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Method for Optimizing the Production Process of Domestic Water Tank Manufacturing Companies

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ABSTRACT

The Peruvian plastic industry's water tank manufacturing has increased by 22% since 2013. Regarding the annual sales data during 2014 – 2015, the industry in Peru ranks seventh in America behind the US, Mexico, Brazil, Argentina, Colombia and Chile. However, a portion of the companies in this category do not currently meet the estimated delivery time for final products, largely due to changes in configuration or format and unscheduled company stops, which generates losses in production.

Thus, this study developed a methodology for optimizing production of domestic water tank manufacturers by applying lean manufacturing and preventive maintenance techniques that reduce lead time, delays and faulty equipment. The proposed model was validated in a water tank company where the implementation of the two proposals generated significant cost savings due to the elimination of waste in the processes of production. Our methodology reduced lead time by 2 days, eliminated unscheduled equipment stops and acheieved a percentage higher than 80% in the Overall Equipment Effectiveness (OEE), in addition to implementing good practices in process management.

Keywords: Lean Manufacturing, Value Chain Map, SMED, Preventive Maintenance.

1. INTRODUCTION

I Currently, the water tank production sector has experienced a significant advancement in development, with rates above 15%. Companies are therefore constantly seeking to optimize their production processes in order to comply with delivery times of final products.

According to Benjamín (2013), the delivery of products within the estimated time is of the utmost importance for a manufacturing industry. There are several costs associated with a late delivery, ranging from fines or payment discounts, to losing customers and consumption [1].

According to a survey published in 2016 by the Peruvian newspaper El Comercio, 74% of consumers consider delivery times to be very important. Responsiveness and delivery speed are two of the most important aspects for customers [2].

In order to meet these expectations, companies' production plants must maintain a continuous flow that avoids unscheduled stops. Cottyn (2011) mentions that there are several ways to sustain a production plant that can work continuously and without setbacks.

Products should arrive in the best possible conditions and within the times demanded by the client. However, on certain occasions, difficulties occur on the delivery date, causing delays. In 2000, the INEI estimated that 36% of manufacturing companies' products were not delivered in the estimated time. These events bring complaints and customer dissatisfaction, which negatively affects the reputations of companies.

Analysis, planning, organization and optimization of a continuous flow in company production are therefore indispensable, since excellence must be achieved through a process of continuous improvement. Improvement must be addressed throughout all processes, such as within personnel and efficiency of resources, as well as in the company's relationships with clients, employees and with society. These changes can translate into improvements in delivery service and product quality.

2. STATE OF THE ART

Various authors have provided information on the management of production processes. These processes play a vital role in competitiveness within the market, since compliance with product delivery estimations is essential for a manufacturing company.

According to Krajewski and Ritzman (2000) and Maarof and Mahmud (2006), it is fundamental that companies implement methodologies and alternatives for continuous improvement with the aim of process optimization and assuming market restrictions. Continuous improvement does not refer exclusively to product quality, but also to the relevant processes. In addition, continous development in communication between managers and employees, especially employees in charge of certain processes, is vital, since employees are often better able to determine critical points that require improvement [3] [4].

Womack (2003) and Calloni (2015) mention that the improvement of production processes should focus on process control, lean manufacturing and preventive maintenance. This should be considered in any optimization method to solve the problem of maintaining an optimal production and efficient results regarding quality, delivery time, increased efficiency and cost reduction [5] [6].

González (2003) and Eti MC et al. (2006) argue that there have been many recent studies linked to industry reliability, availability and operational maintainability that have developed increasingly effective methodologies and analysis projects. The general objective of implementing theories and practices is acquiring new designs, better elaborations and foreseeing conditions for optimum operation and maintenance [7] [8].

Hernández (2003) and Dinas (2010) point out that time which effectively generates added value in the production process is between 0.05% and 5%, and manufacturing activities represent 33% of the total production time. Likewise, in some companies, non-aggregated time value can reach up to 65%, which designates a company as uncompetitive [9] [10].

Melton (2005), Olofsson (2015) and Patrocinio (2015) state that a VSM can provide a detailed diagnosis, which allows companies to identify the areas with greater degrees of opportunity for improvement in order to achieve the highest production process efficiency. Furthermore, only 5% of activities in manufacturing companies generate value, and 60% add partial value [11] [12] [13].

Cuatrecasas (2006), Rivera (2007) and Hernández (2013) explain that for decades, the analysis of the failures linked to the processes, has been assigned a special attention with the need to perform more thorough the operation of them, which influences a greater economic, ecological and human benefit. Definitions such as security, reliability and risk have become relavent in process analysis, as they aid in obtaining greater operational reliability and eliminating economic, ecological and human losses due to unforeseen stops and serious consequences [14] [15] [16].

Nash and Poling (2008) and Haefner et al. (2014) have managed to determine that VSM implementation in a company allows for visualization and a better understanding of processes, since it allows companies to identify values, differentiate losses and form action plans to optimize production. In addition, it is possible to optimize the product quality of multiple production processes [17] [18].

Taj S. (2008) affirms that companies that apply lean manufacturing can eliminate losses in all production processes. Whether manufacturing a product or providing a service, there are components considered to be "waste". On average, 70% of all available resources in manufacturing companies are wasted [19].

Lefcovich (2009) and Rajadell (2010) state that the primary goal of a company should be compliance with product delivery terms. Companies must focus on elimination of activities that do not add value or anything that makes changes to the final product. This is not just another strategy that must put into practice, but a process that contributes to the companies' ability to respond better to market flexibility [20] [21].

