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The Production Model Based on Lean Manufacturing and TPM to Increase the Level of Efficiency in a Company in the Manufacturing Sector

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Abstract

The present research focused on measuring the efficiency level based on implementing Lean Manufacturing and TPM. Relevant data for the research were collected before and after the implementation to identify problems and design solutions based on Smed, Standardized Work, and TPM. First, a root cause analysis was performed with the problem tree tool, where problems such as long set-up stoppages, breakdowns, lack of maintenance, and lack of training of the production team, among others, were identified. Therefore, a solution proposal was implemented based on the methodologies, which improved the efficiency level from 50% to 79.3%. Based on this, the application of the SMED tool focused on decreasing the setup time, the mold change lasted about 7.06 hours and decreased by 5.97 hours. In the case of standard work, operational failures were reduced from 15% to 6%. On the other hand, the implementation of TPM increased the efficiency of the machinery together with preventive maintenance training for the equipment, which increased from 37.56% to 51.31%. Finally, these findings highlight the importance of implementing tools such as Lean Manufacturing and TPM in the manufacturing sector to increase the level of efficiency in the organization.

Keywords
Efficiency, Manufacturing Sector, Lean Manufacturing, TPM, SMED, Standard Work

1. Introduction

This paper will analyze the Manufacturing, this sector groups economic activities that carry out the physical or chemical transformation of materials, substances, or components into new products. In addition, it is one of the most relevant sectors of the country's (INEI 2014). According to the Ministry of Production in Peru, this sector is mainly classified into two branches. Firstly, primary manufacturing, which represented a quarter of the sector in 2019 and includes the industry of fishery products, meat, precious and non-ferrous metals, petroleum refining and sugar processing (Ministry of Production 2023).

On the other hand, non-primary manufacturing encompasses the sector of consumer goods, including the production of canned fruits and vegetables, dairy products, furniture, clothing, knitwear, crochet items, pharmaceuticals, and bakery products. Additionally, within this branch, there are intermediate goods, which include industries producing metal structures, plastic products, cement, chemicals, glass products—the latter will be the subject of analysis in this chapter. Finally, capital goods, which cover the production of machinery for mining, electric motors, and transformers (Ministry of Production 2023). The main issues in the industry are the level of shrinkage, a factor that most manufacturers expect to have a minimum amount. Secondly, the level of efficiency, as it demonstrates the ability to produce in each time and with a given number of resources.

After an analysis, it has been identified that the most relevant problem in the case study is the low level of efficiency, since the process can stop due to high set up times, breakdowns, operational failures, lack of maintenance, among other factors. Therefore, the research chose to define the ideal efficiency percentage in the sector, this was selected from a similar manufacturing process which was 75% (Moya 2017). In this way, a comparison was made with the case study that had 50% efficiency in its production process. Therefore, our technical gap is 25%, which indicates an opportunity for improvement where we can apply engineering tools to achieve a higher percentage.

Objectives
The main objective of this research is to increase the efficiency level in the pipe production line by 25% after the implementation of the improvement proposal with Lean Manufacturing and TPM tools.
Specifically, the objectives of the project will be detailed as follows:
Reduce the setup time of the manufacturing process to 4.5 hours by employing the SMED tool.
Decrease the percentage of operational failures to 8.05% using standardized work.
Increase machine operating efficiency to 45% using the TPM tool.

2. Literature Review
As the implementation of Lean Manufacturing and TPM tools in the manufacturing sector has been gaining recognition for the great results obtained from their applications, numerous scientific studies have addressed this issue, trying to understand and analyze the results obtained through their application.

