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Integrating SMED, Preventive Maintenance, and Standardized Work Practices: A Study of Productivity Gains in Metalworking SMEs

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Abstract

The low productivity levels in the metalworking industry, particularly in casual and small industries, are often attributed to the long times it takes to carry out a changeover, the recurrent machine downtime as well as overexertion of rework tasks. Prior research studies undertaken have shown the usefulness of lean manufacturing tools such as SMED, regular maintenance and formatted work in eliminating such wastages. Hence, this study sought out to solve these issues by looking at the design and application of a new production model in a chrome roller making SME. Some of these included employing SMED, so as to reduce changeover processes; great or increased reliability of equipment through preventive maintenance; and the reduction of operational variability through standardized operating procedures. The results obtained were significant change; a 22.9% reduction in change over time, a 65.4% reduction in rework and a massive 76.4% reduction in machine downtime which resulted into a 30.9% increase in productivity levels. These findings demonstrate the feasibility of the model to be effectively employed for improvement of other business parameters in a company. Further studies that incorporate complex technologies are welcomed, aimed at developing effective and unique solutions for different manufacturing environments.

Keywords

Productivity, Standardized work, Maintenance Program, Productivity, Metalworking sector.

1. Introduction

Regarding the sector to which the company under study belongs, it is the metalworking industry. According to the Ministry of Production, during the years 2017 and 2022, the production of the metalworking industry experienced an average annual increase of 7.0%, even though there were declines in the years 2017 (-1.6%) and 2020 (-27.6%). The latter was mainly due to the COVID-19 pandemic that affected all economic activities, and the strict quarantine imposed during the months of March, April and May. However, in 2021, the metalworking industry experienced a growth of 48.3%, partly due to a statistical effect and the gradual recovery of economic activities thanks to the progress of the vaccination process against the pandemic. Currently, in 2022, the metalworking industry continues to grow (+10.5%) thanks to the increase in orders favored by the good performance of the mining and construction sectors (Ministry of Production, 2022, p.17).

However, industries in this sector are currently facing significant productivity challenges. In 2019, it was found that manufacturing sector productivity was 28% below average, and when compared to other industries, the disparity was even more pronounced (Annual Economic Survey, 2019). Likewise, according to a study, the main challenges for micro and small enterprises (MSEs) in the manufacturing industry were identified as the informality of companies, staff training, and access to financing. These factors had a negative impact on productivity, since companies did not have the tools and conditions necessary to carry out their work efficiently (National Society of Industries, 2019).

This approach allowed us to go beyond the superficial symptoms and discover the real problems that affect productivity. In this context, the research focuses on addressing the problem in a metalworking company specialized in the manufacture of chrome-plated rollers, through the implementation of SMED tools, Standardized Maintenance and Work Program. We rely on these tools because several investigations have demonstrated their effectiveness. According to Córdova-Pillco et al. (2022), regarding the search for the determination of the main tools related to efficiency and productivity in an SME, SMED, TPM, SLP and the 7s methodology were found to be the main ones for their solution, obtaining as a result an increase in the indicator used OEE (Overall Equipment Effectiveness), a direct indicator that allows to know the positive aspects of productivity, from 20.78% to 28.03%.

Another related research indicates that the problem is low productivity due to high levels of downtime and defective products. To this end, standardized work, TPM, and Six Sigma were implemented based on a simulation of discrete systems. As a result, the indicators were positive: machine downtime for corrective maintenance was reduced by 27%, thus generating greater availability of the machines to continue production. Likewise, the process waste indicator reduced downtime by 13%, resulting in fewer process delays that do not generate value, such as machine cleaning and backlog. All these improvements were reflected in the increase in overall project productivity by 9.60% (Carranza Inga, I., et al., 2020). with all the above mentioned this research aims to develop a production model applying SMED tools, Maintenance Program and Standardized Work to increase productivity in a SME in the metalworking sector.
The objectives of this research are directly aligned with the research of the production model to reduce problems associated with productivity, such as changeover times, reprocessing by operators and downtime due to failures.

2. Literature review

The implementation of Lean Manufacturing principles has been widely studied as an effective approach to address various inefficiencies in production processes, particularly in reducing downtime and rework. Key tools such as SMED, TPM and the application of standardized work have been identified as successful strategies to improve operational efficiency. For example, SMED has proven effective in minimizing machine downtime and unnecessary movements, while its combination with tools such as 5S has led to reductions in production time and costs, especially benefiting small and medium-sized enterprises (SMEs). Standardization, particularly through techniques such as standardized work and value stream mapping (VSM), plays a crucial role in both reducing downtime and improving product quality by streamlining processes and eliminating unnecessary steps. Furthermore, automation systems and smart maintenance models have contributed to reducing downtime and waste, thereby boosting overall productivity. The studies also highlight the importance of using optimization models and simulation tools, such as ARIMA and Witness, to predict and address production inefficiencies, ultimately improving productivity and economic impact across several sectors, including food production and manufacturing.