According to Valencia and Plazas (2010) and Arrieta (2011), tools that have been successful in companies can be met with certain obstacles, among which are the management of information systems, customer-supplier relations, organizational culture, job stability and staff turnover. These cases are limited to some industrial sectors where plastic companies stand out, as well as the use of some tools (with SMED being the most widely used at 36%) [22] [23].

Rajadell and Sánchez (2011) and Ringena (2014) reaffirm that the improvement of manufacturing processes, focused on the elimination of waste and activities that do not add value to production, leads to instant results in company productivity, competitiveness and profitability, because it increases the value of each process and eliminates unnecessary activities. With the elimination or reduction, production costs, inventories and delivery times increase by 50%. Quality and team efficiency also improves. Lean manufacturing ratifies that more value should be created for customers by eliminating activities that are considered waste.

Any activity or process that consumes resources and increases costs or time without creating value should be eliminated [24] [25].

Tejeda (2011) and Khusaini (2014) comment that these non valuable activities must be eliminated because almost 60% do not add any value [26] [27].

According to Kumar and Kajal (2015), the best way to provide reliability and high quality services directly to customers is by meeting the estimated delivery times and increasing the level of efficiency in production processes, thus gaining the interest of potential customers. Failure to comply indicates issues in production processes and will lose customers [28].

Therefore, for a company to function properly, it has to define and manage numerous activities.

These authors confirm that companies that apply lean manufacturing and preventive maintenance help eliminate all operations that do not add value to products, reducing waste, improving operations and above all, meeting final product estimated delivery times.

Therefore, we have proposed a methodology that can be applied by companies to eliminate waste in production processes.

3. PROPOSED METHODOLOGY

The proposed methodology consists of analyzing and identifying issues within a company.

Then, a diagnosis is made of the situations that affect the production processes in order to determine the root cause of the issue. This can be more easily observed through a VSM diagram, since it allows an observation of the production process and an easier understanding of the flow of information that passes through it.

This study focuses on the analysis of cycle times and the identification of waste throughout the water tank production process. Among the main problems found in these companies were: lack of preventive machine maintenance, cleaning and excess changes to the time it takes to set-up.

We then analyze, develop and present improvement proposals to solve company problems (SMED and Preventive Maintenance). We then validated the improvement model and analyzed the results of the improvement proposal.

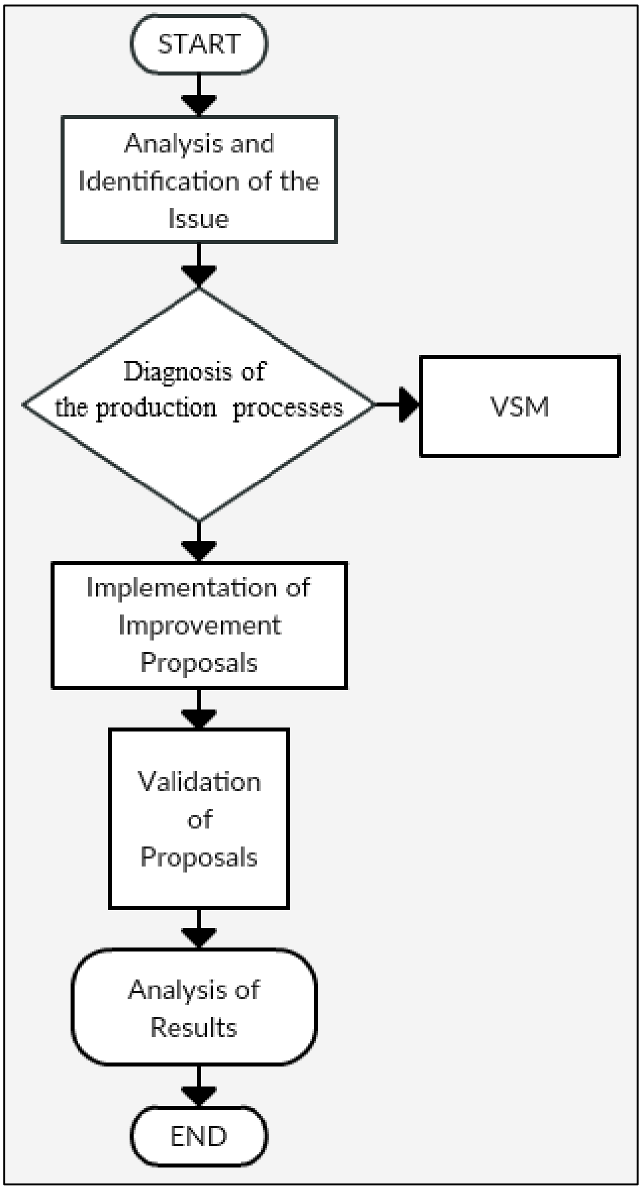

Figure 1. Proposed methodology for optimizing production processes.

For a diagnosis of production processes and identification of delays in delivery times, a VSM diagram was created to determine the flow of the value chain, eliminating all activities that did not add value to the product, which were considered to be waste in the production process. In addition, this tool allows the visualization of the current situation regarding materials and information in order to detect improvement opportunities and apply an optimal model for companies to achieve these improvements.