In this sense, some typologies of results found in the literature have been identified, which allow examining and evaluating the impact of improvements based on SMED, Standard Work, and TPM. The objective of this section is to analyze the different results found in scientific articles related to the implementation of these engineering tools in the manufacturing sector. In this context, manufacturing companies are focused on improving resource efficiency during production and evaluating the use of optimization software tools (Pressmair et al. 2023). One of the main challenges in the industry lies in mechanical, electrical, design, and production functions, which often exhibit low efficiency. To address this, new engineering tools are being applied (Parwani and Hu 2021). An example of this evolution is the transformation of The Industrial Internet of Things from a traditional manufacturing model to a more advanced one (Zhang et al. 2023), providing companies with effective tools to manage their process inputs and outputs (Smagowicz et al. 2022).

Some studies segment efficiency into short, medium, and long terms, measuring these periods differently (Badunenko et al. 2020). It is essential to allocate factors appropriately and propose precise optimized methods, clearly defining the factors to obtain effective results (Li et al. 2023). The authors highlight the urgency of reducing material consumption in the manufacturing sector, focusing on improving resource efficiency in production through structural optimization software. Their key contribution is achieving the same production effectiveness with a reduced number of materials, aiming to save costs and promote sustainability. In the research, trials were conducted with eight specimens, evaluating parameters related to the optimization strategy. Finally, the comparison between the final product without efficient manufacturing and after its implementation revealed a reduction in material and an increase in overall performance by 16.75% (Pressmair et al. 2023).

On the other hand, According to Teguh Ngadono, Lean Manufacturing is widely recognized across industries as a strategic tool adopted to compete in fierce competition. It is not only ideal for improving production and reducing time and costs (Chaurey et al. 2023), but is also crucial for optimizing resources, costs, and production time, particularly for suppliers (Tebar et al. 2022). Simultaneously, it serves to prevent pollution and reduce waste (Caldarelli et al. 2022).

Digging deeper into Lean Manufacturing, its application involves analyzing collected data using an Analytical Hierarchy Process (AHP) and systemic thinking approaches to determine the criticality of evaluated factors (Omotayo et al. 2021). Techniques like fishbone diagrams, Failure Modes, and Effects Analysis (FMEA), or ABC analysis are also employed to study causes and effects (Debnath et al. 2019); these methods manage line balancing activities within everyday industrial realities (Cannas et al. 2018).

The authors of this research advocate for implementing Lean Manufacturing in a company facing low-efficiency issues due to supply chain lead time. The research outlines the implementation process, emphasizing that it involves not only deploying the tool but also training and evaluating its application. Employing an experimental methodology with a pilot study in the target company, the authors applied all phases of Lean Manufacturing. Ultimately, they achieved a reduction in the delivery time for the extrusion process from 13.72 to 12.8 minutes per batch, and the Work in Progress (WIP) stock was reduced from 12.8 hours to 10.6 hours (Ngadono et al. 2020).

Also, preventive, and predictive maintenance are planned strategies, while corrective or breakdown maintenance is unplanned (Gurpreet et al. 2020). Total Productive Maintenance (TPM) has been found to influence manufacturing performance both directly and indirectly (Al-Refaie et al. 2022). Furthermore, adopting TPM can lead to improvements in profitability, efficiency, responsiveness, quality, and customer satisfaction (Garza et al. 2018). It even contributes to the well-being and understanding of professionals involved in top management (Rajnoha et al. 2018), ultimately enhancing overall competitiveness (Prabowo et al.2020). In today's competitive landscape, companies must maintain and even increase the efficiency of their equipment. However, the application of TPM is a significantly more complex activity if not applied correctly. This article highlights the importance of autonomous maintenance for achieving 100% production capacity and reducing costs. The authors employed an empirical method, studying machines in a plant, collecting data, and selecting the most critical machine for the implementation of autonomous maintenance. The results demonstrated an OEE improvement from 14% to 15% after implementing autonomous maintenance (Alcaráz et al. 2021).