2.1 Lean manufacturing approach to reduce downtime

Within this typology, studies were found that used the SMED tool to reduce downtime, machine breakdowns, problems in order delivery, non-conformity levels and unnecessary movements. In this sense, the studies considered SMED as a tool to reduce downtime in general within processes, and it was concluded that its implementation brings great benefits to organizations. Additionally, when combined with other tools, it can be highly effective in addressing low productivity. Even when combined with 5S, total production times and costs are reduced, which is considered essential for SMEs. Other researchers used the Lean approach combined with standardization to reduce downtime along with other issues. In this context, Byme , B., et al. (2021) conducted a study in a pharmaceutical company to address customer order delays caused by increased demand and downtime on the packaging line. After implementing a Lean standardization improvement, the customer demand was met and the product quality was also increased. Similarly, Daniel Lee Hardy, et al. (2021) mention that in the context of inefficiency and downtime, the application of Lean standardization is crucial as it provides key advantages over competitors and ensures that the project aims to improve its critical quality measures. Furthermore, the combined implementation of the SMED tool and Lean standardization reduced unnecessary movements, downtime, and overall production gains (Lee Hardy et al., 2021). From this, the DMAIC methodology is important as it serves as a means to analyze manufacturing efficiency. This method, like PDCA, includes business requirements in the definition phase through the voice of the customer, the voice of the process, and the voice of the business to define the critical quality plan. However, there is a major limitation in the implementation of this tool, leading to the need to exclude it as it can result in high costs and implementation times in SMEs. As Sibanda & Ramanatán (2020) mention, Lean standardization usually takes a relatively long time to complete. In another related study, Ahmed M. Abed, et al. (2020) developed an intelligent automation system through more detailed predictive model monitoring of deviation behaviour in time series to enable machines or systems to be stopped for maintenance when necessary. Poka Yoke was proposed to identify any deviation during operation, stopping the process until maintenance is performed. This was used as a measure to avoid extra fuel consumption at high torque output. The study yielded positive results such as a reduction in downtime and waste, generating savings through ARIMA. Other studies noted that, as far as the human factor is concerned, an information system (software-hardware) was implemented to automate the data collection process, thus solving the problems of low staff productivity and high machine downtime. The idea of loading machines in an automated manner, without the influence of the “human factor”, was developed. This information system allows generating a report and a loading schedule for each machine for a selected period of time. As a result, downtime was reduced by up to two times, production increased, and loss of working time was reduced by 20% compared to typical industry levels (Kotov, et al., 2019).

2.2 Lean manufacturing approach to reduce rework

Previous studies have shown that one of the most successful Lean Manufacturing tools to address rework issues is TPM (Total Productive Maintenance). As mentioned by García-Alcaraz et al. (2022), TPM programs that generate high levels of OEE (Overall Equipment Effectiveness) and automation have been shown to reduce rework, production costs, material handling, order rejections, and administrative penalties. Furthermore, monitoring and evaluation (M&E) systems increase employee safety, boost morale and motivation, and improve product quality. Emphasizing the importance of TPM, Nallusamy et al. (2018) highlight the significant financial and productivity benefits of TPM implementation. Different approaches to its implementation have been proposed, and success is determined by specific sequences. Most attempts to implement TPM have resulted in improvements.

In another case study, where SMED and 5S tools were used, the percentage of defective products was reduced by 3.99% compared to the current situation, which represented 8.92% of the total products manufactured. Similarly, the percentage of rework also decreased (Wong, Josiel Y., et al., 2021).

Preliminary studies conducted on an APEX machine involved in the tire manufacturing process showed that proper implementation of Lean Manufacturing in manufacturing companies facing rework and defective products resulted in a 62% reduction in processing time (Wong et al., 2021, cited in FLP Santos, 2018).

2.3 Lean manufacturing approach to reduce downtime and rework

As for Lean Manufacturing (LM) tools that reduce both downtime and rework, Value Stream Mapping (VSM) has been shown to be particularly effective. VSM is a Lean tool that allows for both the current and future state of a case to be analysed and has been used successfully in various studies. It creates a systematic visual map of the current situation of the company and projects a future state for improvement proposals. Another important tool within LM is the Overall Equipment Effectiveness (OEE) indicators, which measure equipment efficiency as well as productivity, economic impact and overall effectiveness, allowing for the measurement of both equipment and operator productivity.

Additionally, it is important to consider that tools such as SLP (Systematic Layout Planning) and standardized work can solve downtime and rework problems, leading to cost reduction. When used together, these tools improve flow, significantly reduce costs, and minimize plant movements, thus increasing process efficiency. In addition, Josiel Y. Wong et al. (2021) mention that applying SMED with other tools, such as VSM, leads to better results in reducing inefficiencies in the manufacturing sector. With the combination of SMED and 5S, improvement proposals were developed, resulting in a reduction in setup times (downtime), fewer trips, fewer delays, and a decrease in defective products (rework). These tools also helped reduce total production time and costs caused by delays in order deliveries. Additionally, these techniques can be combined with an innovative approach, as mentioned by Carranza Inga, I. et al. (2021). To address low productivity caused by high levels of downtime and defective products, a combination of Lean Manufacturing tools such as 5S, TPM, Poka Yoke, and Lean Six Sigma were used. Among these, Poka Yoke was the primary solution tool, with the aim of designing a prototype that addresses variability issues. Using indicators, it was possible to verify that downtime and delays were reduced, leading to increased productivity. In this context, Lean Six Sigma is an appropriate tool when multiple tools are used and key factors such as leadership alignment, proper selection of people and projects, training, motivation, accountability, information technology, marketing, and effective supply chain management are considered. However, as mentioned above, the implementation of Lean Six Sigma poses several limitations, especially for small and medium-sized enterprises (SMEs).

3. Methods

The proposed solution model to optimize low productivity seeks, as a first instance, to carry out preventive maintenance, with the commitment of senior management, which allows to identify losses and waste in the processes and then implement measures to eliminate them, and finally, establish a system of continuous improvement and monitoring. Then, carry out a standardization of the work, in which it is observed and understood in detail how a task or process is carried out, then each step is documented and the time required to carry out each task is recorded. Subsequently, the documented steps are analyzed and ways are sought to eliminate unnecessary steps. Then, each activity or process is simplified, optimized and a detailed standard is established. Finally, to implement SMED, an analysis of the current configuration change process is carried out, the times and resources used in each step of the change process are recorded. Then, the areas that do not add value are identified and the activities that can be carried out in parallel during the change are grouped. Finally, the improvements identified in the change process are implemented, tests are carried out to evaluate the implemented improvements. Figure 1 shows this process in detail for the proposed solution.