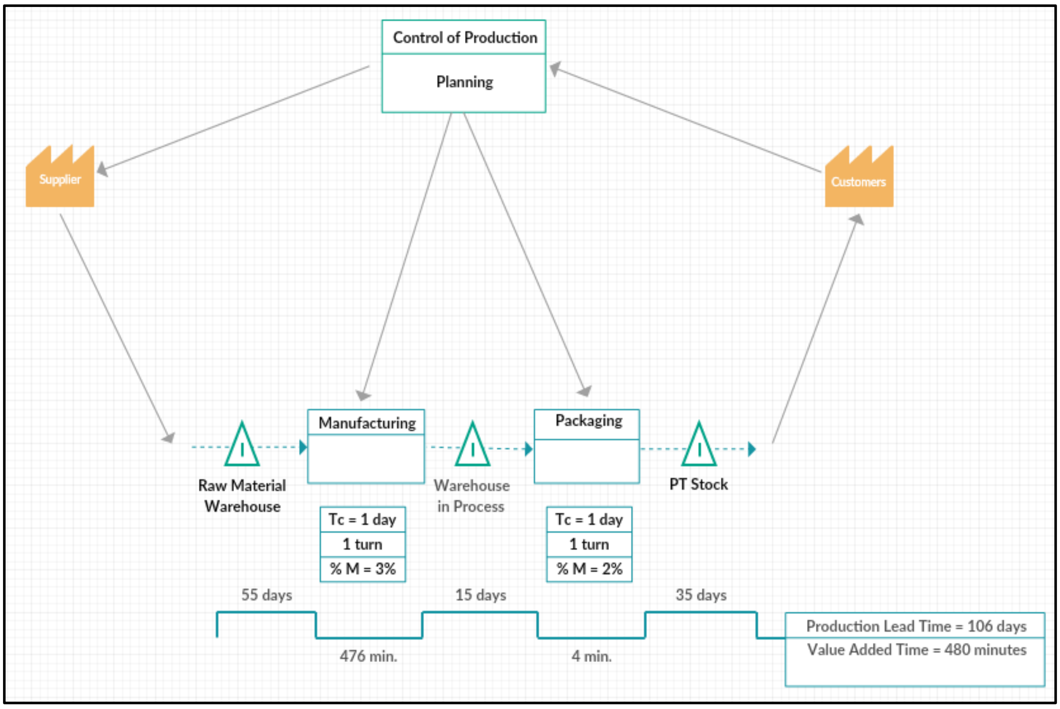

Figure 2. Value Stream Mapping (VSM)

Then, lean manufacturing, SMED and preventive maintenance were proposed in order to reduce the primary waste identified in the value stream map.

First, SMED was applied, which served to increase asset reliability and reduce set-up time.

The objective of this proposal was to reduce the time it took to make various products, without stopping production.

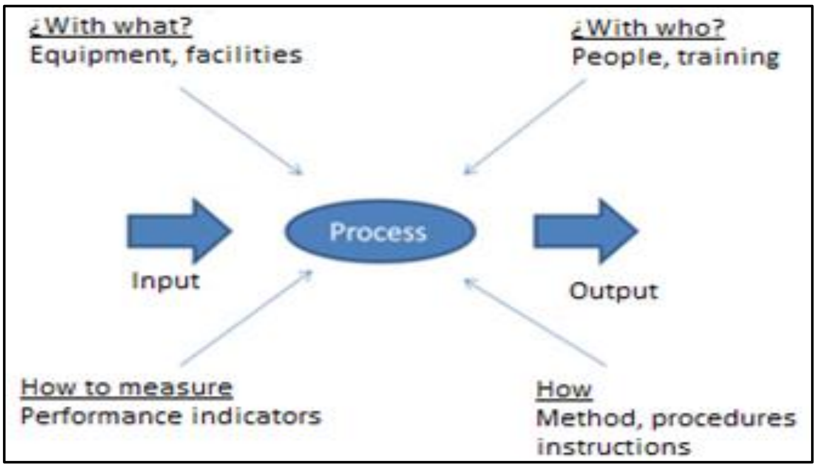

Figure 3. Single-Minute Exchange of Die

For the implementation of preventive maintenance, a Turtle Diagram, represented by the SIPOC, was created so that the stream mapping could display which activities generated added value.

In addition, it displayed sequential steps of the process and defined inputs, outputs, suppliers and clients, as well as key elements regarding the start and finish of the process.

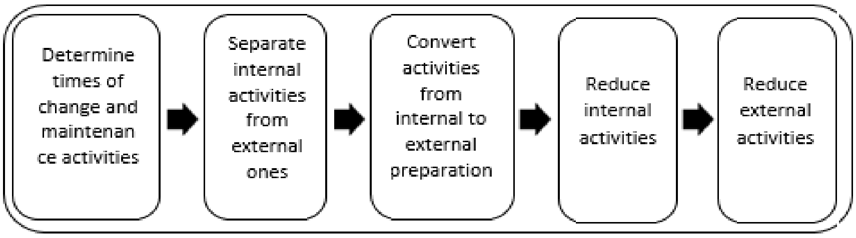

Figure 4. Turtle diagram – SIPOC

Finally, Overall Equipment Effectiveness (OEE) was used in order to establish the total machine efficiency, by enclosing three main parameters under a single index related to machine activity: Availability, Performance and Quality

Therefore, the OEE metric notifies losses and bottlenecks in the production process and links financial decisions to the performance of company operations, since it provides evidence of the effect of any decision on new investments.