Finally, the primary author in this typology emphasizes the importance of integrating engineering tools to enhance efficiency, such as Lean Manufacturing and Total Productive Maintenance (TPM), which can be combined for benefits like reduced downtime, extra costs, and overall process improvement (Abanto et al. 2020). Some authors advocate combining tools that target different breakpoints using various methodologies, achieving positive results (Hu et al. 2023). Also, Single-Minute Exchange of Die (SMED) begins with a time study and analysis of each stage of the process, breaking it down into simpler steps (Fazinga et al. 2019). On the other hand, Standard Work (SW) allows for the definition of optimal and uniform criteria in executing a specific task or operation. The authors propose implementing an optimization model based on the Johnson method, SMED, and 2 pillars of the TPM methodology to achieve a well-supplied inventory of high-quality products. Their methodology was experimental, as the studied SME provided access to the factory to test this set of tools. Ultimately, the results showed a 24.39% increase in the company's productive efficiency, attributed to reduced setup times and increased time between failures.

3. Methods

The improvement model was based on three components. The first focused on analyzing the environment and the case study to identify opportunities for improvement; in addition, the root causes of the low level of efficiency were identified. The second component was based on the application of tools (SMED, SW and TPM). During this stage, the production team was trained, and manuals and visual material were shared to support the learning of these new methodologies. Finally, validation is a very important component because it remeasures all relevant indicators in the research, thus concluding the impact of the proposed improvement in the manufacturing process.

- Component 1: Problem analysis
  The objective is to identify the main problem in the production process. To achieve this, a manufacturing sector analysis was initially conducted to identify the most relevant indicators. In this case, the efficiency percentage was selected, and a comparison was made with the current results of the company to determine the technical gap. Subsequently, a problem tree was developed, starting from the low efficiency percentage of the company. This was further broken down into main reasons and then into root causes to identify improvement objectives. Once the causes and their priority are established, they should be correlated with Lean Manufacturing tools (Standardized Work and SMED) and TPM that can be applied to address the identified causes that require intervention.
- Component 2: Method Implementation
  In this phase, the tools SMED, Standard Work and TPM will be implemented.

Firstly, the SMED tool will be implemented to reduce setup time. Subsequently, standardized work will be employed to decrease operational errors and enhance team productivity. Finally, TPM will be implemented to ensure the proper functioning of the machines and establish a preventive maintenance plan.

- Component 3: Validation
  The final phase of the model focuses on validation, as it is crucial to verify that the proposed objectives are being met. It will also be necessary to measure the impact of implementing this set of tools reflected in the key indicators of the process and analyze whether the results met the expectations.

In the following figure (Figure 1), there is description of the components.

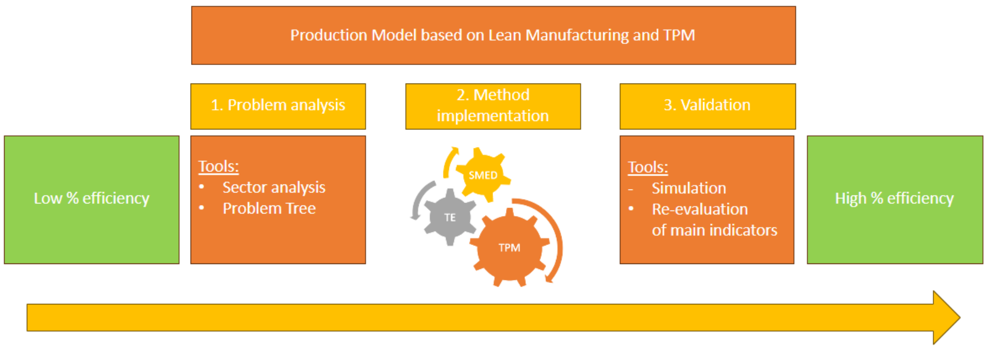

Figure 1. Proposed model of improvement

4. Data Collection

A detailed analysis of the entire pipe manufacturing process was carried out with the support of the engineer in charge, supervisors, and operators. To carry out a better investigation, during the exploratory stage, a few visits to the plant were made to understand each activity of the process and to identify with the team each problem that exists and what was the reason for it. This qualitative analysis was the main tool to develop component 1 of this research.