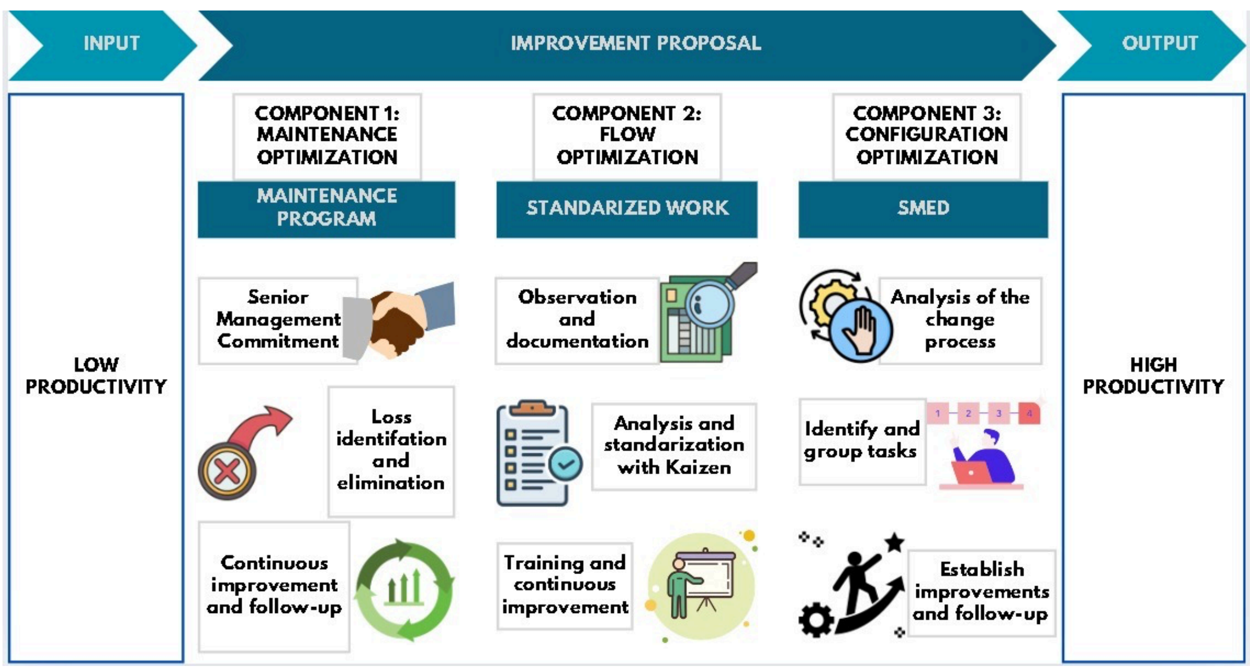


Figure 1. Macro design of the proposal

4. Validation

4.1 Diagnosis initial

The company was faced with the need to improve its low productivity, which was mainly attributed to reprocessing and changeover times. The first reason accounted for 49.99% of the problems identified. Among the causes analyzed, it was found that constant machine failures were a main factor, representing 66.7% of the first reason. This situation could be attributed to the lack of a maintenance program, which is key to the cause found. In addition to this, the inadequate verification of standard measures, which represents 33.3% of the reason given, is represented by the lack of a training plan that employs 82.47% and a defective work method with 17.53%, with the next reason to be exposed being changeover times covering 50.01% of the problem to be treated. Among the causes analyzed, the main point is the ignorance of operators regarding the assignment activities, which accounts for 6.66% of the reason, and the root cause is the lack of a training plan, which accounts for 19%, and the lack of procedures for changing couplings, which accounts for 81%. This raises the second cause of the second reason given, which is the inadequate distribution of activities to follow, which increases setup times, with 93.34%, with the root causes being the high configuration time, which accounts for 90.41% of this cause, and late planning, which accounts for 9.5%.

This aspect underlined the importance of focusing on reprocessing and changeover times. Figure 2 The case study illustrates a problem tree that summarizes the key points of the diagnosis, providing an integrated view of the critical areas that need to be addressed to improve the company's productivity.