Table 1. OEE Template

AREA - COMPANY		
CONCEPT	**Time (minutes)**	**OBSERVATION**
Failures and interruptions		
Time of operations		
AVAILABILITY		
Effective minutes		
Real minutes		
PERFORMANCE		
Defective units		
Total units		
QUALITY		
OEE		

Case study

The company under study is dedicated to the production and commercialization of domestic water tanks. This company began operations in 2000 and is located in Lima, Peru.

The raw material used is high density polyethylene (HDPE), because it is rigid, prevents corrosion, resists high temperatures, etc.

The company's primary issue was delays in the delivery of final products to the client. Increased delivery times were caused by difficulties in production.

Delays typically lasted up to 2 days after the defined delivery time.

This translated to serious problems, since it caused dissatisfaction in clients.

The maximum delivery time for companies of the same category is 8 days; however, the company under study typically delivered within 10 days, which rendered them unable to compete.

To obtain a thorough analysis, a current VSM was performed (See Figure 5). The primary areas of waste found within the value stream map were identified, since the purpose was to eliminate those areas, or to at least reduce their impact by establishing improvements.

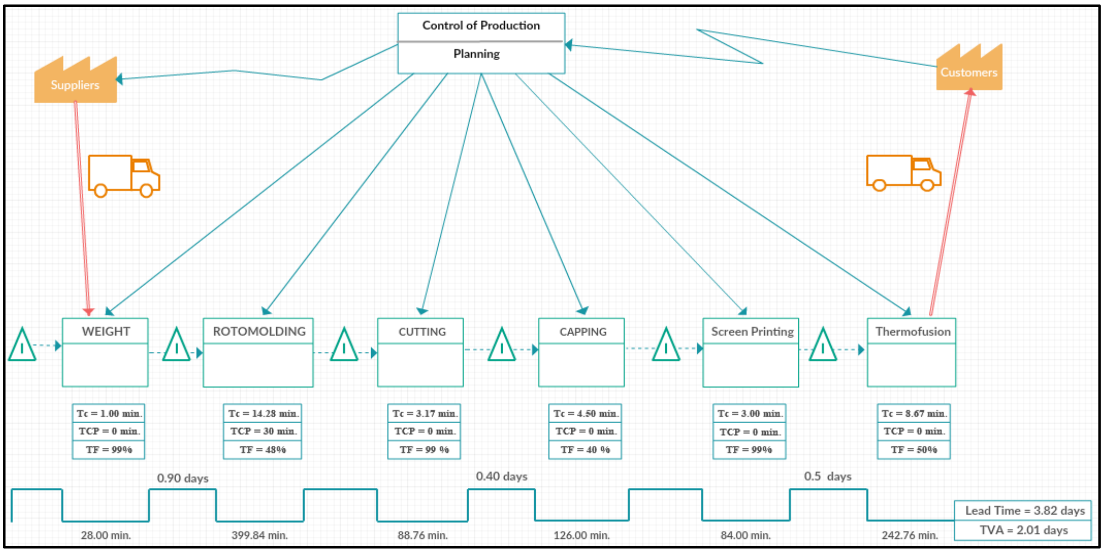

Figure 5. Current company VSM

According to figure 5, the Value Added Tax (VAT) was 2 days, while the Lead Time was 3.82 days, which represents a difference of 1.81 days of excess manufacturing time.

Problems with each Machine

An analysis of issues throughout the production process was then completed, detailing the extra time of each critical machine in order to link it to excess hours during the production process.

Tables 2, 3 and 4 show critical machine problems in production, where most of the problems are due to breakdowns, interruptions and general cleaning.

Table 2. Rotomold problem delay times

ROTOMOLDING		
CONCEPT	**TIME (minutes)**	**OBSERVATION**
Total available time	**2160**	(1) 4 day X 9 hours X 60 minutes
Time of programmed stops		
Lunch	240	(2) 4 days X 60 minutes
Total Time of Programmed Stops	**240**	
Time of Non-programmed Stops		
Failures and interruptions	110	
Calibrations	45	
Lack of Cleanning	90	
Change of tools or parts	45	
Outbreaks	120	
Adjustments	22	
Total Time of Non-programmed Stops	**432**	(3)
Total Time of Operation	**1920**	(4) = (1) - (2)
AVAILABILITY	**77.50%**	(5) = (((4) - (3)) / (4)) * 100%
Effective Minutes	399.84	(6)
Real Minutes	831.9	(7)
PERFORMANCE	**48.06%**	(8) = ((6)/(7)) * 100%
Defective Units	1	
Reprocessed Units	0	
Rejected Units	0	
Good Units	27	(9)
Total Units	28	(10)
QUALITY	**96.43%**	(11) = ((10) / (9)) * 100%
OEE	**35.92%**	(12) = (5) * (8) * (11)