With the help of the qualitative analysis conducted in the exploratory stage of the research, we were able to determine and recognize the main reasons why the process has a low level of efficiency. These reasons are listed in the following table (Table 1).

Table 1. Reasons of the lack of efficiency

List of motives
1. Unscheduled shutdowns
2. Machine failures
3. Operational errors
4. Set up time delays

Once the diagnosis has been completed and the root causes of the low level of efficiency have been identified, Figure 2 shows the problem tree. This diagram summarizes the diagnostic process and will serve as a basis for identifying cause-specific engineering solution tools.

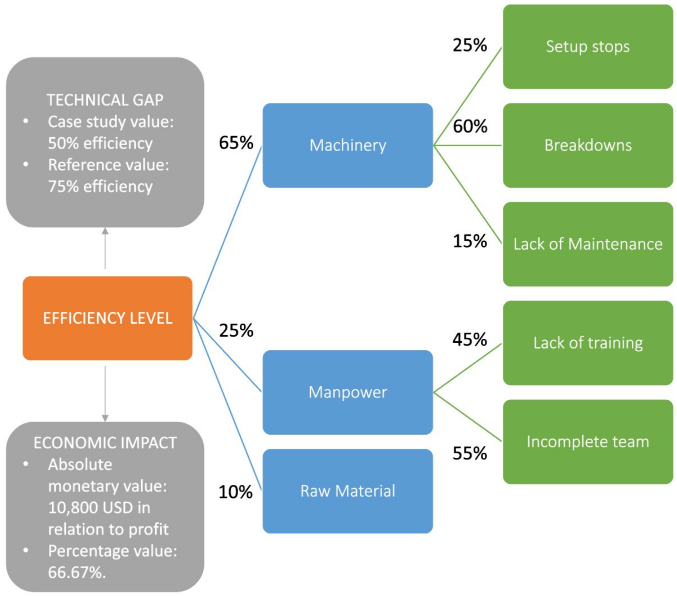

Figure 2. Problem Tree

By evaluating and validating the root causes identified, as illustrated in Figure 3, an objective tree has been created for each cause. This set details the techniques and tools employed to provide a solution to the identified problem.

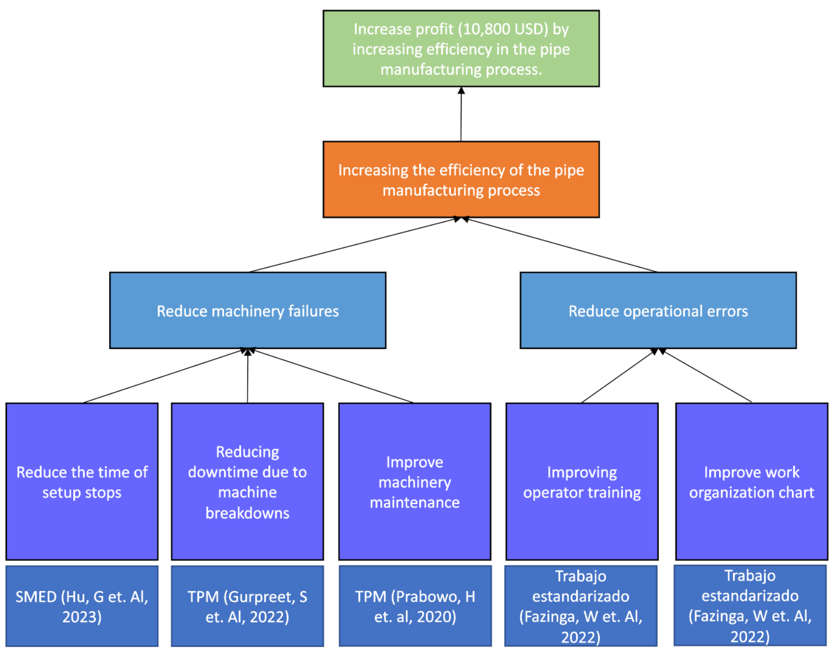

Figure 3. Objective tree

5. Results and Discussion

In this section below we will perform the validation of our proposed solution within the production process previously described. This will be done through two validation methods which will allow us to analyze our main indicator, efficiency, after the implementation of our proposed solution.