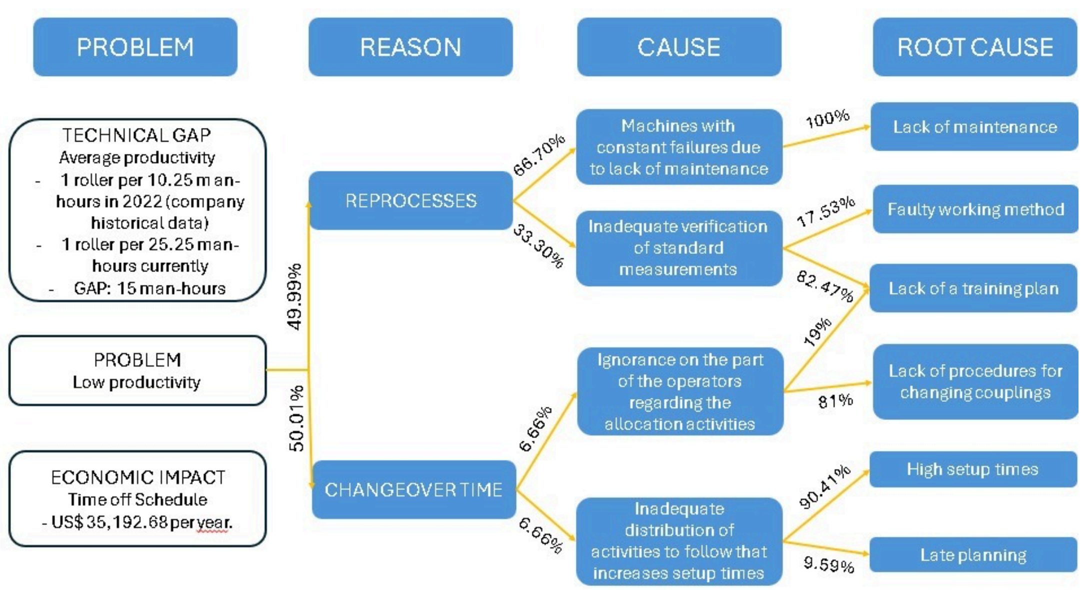


Figure 2. Problem tree

4.2. Implementation of SMED, Maintenance Program and Standardized Work

Figure 3 shows the implementation of the SMED tool to reduce tool change times and improve operational efficiency in a case study from the metalworking sector. It details the conversion of internal activities to external ones, process standardization, and preparation for parallel changes, which allowed for the optimization of production capacity and the minimization of idle times.

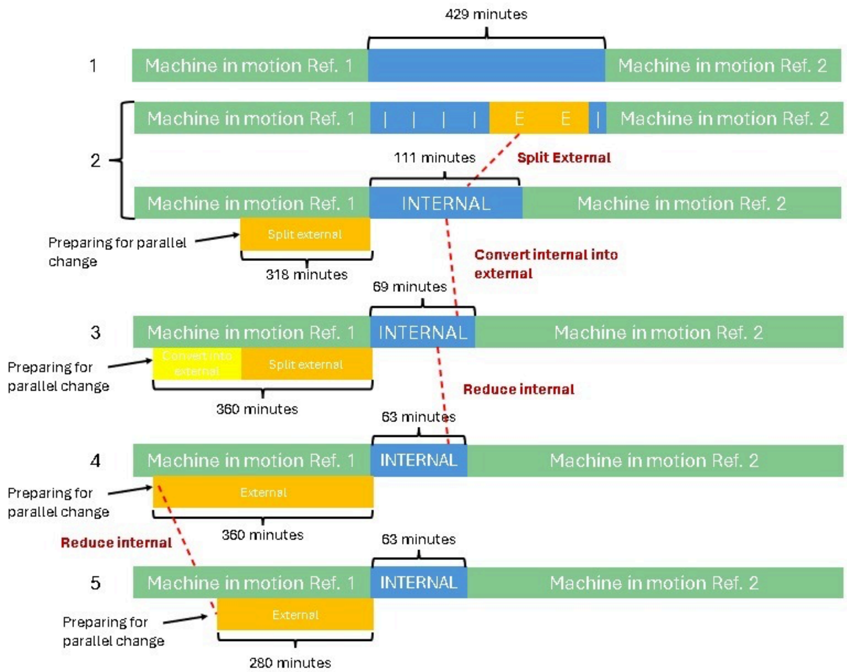


Figure 3. Five Steps for SMED Implementation

Based on Figure 3, the implementation of SMED is explained in detail through five strategic steps to optimize changeover times and reduce downtime in the manufacturing process. The first step consists of the decomposition of the change to obtain a detailed analysis of operations and the measurement of standard times through timing. The second step opens the way to the separation of activities obtaining the differentiation between internal and external activities. Consequently, the third step transformed internal activities into external ones in order to reduce process times. Finally, the fourth and fifth steps are the optimization of activities through external components to be implemented. Below, the before and after of the implementation of the tool in the process studied in Table 1 in the workshop area are presented.

Table 1. SMED results

Area: Workshop		**Machine/Equipment: Lathe Tools for the set- up: Portas, inserts component, precision tools, etc.**		**Operator: Paul Guadalupe**	**Standard set up time: (Minutes) 350 min**	
Current set up process		**Set up Time**		**Improvement**	**Improved Time**	
N°	**Task/operation**	**Internal**	**External**	**Task/operation**	**Internal**	**External**
1	Transfer of component to machine	11 min		Component transfer by manual lifting device handled by machine column radial crane		5 min
2	Classification and search for types of tools to use	42 min		Select the tools to be used from the metal cabinet		8 min
3	Tool insert in machine	23 min		Tool insert in machine	23 min	
4	Set RPM and cut level	17 min		Set RPM and cut level	17 min	
5	Component machining		272 min	Component machining		272 min
6	Pour coolant into the component		46 min	Activate the use of cooling hose		0 min
7	Check component measurement	18 min		Filling water into washing machine and washing process	18 min	
Current total time		**429 min**		**Improved total time**	**331 min**	

Table 1 shows the improvements which shorten machining time, resulting in less setup time.
For the second tool, with the implementation of the maintenance program, 5 steps will be followed in which the improvement process will be described based on the reduction in the number of failures (Table 2).

Table 2. Steps for implementing a maintenance program

No.	**PASSED**	**Stage description**
1	Machine Identification and Code Assignment	It is necessary to assign codes to the machines so that each one can be labeled and in a better order.
2	Create a list of machines	A machine list is created to know the equipment that will be included in the maintenance.
3	Identify machines with labels.	The machines are labeled after coding.
4	Create a preventive maintenance plan for each type of machine	The preventive maintenance plan is created taking into account the instructions in the manual for each machine.
5	Create a preventive maintenance sheet to hang near each machine	The maintenance plan is printed and laminated so that it can be carried out by the operators using a date given by the manufacturer according to the manual.