Table 3. Capping problem delay times

CAPPING		
CONCEPT	TIME (minutes)	OBSERVATION
Total available time	**2160**	(1) 4 day X 9 hours X 60 minutes
Time of programmed stops		
Lunch	240	(2) 4 days X 60 minutes
Total Time of Programmed Stops	**240**	
Time of Non-programmed Stops		
Failures and interruptions	97	
Calibrations	20	
Lack of Cleanning	30	
Change of tools or parts	25	
Outbreaks	0	
Adjustments	20	
Total Time of Non-programmed Stops	**192**	(3)
Total Time of Operation	**1920**	(4) = (1) - (2)
AVAILABILITY	**90.00%**	(5) = (((4) - (3)) / (4)) * 100%
Effective Minutes	126	(6)
Real Minutes	318	(7)
PERFORMANCE	**39.62%**	(8) = ((6)/(7)) * 100%
Defective Units	0	
Reprocessed Units	1	
Rejected Units	0	
Good Units	27	(9)
Total Units	28	(10)
QUALITY	**96.43%**	(11) = ((10) / (9)) * 100%
OEE	**34.39%**	(12) = (5) * (8) * (11)

Tabla 4. Thermofusion problem delay times

THERMOFUSION		
CONCEPT	TIME (minutes)	OBSERVATION
Total available time	**2160**	(1) 4 day X 9 hours X 60 minutes
Time of programmed stops		
Lunch	240	(2) 4 days X 60 minutes
Total Time of Programmed Stops	**240**	
Time of Non-programmed Stops		
Failures and interruptions	90	
Calibrations	30	
Lack of Cleanning	30	
Change of tools or parts	40	
Outbreaks	0	
Adjustments	50	
Total Time of Non-programmed Stops	**240**	(3)
Total Time of Operation	**1920**	(4) = (1) - (2)
AVAILABILITY	**87.50%**	(5) = (((4) - (3)) / (4)) * 100%
Effective Minutes	242.76	(6)
Real Minutes	483	(7)
PERFORMANCE	**50.26%**	(8) = ((6)/(7)) * 100%
Defective Units	0	
Reprocessed Units	2	
Rejected Units	0	
Good Units	26	(9)
Total Units	28	(10)
QUALITY	**92.86%**	(11) = ((10) / (9)) * 100%
OEE	**40.84%**	(12) = (5) * (8) * (11)

After developing the current VSM and identifying delay times for each critical machine, and with support from the Pareto diagram, we identified which Industrial Engineering tools could be used to improve the production processes of the company.

Figure 6 identifies the four main problems within the company, which represented 80% of delay times that did not add value in the production process.

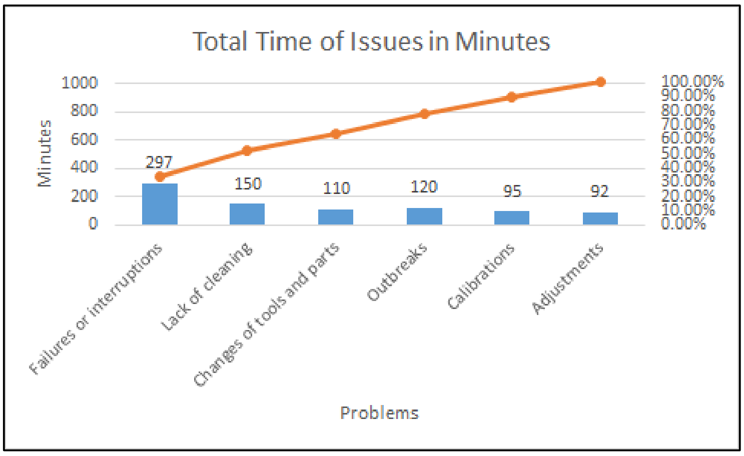

Figure 6. Total delay times in minutes for each problem.

METHOD OF IMPROVEMENT

Our improvement proposals consisted of 2 solution tools. The first was based on the concept and principle of lean manufacturing, and the second was based on preventive maintenance.

SMED

The application of the SMED tool was oriented towards the rotomold set-up process. This activity was one of the main causes of excessive delay times. According to the methodology implemented by Barcia Villacreses & Mendoza (200X), the following steps were performed in the application of SMED.

Step 1:

Step 1 consisted of the formation of a team to implement SMED. The team was organized for optimal execution, because this step is a fundamental point in the implementation where the team can be integrated into the tool.

Step 2:

A survey of the current situation of all rotomolding activity was carried out, for which we:

- filmed during the entire change process

-took time measurements using a digital chronometer

-took measurements of distance traveled by the operator during the process.

Once the necessary information on the processes was obtained, we began to identify the activities required when the line was stopped or in operation. See table 5.

Table 5. Rotomold Set-up

N°	Activity	Start	Final	Duration	Internal Time	External Time
1	Letting the machine cool	00:00:00	00:15:00	00:15:00	X	
2	Searching for gloves	00:15:00	00:15:15	00:00:15	X	
3	Walking to tool box	00:15:15	00:15:35	00:00:20	X	
4	Searching for maladjustment tools	00:15:35	00:15:50	00:00:15	X	
5	Mismatched nuts	00:15:50	00:18:20	00:02:30	X	
6	Take out nuts	00:18:20	00:18:50	00:00:30	X	
7	Preserving nuts	00:18:50	00:19:00	00:00:10	X	
8	Preserving maladjustment tools	00:19:00	00:19:10	00:00:10	X	
9	Openning rotomold	00:19:10	00:19:18	00:00:08	X	
10	Removing tank and burrs	00:19:18	00:19:57	00:00:39	X	
11	Find object to clean	00:19:57	00:20:05	00:00:08	X	
12	Clean rotomold	00:20:05	00:24:25	00:04:00	X	
13	Put polyethylene	00:24:25	00:24:37	00:00:32	X	
14	Close rotomold	00:24:37	00:24:45	00:00:08	X	
15	Locating nuts	00:24:45	00:25:15	00:00:30	X	
16	Removing maladjustment tools	00:25:15	00:25:25	00:00:10	X	
17	Adjust nuts	00:25:25	00:27:55	00:02:30	X	
18	Walking to control board	00:27:55	00:28:05	00:00:10	X	
19	Programming control board	00:28:05	00:29:05	00:01:00	X	
20	Lighting the flame	00:29:05	00:29:15	00:00:10	X	
21	Walking to rotomold	00:29:15	00:29:25	00:00:10		X
22	Inspection	00:29:25	00:29:55	00:00:30		X
	TIME			00:29:55	00:29:15	00:00:40
	PERCENTAGE			100%	97.77%	2.23%