(A) The first method is based on a pilot test performed within the actual manufacturing process for the analysis of time and employee training.
(B) The second method is to perform a second validation with the help of a simulation software called Arena 16.1, which will allow us to analyze with many more repetitions and more accurate results.
Furthermore, within both methods, we will implement the SMED, Standardized Work, and TPM tools.

5.1 Numerical Results

In this section, after data collection and simulation replication, we will evaluate the results of the main indicators regarding the before and after the implementation of the proposed solution. This information can be seen in the following table (Table 2).

Table 2. Comparison of indicators

Tools	Selected Indicator	Unit	As Is	To Be	Improvement
Surrounding analysis	Technical Gap: Efficiency level	Percentage	50	70	79.63
SMED	Mold change time	Hours	7.06	4.5	5.97
Standardized work	Operational failures	Percentage	15	8.5	6
TPM	OEE	Percentage	37.56	45	51.31

According to the comparison, we can define that the proposed solution achieved its main objective. This consisted of increasing the main indicator, efficiency, overcoming the technical gap compared to the value of the industry. As we can see, it exceeded the target value set prior to the implementation of the proposal.

The implementation of SMED reduced mold changeover time by 15.44%, although it did not achieve the "To Be" target due to the rigorous nature of the process. The Standard Work tool was able to reduce failures to 6%, exceeding the initial target and improving the quality of the final product. In addition, the application of TPM resulted in an increase in OEE from 37.56% to 51.31%, exceeding the target of 45%. An improvement from 42% to 57% in performance was observed. The efficiency analysis shows how each tool positively impacts production, highlighting the direct relationship between the reduction of times and faults with the increase in efficiency, which was measured at 79.63%. This information can be seen in the following figures (Figure 4) (Figure 5).

5.2 Graphical Results

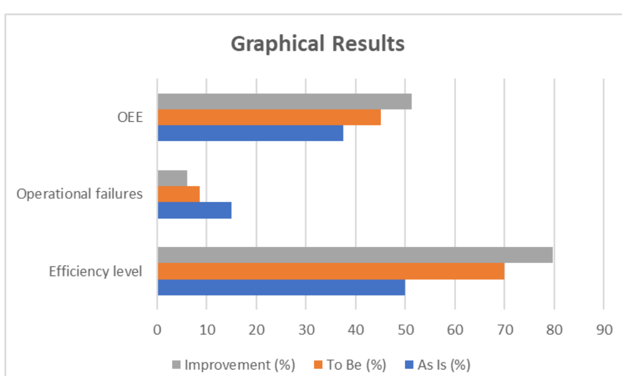

Figure 4. Main research indicators 1

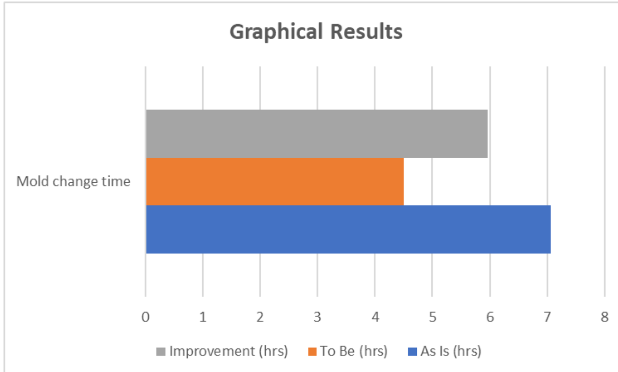

Figure 5. Main research indicators 2

5.3 Proposed Improvements

In this section, the integral objective is to prove the process and results after the application of the proposed solution. For this purpose, a pilot test had to be carried out where we would obtain the time measurement in each individual activity of the pipe manufacturing processes. Also, with this data collected, we would apply the tools described below, to finally perform another pilot test and obtain the new time results obtained.