The code is the process where the machine is located, then it differentiates between a tracking equipment or machine, identified this is assigned a numerical sequence for the existing type of machine; after having identified the type of machine the quantity is identified by type (Table 3).

Table 3. Equipment code identification

Process	Process code	Tracking equipment or machine	Code by type	Number of equipment by type
Machining	MC	MQ	01	01
Rectified	RC	MQ	02	01
Chromed	CR	MQ	03	01

Once each machine is coded, a list of machines is created that includes the above, brand, model, condition and location (Table 4).

Table 4. List of coded machines

Machine	Code	Brand	Model	State	Location
Parallel lathe	MC-MQ-01-01	HELLER	LC360 X 2000	OPERATIONAL	Workshop area
Cylindrical grinding machine	RC-MQ-02-01	HELLER	RCE 2000	OPERATIONAL	Workshop area
Current rectifier	MCR-MQ-01-01	SINFONIX	3000 AMP	OPERATIONAL	Chrome area

Machine identification by means of labeling is carried out by printing adhesive labels using the following formats presented below (Table 5- Table 8).

Table 5. Lathe coding

Name	Code
Parallel lathe	MC-MQ-01-01

Table 6. Grinding machine coding cylindrical

Name	Code
Cylindrical grinding machine	RC-MQ-02-01

Table 7. Current rectifier coding

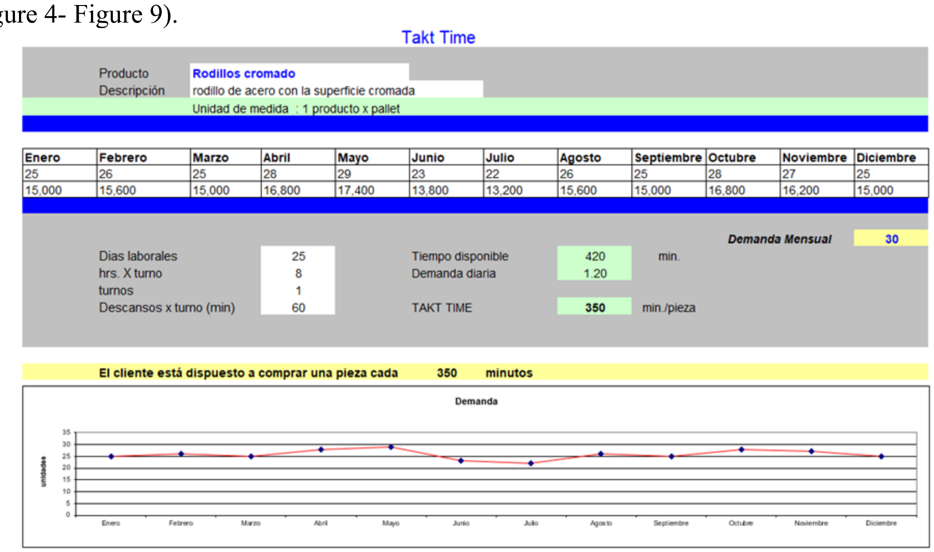
Name	Code
Current rectifier	MC-MQ-01-01

With what has been mentioned and implemented, we proceed with the results of the maintenance program.

Table 8. Comparison of indicators between the pre-implementation situation and the post-implementation situation of the work standardization tools

Maintenance Program		
Fault description	**Pre-Implementation**	**Post-Implementation**
Time that the fault lasts (min)		
Lathe failure due to roller	62	12
Roller current grinding machine failure	123	27
Failure of cylindrical grinding machine due to roller	61	19
TOTAL (min)	**246**	**58**

For the third tool, the first step was to calculate the Takt time to find out how many minutes per piece the market demands (Figure 4- Figure 9).



Takt Time

Producto: Rodillos cromado
Descripción: rodillo de acero con la superficie cromada
Unidad de medida : 1 producto x pallet

Enero	Febrero	Marzo	Abril	Mayo	Junio	Julio	Agosto	Septiembre	Octubre	Noviembre	Diciembre
25	26	25	28	29	23	22	26	25	28	27	25
15,000	15,600	15,000	16,800	17,400	13,800	13,200	15,600	15,000	16,800	16,200	15,000

Demanda Mensual: 30

Dias laborales	25	Tiempo disponible	420	min.
hrs. X turno	8	Demanda diaria	1.20	
turnos	1			
Descansos x turno (min)	60	TAKT TIME	350	min./pieza

El cliente está dispuesto a comprar una pieza cada 350 minutos

Figure 4. Takt Time Calculation

When calculating the takt time, the times of each of the processes are measured in order to find the cycle time.

PROCESO	FABRICACIÓN DE RODILLO	HOJA DE MEDICIÓN DE TIEMPOS						Fecha análisis			10 de JULIO 2022			Número del proceso			
								Hora análisis			8:05 a. m.			Observador	Alumnos		
No.	Elemento de trabajo	1	2	3	4	5	6	7	8	9	10	11	12	13	Prom	% Val.	Tn	Tstd
1	Verificación de calidad	15	16	14	15	16	17	14	15	14	13	15	16	16	15.077	96%	14.474	16.64
2	Proceso de mecanizado	300	302	305	302	295	300	302	301	298	300	301	302	304	300.923	117%	352.08	404.89
3	Proceso de soldadura	180	177	182	179	182	181	177	183	178	182	183	179	178	180.077	98%	176.48	202.95
4	Proceso de mecanizado	90	88	89	91	93	95	91	89	88	91	87	92	91	90.385	115%	103.94	119.53
5	Proceso de Pre-rectificado	120	119	117	121	123	122	119	117	119	121	118	124	125	120.385	105%	126.4	145.36
6	Proceso de cromado	502	512	503	508	499	501	505	503	501	508	501	502	506	503.923	122%	614.79	707.00
7	Proceso de Post-rectificado	238	234	241	244	234	231	239	245	248	234	231	239	245	238.692	105%	250.63	288.22
8	Proceso de pulido	42	40	46	43	38	41	44	37	42	45	41	42	39	41.538	95%	39.46	45.38
9	Etiquetado y embalado	32	29	35	33	31	30	33	27	31	26	29	32	33	30.846	105%	32.388	37.25
Tiempos de ciclo															1522			1,967.23