Step 3:

Step three consisted of the conversion of internal time to external time. Improvements were made by converting internal time activities, such as cleaning, tool transport and waiting, machine adjustment and quality inspection while the machine is running.

A chronological list was created of all activities performed during the time in which the machine was stopped in order to assess which machines can be optimized.

Step 4:

Step four focused on external times. Technically, this step relied on the qualification of all tools and materials that make up external activities. These elements had to be available near the rotomold while the machine was running to save time on transportation, searching for tools, etc.

Step 5:

The final step was to minimize internal delay times. This was achieved through the implementation of three electrical products, as shown in Table 6 where, in addition to the use of the previous method, improved method and reduction time is detailed.

Table 6. Improvement in internal delay times

Activity	Prior Method	Improved Method	Prior Time	Improved Time	Reduced Time
Cooling Rotomold	Natural cooling	Industrial ceiling fan	15'	4'	11'
Adjusting / un-adjusting nuts	Adjustable wrench	Pneumatic pistol	2' 30" (x2)	1'(x2)	1' 30" (x2)
Cleaning Rotomold	Cloth	Industrial vacuum cleaner	4'	1' 30"	2' 30"
TOTAL			**24'**	**8' 30"**	**16' 30"**

Preventive Maintenance

Another implemented improvement was Preventive Maintenance of machines. Preventive Maintenance is an improvement that is considered to be crucial for company purposes, expectations, objectives and goals.

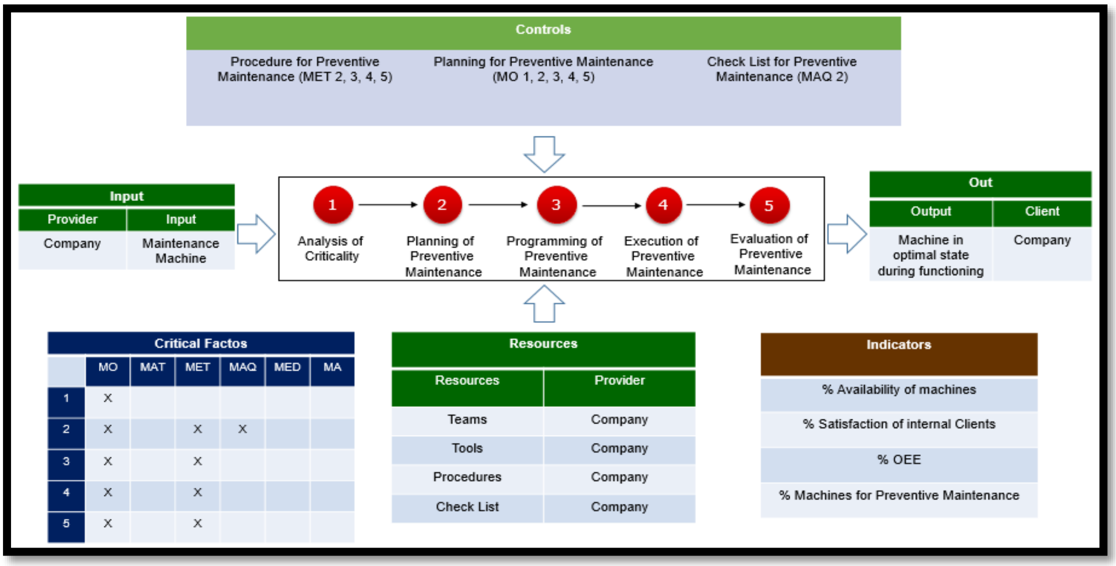

Figure 7. SIPOC for Preventive Maintenance

The company sought to assure that the implementation was communicated and understood at all levels through training activities and the allocation of required resources. A correct mapping of the maintenance process was represented by the SIPOC (See figure 7), which demonstrates the activities that can generate added value.

Step 1: Analysis of Criticality: The analysis of criticality was associated with 4 fundamental aspects: human reliability, process reliability, design reliability and maintenance reliability. Through this analysis, it was possible to confirm that rotomolding, cutting and hot melting activities were critical activities.

Step 2: Preventive Maintenance Planning: Consisted of forming the implementation team. Those put in charge of implementation were company employees, since they already knew how to operate the machines, and the implementation activity could also serve as complementary training. Table 8 presents the Preventive Maintenance Plan.

Step 3: Preventive Maintenance Program: Step three established specific dates on which the machines must be serviced throughout the year. Each machine was scheduled to receive preventive maintenance on the same dates, according to frequency of failures, with different actions established for each type of maintenance.

Step 4: Preventive Maintenance execution: The main objective of step 4 was to ensure that machines were kept in optimum operating conditions, preventing possible breakdowns and failures, thus leading to the work being performed with the highest levels of quality and safety in the production plant.

