater production, as can be seen in table 7.

Concept	Week 5 (min)	Week 6 (min)	Week 7 (min)	Week 8 (min)
Slicer	16	15.5	12	10
Coil	14	14.5	14	11
Tube Cutter	4	6	3	3.5
Rewinder	4	3.5	1.5	1.6
Total	**38**	**39.5**	**30.5**	**26.1**

Table.7. Result % preparation and adjustment

As the tool is being developed, it will be evaluated with the specific indicator to see how viable the proposal is and then it will be simulated. To do this, it will take as a reference, a shift of 7 hours as the operating time of the machines translates to 420 min and the result is displayed in table 8.

Concept	**Week 5**	**Week 6**	**Week 7**	**Week 8**
%preparation and adjustment of machinery	3.81	3.69	2.86	2.38

Table .8. Result of the SMED tool.

The results of the reduction of machine stops area shown at 5.40%, which can be seen intable 9.

Indicator	AS IS-diagnosis	TO BE-diagnosis	Implementation Month 2
% adjustments and preparation	10.97	5.33	5.40

Table.9. Result of poorly dried cardboard tubes.

1.2.2. Implementation of Simulation Plans with the tool with the pillars of the TPM:

Regarding the design of the implementation of the TPM, preventive and corrective maintenance activities were listed for the machinery that is in charge of the coil cutting and winding process. For this phase, the development of the TPM tool within the cardboard tube production process is evidenced, where the operators and the external mechanical personnel are the main executors of the implementation of the tool. It consists of the application of certain checklist activities for the collection of information from the machinery. The partial results of the development of the TPM are shown in this section, where the activities that were applied during the execution of the tool in order to achieve the expected results are displayed. Table 10 shows the availability of the cutting machine and table 11 shows the availability of the winding machine.

Concept	**Week 5**	**Week 6**	**Week 7**	**Week 8**
Availability of coil cutter	74.45	73.69	74.88	75.26

Table.10. Availability of coil slitting machine

Concept	Week 5 (%)	Week 6 (%)	Week 7 (%)	Week 8 (%)
Availability Winder 1	73.01	74.12	74.86	75.04
Availability Winder 2	72.11	72.58	73.29	73.85
Availability Winder 3	74.65	75.13	75.28	75.97
Availability Winder 4	78.81	75.33	75.51	75.87
Availability Winder 5	75.65	75.91	76.24	76.41

Table. 11. Availability of coil slitting machine.

The results for the availability of failures at 74.46% are shown, it can be seen in table 12.

Indicator	AS IS-diagnosis	TO BE-diagnosis	Implementation Month 2
Availability(%)	73.78	79.04	74.66

Table. 12. Machine Breakdown Availability.

V. Discussion

A. Scenarios vs Results

Regarding the new scenarios, these were considered based on the importance of certain variables under study, such as: total system time, level of care and costs. On the other hand, the time interval of two shifts per day was takenas the company has already been working and the costs thathave been considered for both scenarios are shown in the following table 13:

COSTS	S/.
Abandonment due to bad bonding	189
Abandonment due to poor drying	
Machine breakdown cost	137.22
Cost for setup times	57.50
Permanence cost	210
Operators	60

Table.13. Costs incurred by the company.

***a)* First stage**

For this scenario, it has been considered to have an extra operator in the machine in charge of cutting the coils, which will favor the reduction of the queue of work orders that arrive during the day. In addition, the correct operation of two piping machines that are part of the rolling and gluing process is added. In this way, through the simulation in the Arena software, the following results were obtained in comparison of the current situation present in the tube production line:

- The size of the queues of the reels was reduced to a minimum; in the same way with the tail size of the coil cutter.
- The percentage of use of the operator in charge of the coil cutting machine went from 92.66% to 49.88%; Consequently, the utilization of one of the operators in charge of the first winding machine was also reduced from 92.81% to 51.63%.
- The total number of operators present on the line is 9.
- It was possible to visualize the reduction of the Work In Process (WIP) from 7.52 purchase orders to 6.69. This means that fewer orders remain incomplete on the production line.
- The time it takes for the entire system to run was reduced by 21.55 minutes.
- Work orders served in this scenario reach 4 orders per day.
- Regarding the variables evaluated, the following summary table is shown, displayed in table 14:

Variables	Current situation	Scenary 1
Total System Time (min)	706.94	771.02
Level of attention	60%	80%
Total cost (s/.)	4310.46	2523.88

Table 14. Summary table of the comparison of variables for the first scenary.

***b)* Second stage**

For the following scenario, it has been considered to maintain an extra operator in the machine in charge of cutting the coils, which will favor the reduction of the queue of work orders that arrive during the day. In addition, the operation of all the piping machines that are part of the winding and gluing process is preserved, specifically the five that make up the production line.

On the other hand, an operator has been added in the drying area to help in the transport of pallets and reduce its time. Another reason why one more operator is included in the drying area is that a larger queue is formed compared to the first scenary.