Suplementos variables a considerar	
	HOMBRES
Trabajo a pie	2
Trabajo de fuerza	4
K	9
	15
	115.00%

K = suplementos

Figure 5. Time measurement

Given the above, in order to be able to go deeper and understand the monitoring of the process, the capacity of this process is carried out by using the process activities, number of machines, standard time and the change interval in minutes.

Manager	Jorge Moreno	Operation Capacity	Part No.		Product Type		Section	
Assistant	Paul Guadalupe		Name	Axl Moreno	Parts/Product		Available Time	420 min

No.	Process Name	No. of Machines	Standard Time			Tool Changes	Manufacturing Capacity	Observations
			Manual	Automatic	Total	Change Interval (min)		
1	Quality Verification	0	15		15	0	28	
2	Machining Process 1	3	250	50	300	20	1.3	
3	Welding Process	2	180		180	15	2.3	
4	Machining Process 2	3	40	50	90	15	4.5	
5	Pre-Grinding Process	2	50	70	120	13	3.4	
6	Chrome Plating Process	1	60	440	500	0	0.8	
7	Post-Grinding Process	2	30	210	240	15	1.7	
8	Polishing Process	1	30	10	40	16	10.1	
9	Labeling and Packaging	0	30		30	0	14	

Figure 6. Process capability

The current VSM is then found.

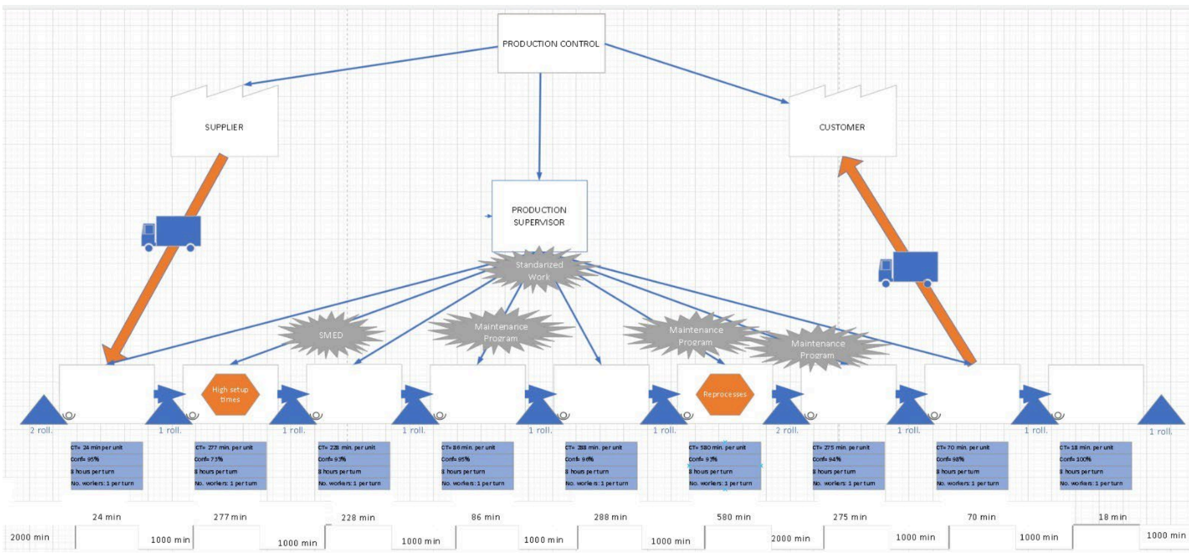


Figure 7. Current VSM

Next, the first balance analysis is carried out, which is where the imbalance that this process suffers can be seen.

Operación	Operador	Descripción	Tiempo	Takt
1	Claiberth Castillo	Verificación de calidad	16.64	350
2	Paul Coronel	Proceso de mecanizado	404.89	350
3	Anthonio Gonzales	Proceso de soldadura	202.95	350
4	Anthony Barrientos	Proceso de mecanizado	119.53	350
5	Fidel Peña	Proceso de Pre-rectificado	145.36	350
6	Kevin Peña	Proceso de cromado	707.00	350
7	Fidel Peña	Proceso de Post-rectificado	288.22	350
8	Anderson Salvador	Proceso de pulido	45.38	350
9	Jhonathan Ramirez	Etiquetado y embalado	37.25	350

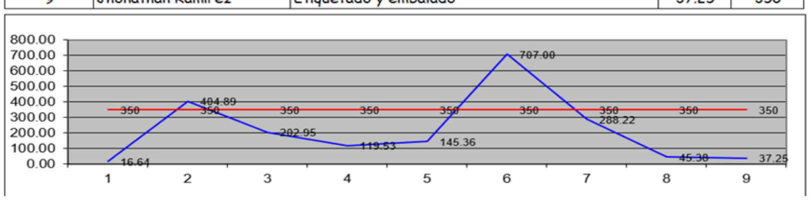
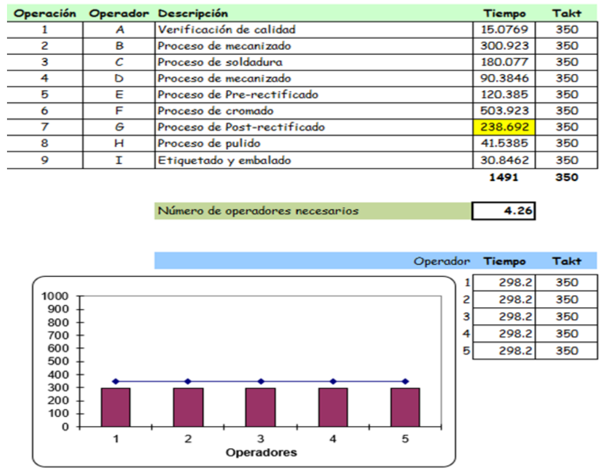


Figure 8. Balance analysis

And the second is where the balance of operations is given.