Step 5: Preventive Maintenance Evaluation: Optimal management of preventive maintenance focused mainly on the effects of deterioration of the industrial equipment. It was stressed that companies must anticipate possible machine failures.

In order to improve and maintain maintenance management standards, checklists were created so that consistency and completeness of maintenance activities were ensured. In addition, procedures were evaluated according to indicators of preventive maintenance management to measure and evaluate the performance of implementation in the company for future decision making.

Table 7. Preventive maintenance plan

Preventive Maintenance Plan				
Machine	**Frecuency**	**Activities**	**Objetive**	**Responsable**
Rotomold	Biweekly	Revision of machine temperatures	Temperature between 35 - 40 C°	Operator
		Revision of vibrations	Eliminate abnormal vibrations	
		maintenance to motor fan	1500 RPM / no dirt / no abnormal noise	
		Maintenance of motor	Revision of terminal board/ revision of bearings	
		Maintenance of gas canisters	No leakage/ no corrosion	
		Cleaning of machine	No dirtiness/ no residual polyethylene in interior	
		Lubricating moving parts	Lubrication of tread, bearing, shafts, pinion, gears, etc.	
Capping	Biweekly	Revision of machine temperatures	Temperature between 35 - 40 C°	Operator
		Revision of vibrations	Eliminate abnormal vibrations	
		Maintenance of motor	2500 RPM / no dirt / no abnormal noise	
		Maintenance of stand	No dirtiness/ no abnormal noise	
		Maintenance of tread	Precision in tank position	
		Cleaning of machine	No dirtiness / no grease stains	
		Lubricating moving parts	Lubrication of tread, bearing, shafts, pinion, gears, etc.	
		Realize precision calibration	Precision between 2500 - 2600 Newton	
Thermosusion	Biweekly	Revision of machine temperatures	Temperature between 35 - 40 C°	Operario
		Revision of vibrations	Eliminate abnormal vibrations	
		Maintenance of motor	2500 RPM	
		Maintenance of rowlock	Lubrication of tread / revision of internal rings / revision of washers	
		Maintenance of thermostat	Revision of terminal board/ revision of bearings	
		Cleaning of machine	No dirt, no grease stains	
		Lubricating moving parts	Lubrication of tread, bearing, shafts, pinion, gears, etc.	
		Realizing calibration of temperature	Adequate fusion temperature between 270 - 280 C°	

SMED Implementation

The implementation of SMED was directed to the Rotomold process.

This was executed in the production plant by the operator in charge of the machine in the rotomolding process, which was reviewed and approved by the production manager.

After each set-up, the checklist was reviewed, which served to control compliance with set-up procedure requirements. This operation was carried out by the production supervisor who performed the coordination and management of set-up during its execution.

Preventive Maintenance Implementation

Fundamental points were as follows: Order, initial cleaning, inspection, order of execution, execution and registration and results.

Stage 1: Initial Cleaning and Order

All areas of the production process were reviewed. The greatest lack of order was found in the storage of raw materials. Bags containing polyethylene were placed randomly, thus complicating transportation for the next activity. Figure 5 demonstrates the raw material sacks that were found in different areas.

Figure 8. Location of raw material sacks before pilot plan

Because of this, the sacks of raw material were placed on pallets to avoid dirt. They were conditioned in a maximum height of 12 bags as specified by the manufacturer. To stop the sacks from falling or any other inconveniences, they were wrapped in film paper as shown in figure 6.

Figure 9. Location of raw material sacks after the pilot plan

Stage 2: Verification of the facilities of the machines and the maintenance schedule.

The objective was to perform the verifications of all critical machines and to evaluate the spaces and tools needed to execute the preventive maintenance.

Stage 3: Preventive Maintenance Order.

The operator performed different orders of execution of preventive maintenance for the machines.

Stage 4: Execution of Preventive Maintenance.

The execution of the preventive maintenance to the machines of high criticality began in this stage. The proposed procedures for the rotomold, capping and thermofusion were taken into account.

Stage 5: CheckList and Preventive Maintenance Record.

During the preventive maintenance, total compliance was registered in a file, which recorded and monitored the time of each activity by the Supervisor.

4. RESULTS

In this section, the results obtained are shown in detail in order to validate the improvement implemented in the company.

The objective was to increase the OEE of the critical machines (34%, 35% and 40%) to an OEE greater than 80% for which the SMED and preventive maintenance were implemented.

RESULTS OF THE SMED IMPLEMENTATION

After the implementation of SMED, we established a significant reduction of the set-up time from 29:55 minutes to 11:47 minutes (707 seconds), which represents a 60% decrease in set-up time.

We took 15 samples of changes in set-up time (See Figure 7) and observed that the times are within a margin of error of +/- 3 seconds. Thus, it can be concluded that the reduction of 60% of set-up time was achieved as established in the objectives proposed for improvement.

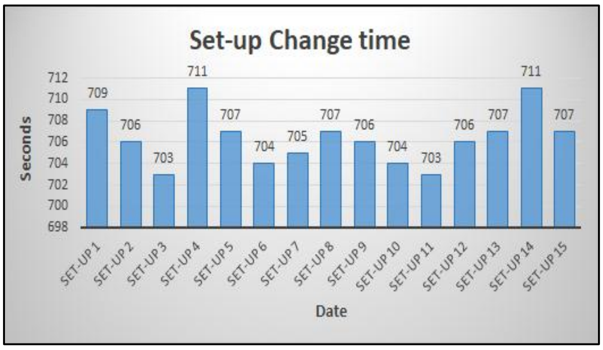

Figure 10. Time Change for Set-Up

Results of the Implementation of Preventive Maintenance

The results obtained from the implementation of preventive maintenance in the company showed positive results.