In this way, as for the previous one through the simulation in the Arena software, they produced the following results in comparison of the current situation present in the tube production line:

- The size of the reel queues was also reduced to a minimum as for the first scenario; in the same way with the tail size of the coil cutter. In addition, the glue generated in the drying area was also considerably reduced to the minimum possible.
- The utilization percentage of the operator in charge of the coil cutting machine went from 92.66% to 49.95%; Consequently, the use of the operators in charge of the winding machines was also reduced to percentages of less than 60%.
- The total number of operators present on the line for this scenario is 10.
- It was possible to visualize the reduction of the Work In Process (WIP) from 7.52 purchase orders to 5.31. This means that the orders remaining in the production line process are much lower than the current situation of the company.
- The time it takes for the entire system to function increased by 64.08 minutes.
- Work orders served in this scenario also reach 4 orders per day.
- Regarding the variables evaluated, the following summary table is shown, observed in table 15:

Variables	Current situation	Scenary 2
Total System Time (min)	706.94	771.02
Level of attention	60%	80%
Total cost (s/.)	4310.46	2293.43

Table 15. Summary table of the comparison of variables for the second scenary.

B. Analysis of results

Table 16 shows the result obtained for the two scenarios.

Data obtained from the simulator	Current situation	Scenary 1	Scenary 2
Abandonment due to bad bonding	0	1	1
Abandonment due to poor drying	0	0	1
Number of work orders handled	3	4	4

Table .16. Data obtained for the first and second scenary.

The analysis of the comparisons of the results obtained is detailed:

C. Regarding the System Time indicator, the standard of the current situation indicates that it is at 706.94 minutes, equivalent to 11.78 hours. However, scenarios were proposed where it is validated that this time can vary. For the first scenario, although the production time is reduced, the size of the queues of the winding machines where the bottleneck of the line is generated and the costs generated by abandoning poor gluing and/or drying; the tail size of the drying rises considerably. This is due to the fact that orders do not have queues that prevent their arrival and processing, flow faster until they reach the drying area, which is one of the processes with the longest time required. The situation of scenarios 1 and 2 are found by similar values since they handle similar processes and similar applications. For this reason, the possibility of strengthening the line through a PDCA cycle of continuous improvement in the medium and long term, it sounds more sustainable to do it over time.
D. Likewise, in the second scenario, a lower lost cost was obtained, even though one more operator had been addedto the coil cutting machine. This is due to the fact that theWIP of the work orders decreases with respect to the current diagnosis, which indicates a variability between results, providing reliability to the possible scenarios. Onthe other hand, the system time for this scenario increasesdue to the arrival of more work orders to the process.
E. Another factor that is taken into account is the use of theoperators, it can be seen that in the current situation there are operators who exceed their percentage by more than 90%, which is unheard of for any production line. It wassought to propose scenarios in which the percentages aremore balanced and according to what an operator must work. In both scenarios, it can be seen that the operatorshave a reasonable use.
F. An average improvement of 20% in the level of care was achieved considering the two new scenarios. Taking intoaccount that within the company the goal is to achieve between 4 to 5 orders per day, it is possible to increase up to 80%.
G. In both the first and second scenarios, it can be seen that there are some orders that are abandoned due to poor gluing or poor drying, this is due to the fact that they areprocessed more compared to the current situation. It is understood that the higher the work orders processed, the more likely it is to generate abandonment due to some type of failure.

VI. CONCLUSIONS.

- At the end of this work, it can be concluded that the improvement proposal is viable since with the Lean Manufacturing tools implemented, the efficiency ofthe cardboard tube production line increased from acurrent value of 77.02% to 84.7%, being these fundamental when intervening satisfactorily in eachone of the causes. The solution of the general problem was achieved through the small improvements of the causes identified, such as: machine stops due to setup, faults present in the machines, inconsistency in the rolling and gluing process and the lack of inspection and order. of the drying area.
- Regarding machine stops due to setup, it was possible to reduce the percentage of preparation of machinery adjustments from 10.97% to 5.40%. Likewise, machine availability increased from 73.78% to 80.36% by reducing machine breakdowns. On the other hand, the percentage of poorly glued cardboard tubes decreased from 5.62%to 0.66% and finally, the percentage of wet or poorlydried cardboard tubes also decreased from 3.75% to0.66% for the two-month interval. application of the improvement proposal.
- Savings in lost costs due to defective products, setup times and machine breakdowns of approximately 20% were achieved.
- The objective of this model is to improve efficiencyin the production process of cardboard tubes in an SME company. Improvement tools present in the manufacturing SME sector at a global level were analyzed; and this case study was applied in a SME company in the paper and/or cardboard sector.
- Through the 5S tool and its application, the percentage of wet tubes was reduced to 0.66%.
- With the help of the SMED tool, the preparation and adjustment time of the machinery was reduced, equivalent to 5.40% of the operating time of the machines per shift per day.
- The use of preventive and corrective maintenance of the TPM tool contributed to the increase in the availability of machinery by 74.63%.
- With the Jidoka tool, it was possible to reduce the level of poorly glued tubes to 0.66%.

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