Operación	Operador	Descripción	Tiempo	Takt
1	A	Verificación de calidad	15.0769	350
2	B	Proceso de mecanizado	300.923	350
3	C	Proceso de soldadura	180.077	350
4	D	Proceso de mecanizado	90.3846	350
5	E	Proceso de Pre-rectificado	120.385	350
6	F	Proceso de cromado	503.923	350
7	G	Proceso de Post-rectificado	238.692	350
8	H	Proceso de pulido	41.5385	350
9	I	Etiquetado y embalado	30.8462	350
			1491	350

Número de operadores necesarios	4.26

Operador	Tiempo	Takt
1	298.2	350
2	298.2	350
3	298.2	350
4	298.2	350
5	298.2	350

Figure 9. Balance analysis

With the above mentioned, we proceed to have the results of the work standardization tool versus the time that the reprocessing lasts (Table 9).

Table 9. Result of the work standardization tool

Standardization of work		
Fault description	**Pre-Implementation**	**Post-Implementation**
	Time taken for reprocessing (min)	
Reprocessing by operators	179	62
TOTAL (min)	**179**	**62**

4.3 Proposal for improving the simulation

Based on this design, a simulation was carried out to show that initially there is a low productivity in the manufacturing process of chrome rollers and with the implemented tools, there is an improvement in the productivity of the company. Below is the simulation carried out in Arena (Figure 10).

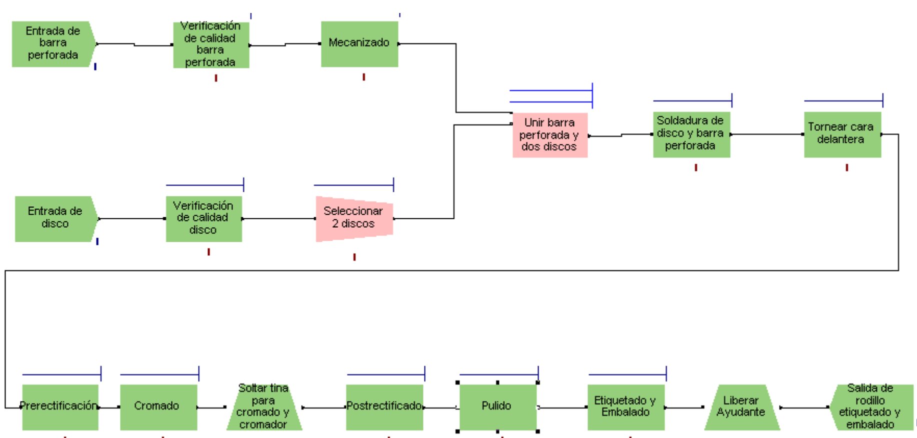
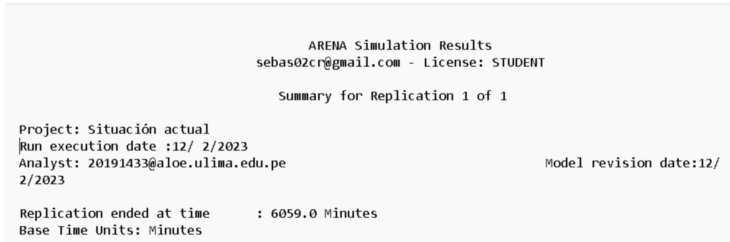


Figure 10. Process simulation

In this Arena simulation design, the respective simulations were performed, and the focus was on identifying the simulation duration for both the current situation and the improved situation. Evidence of the results obtained is shown below (Figure 11).



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ARENA Simulation Results
sebas02cr@gmail.com - License: STUDENT

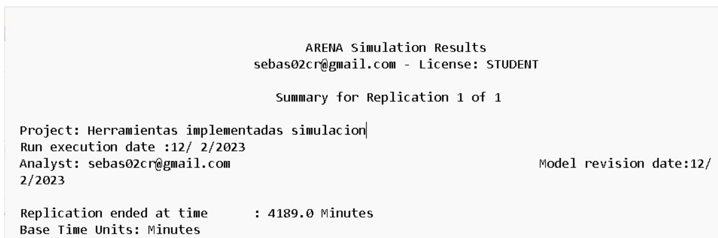
Summary for Replication 1 of 1

Project: Situación actual
Run execution date :12/ 2/2023
Analyst: 20191433@aloe.ulima.edu.pe                    Model revision date:12/
2/2023

Replication ended at time      : 6059.0 Minutes
Base Time Units: Minutes
```

Figure 11. Arena simulation results of the current situation

It can be observed from the simulation of the current situation that it generated a result of the process duration of 6059 minutes, dividing it by 60 to obtain it in hours and by 4 to obtain the duration per chrome roller at approximately 25.25 hours (Figure 12).