The objective was to increase the OEE by more than 80%.

After the implementation, the machines increased their availability and, therefore, showed an increase in OEE.

Likewise, in table 9, the OEE of all production machines is displayed. It can therefore be concluded that the implementation of the improvements met the objective set by exceeding 80%.

Table 8. Current OEE of the Company

ACTIVITY	INDICATORS	PERCENTAGE	OEE
Weight	Availability	98.75%	98.05%
	Performance	99.29%	
	Quality	100%	
Rotomold	Availability	99.32%	92.72%
	Performance	96.81%	
	Quality	96.43%	
Cutting	Availability	97.24%	92.48%
	Performance	98.62%	
	Quality	96.43%	
Capping	Availability	99.48%	88.88%
	Performance	92.65%	
	Quality	96.43%	
Screen Printing	Availability	96.46%	92.79%
	Performance	99.76%	
	Quality	96.43%	
Thermofusion	Availability	99.43%	91.63%
	Performance	95.57%	
	Quality	96.43%	

Ecomomic Impact

The data on all production costs incurred for the elaboration of each tank, also known as operating costs, were collected.

These costs included raw materials and labor, as well as indirect costs of fixed and variable manufacturing.

In conclusion, there was an increase of 95.95% in Operating Profit after the implementation of the improvement proposal. This increase is due to the decrease in the fixed CIF and the increase in units produced in the company.

Finally, with the data obtained, the company's income statement was demonstrated, which showed that the two results from that year were obtained during the previous period and the period in the normal operating conditions of the company.

Therefore, each cost must be applied correctly at the beginning of the accounting period so that the information presented is useful and reliable for decision making.

The state of the results allows an analysis of income, expenses and profits generated by the company using the improvement proposal, in order for management to make the best decisions.

STATUS OF RESULTS (Before the improvement)							
	550 Liters		1100 Liters		2200 Liters		Consolidated
Sales		1,160,220.34		3,164,949.15		4,479,500.00	S/. 8,804,669.49
Variable Costs							
Raw Material	S/. 298,704.00		S/. 943,488.00		S/. 1,720,128.00		S/. 2,962,320.00
Direct Labor	S/. 466,725.00		S/. 1,474,200.00		S/. 2,015,775.00		S/. 3,956,700.00
Indirect Costs	S/. 8,599.24	(774,028.24)	S/. 13,580.79	(2,431,268.79)	S/. 12,379.97	(3,748,282.97)	S/. 34,560.00
Contribution Margin		S/. 386,192.10		S/. 733,680.36		S/. 731,217.03	S/. 1,851,089.49
Fixed Costs and Expenses							
Indirect Costs	S/. 52,852.24		S/. 143,423.77		S/. 253,027.60		S/. 449,303.62
Administrative Expenses	S/. 276,000.00	(328,852.24)	S/. 276,000.00	(419,423.77)	S/. 276,000.00	(529,027.60)	S/. 828,000.00
Operating Utility		**57,339.86**		**314,256.58**		**202,189.43**	**S/. 573,785.87**

Figure 11. Income Statement before the implemented improvements

STATUS OF RESULTS (After improvement)							
	550 Liters		1100 Liters		2200 Liters		Consolidated
Sales		1,673,305.08		3,983,559.32		5,425,000.00	S/. 11,081,864.41
Variable Costs							
Raw Material	S/. 430,800.00		S/. 1,187,520.00		S/. 2,083,200.00		S/. 3,701,520.00
Direct Labor	S/. 673,125.00		S/. 1,855,500.00		S/. 2,441,250.00		S/. 4,969,875.00
Indirect Costs	S/. 12,385.50	(1,116,310.50)	S/. 17,070.60	(3,060,090.60)	S/. 14,973.00	(4,539,423.00)	S/. 44,429.10
Contribution Margin		S/. 556,994.58		S/. 923,468.72		S/. 885,577.00	S/. 2,366,040.31
Fixed Costs and Expenses							
Indirect Costs	S/. 52,852.24		S/. 180,520.16		S/. 253,027.60		S/. 433,547.76
Administrative Expenses	S/. 276,000.00	(328,852.24)	S/. 276,000.00	(456,520.16)	S/. 276,000.00	(529,027.60)	S/. 828,000.00
Operating Utility		**228,142.34**		**466,948.57**		**356,549.40**	**S/. 1,051,640.31**

Figure 12. Income Statement after the implemented improvements

5. CONCLUSIONS

- With the implementation of the improvements in our case study, we demonstrated that SMED and preventive maintenance are profitable since the operating profit increased by 95.95%.
- Through the implementation of SMED and Preventive Maintenance, lead time was reduced by 2 days.
- The OEE of the rotomold, capping and thermofusion before the implementation of improvements did not surpass 40%. After the implementation, they increased to 80%.
- With SMED, a reduction of 60% in the format change time in the rotational molding area was achieved, and with the implementation of Preventive Maintenance we eliminated all unscheduled stops in the company's production plant.
- After these improvements were implemented, the delivery time of the final products was 8 days and as such, the company will remain competitive in the water tank market.

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