```
ARENA Simulation Results
sebas02cr@gmail.com - License: STUDENT

Summary for Replication 1 of 1

Project: Herramientas implementadas simulacion
Run execution date :12/ 2/2023
Analyst: sebas02cr@gmail.com                           Model revision date:12/
2/2023

Replication ended at time      : 4189.0 Minutes
Base Time Units: Minutes
```

Figure 12. Arena simulation results of the improved situation

Regarding the improved situation, it generated a result of the process duration of 4189 minutes, dividing it by 60 to obtain it in hours and by 4 to obtain the duration per chrome roller, we have an approximate duration of 17.45 hours. Based on this result, it is validated that the model is reliable and the theoretical implementation of the components in the physical scenario is carried out. Procedure for implementing a Maintenance Program**.** To implement the maintenance program, 5 steps will be followed in which the improvement process will be described based on the reduction of the number of failures.

5. Results and discussion

With the Objective to evaluate the results of this implementation. In the following Table, a breakdown of the indicators to be evaluated is provided. evaluate , placing particular emphasis on he productivity indicator , since it is the central problem affecting the company subject to analysis(Table 10).

Table 10. Comparison of indicators

Indicators	Pre- Implementation Company	Post Implementation Company
Productivity (1 roller /HH)	1 roller / 25.25 HH	1 roller / 17.45 HH
Changeover time (min)	429	331
Rework per operator (min)	179	62
Time that the fault lasts (min)	246	58

From these results, you can show that once the SMED tool was implemented there was a reduction in changeover times, from 429 to 331 minutes), which means that machines and production processes stop during a lot less time, thus increasing production availability. In addition , this variable reflects a downtime lower and, thus , higher productivity , since the company can produce further in he same period of time .

On the other hand side , when the workers follow procedures standardized , are committed minors errors in he production process , it reduces the rework , that is , it prevents the same operator do the same thing again task . This is seen reflected in he indicator of rework by operators . The situation in which the company It has not yet implemented the tools it gives as result of this indicator of 179 minutes ; however, when the methodology is introduced a large reduction occurs to 62 minutes . This leads to greater efficiency in production and output , a better product quality.

Going deeper in he maintenance program , a realization appropriate of this program maintains machines and equipment in optimal conditions . Of this way , it looks reflected In the variation of the indicators , in the pre- implementation a failure lasts 246 minutes , which harms the company in terms of production and economy . After having implemented the tool , there is a great reduction , this goes to 58 minutes . This not only prolongs life useful of the assets , but also reduces the need to carry out expensive unplanned repairs . Reducing maintenance costs can contribute to improving the company's profitability.

Reducing tool change time and standardizing processes enhance the predictability and manageability of production planning and scheduling. These improvements enable the company to optimize resource allocation and maximize the utilization of production capacity, leading to greater operational efficiency.

In As for productivity , its increase from 1 roller for 25.25 man hours to 1 roller for 17.45 man hours is a change positive and significant in the efficiency of the company . The fact that the company now produce 1 roll in 17.45 man hours in instead of 25.25 man hours means that it has become further efficient in the use of resources humans and the time . In addition , increased productivity It means that the company can offer prices further competitive in the market. This can help win market share and attract further clients , which in turn time can increase revenue and profitability . On the other hand, side, if the company can deliver products further fast or with deadlines delivery further shorts Due to the higher productivity, this can increase customer satisfaction, as they They usually assess the punctuality and responsiveness of companies.

6. Conclusion

This research reveals that substantially increased productivity and operational effectiveness were achieved as a result of the introduction of the SMED, the preventive maintenance programs and the standardized work practices in one of the metalworking SMEs. These measures tackled the significant challenges of long changeover times, machine breakdowns and high rework levels. Among the notable improvements were a reduction in changeover time from 429 to 331 minutes, in rework time from 179 to 62 minutes and equipment downtime due to breakdowns from 246 to 58 minutes. Besides, productivity registered a marked improvement as the time needed to produce the chrome-plated roller was minimized from 25.25 to 17.45 hours. These improvements indeed attested to the potential of the proposed production model in improving resource and process reliability.

The findings bring to the fore the need to embed the application of lean tools within the operational setting of SMEs, especially in diverse and complex environments. Through process rationalization and the culturing of continuous improvement, the author shows how such measures can turn operational problems into growth opportunities. Emphasis on application and provision of workers with standardized methods not only minimized the chances of errors but optimized their flexibility and willingness to meet greater production targets. Such an all-rounded view 'operationalizes' the dichotomy between abstract models and their actual use in everyday life, thus reaffirming the practicality of lean approach in pursuit of excellence in operations.

Looked at more broadly, the results are of great importance to the branch of industrial engineering as they serve as a distinct evidence-based literature on the impact of lean type production tools in a small-scale manufacturing context. The research strengthens the need for SMED and standardized work as fundamental of being able to respond quickly and effectively to changes while avoiding unnecessary work that adds no value. In addition, the preventive maintenance program enhances continuous operational integrity by mitigating unforeseen downtimes, reducing maintenance expenses in the end and increasing the operational life period of significant assets. Such insights are critical for industry and researchers in a bid to make SMEs enhance their productivity and competitiveness in such environments.

Reliably, the publication presents a well-structured theory that can be modified and used in different industries to combat the challenges that impede productivity. Further studies could look into the possibility of including more cutting-edge technologies like IoT based predictive maintenance or predictive simulation-based maintenance software to increase the range of these activities. Also, longitudinal studies focusing on the sustainability and the possibility for the further commercialization of the used tools would help to better understand their benefits over time. In those relationships between the business activities and institutions further development of lean practices can be expected which would guarantee constant enhancement in the ever-changing environment of the manufacturing sphere.

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