(A) Single Minute Exchange of Die (SMED)

Within the tool implementation, there are a total of five steps to consider. First, the process and subprocess times for mold or mold change are measured. Moving on to the second step, tasks are analyzed to break them down into simpler activities, and unnecessary delays are identified for elimination. As the third step, these identified activities are categorized into external and internal. In this step, external activities are isolated and moved before or after the change, as they can be performed while the machine is in operation. In the fourth step, we aim to isolate internal activities to transform them into external ones, reducing downtime when the machine is out of operation. Following the previously described steps, as the fifth step, it is essential to ensure through personnel training that the entire process is better optimized and standardized. After implementation, the percentage of internal activities decreased from 56% to 33%. In the case of external activities, it increased from 44% to 67%. . This can be seen in the following figures. The details of the times can also be seen in the following table (Table 3).

Table 3. Comparison times for activities for mold change

Sequency of mold change activities			
No.	**Activity**	**After**	**Before**
		Time (hours)	**Time (hours)**
1	**Disassembly of intern mold**	0.9	0.7
	Go for tools	0.15	0.5
	Go for the forklift	0.15	0.5
	Place the forklift	0.15	0.15
	Unset the heat	0.2	0.2
	Take the mold to the head area	0.1	0.1
	Leave the forklift	0.15	0.15
2	**Supply of tools and machine cleaning**	1.4	1.3
	Go for cleaning tools and agents	0.15	0.5
	Clean the mold support and machinery	1.25	1.25
3	**Assembly of the new mold**	0.95	0.85
	Go for the forklift	0.15	0.15
	Place the new mold on the forklift	0.2	0.1
	Adjust the new mold	0.45	0.45

	Leave the forklift	0.15	0.15
4	**Machine Calibration**	1	1
5	**Material Supply**	0.75	0.75
	Go for the forklift	0.15	0.15
	Separate raw material bags (PET)	0.25	0.25
	Add the content of the bags to dispenser	0.2	0.2
	Leave the forklift	0.15	0.15
6	**Test**	2	2
	Total	7	7

(A) **Standardized Work (TE)**

Standardization achieves the goal of reducing incorrect execution in productive activities. Implementing the Work Standardization tool allows for the analysis of operational failures during the pipe manufacturing process.

To correctly implement the Work Standardization tool, a comprehensive understanding of the current process flow is necessary to identify operational failures by operators. This enables the identification of potential downtime within the pipe manufacturing process. Subsequently, the correct workflow for each activity where operational failures occur is determined. From the previous step, the most impactful failures in the process should be selected, outlining the most efficient step-by-step process to avoid delays. As the fourth step, once the above is established, training and work instructions must be provided to the personnel. This is achieved by providing visual material illustrating the optimal development of each activity for the use of the responsible personnel. Likewise, for the profile winding and tube cutting, a manual was developed to ensure that all operators handle the machinery in the same way. Finally, as the fifth step, proper monitoring and ensuring compliance with the steps are essential. This involves measuring the operational failure indicator to determine improvement and assess the impact it had on the process. This can be seen in the following table (Table 4).

Table 4. Comparison of Operational failures in the pipe production line

Activity	Operational Failure	After	Before
Mixed with masterbatch and recycled resin and quality control of the mixture	Profile with average quality due to poor MP filter	9%	6%
Profile winding and tube cutting	Poor use of the command control, the operators are not aware of the speed to roll the profile.	15%	9.8%

(B) **Total Productive Maintenance (TPM)**

The implementation of the following tool involves a total structure of seven steps to follow. Firstly, a team or individuals related to the process will be assembled for the identification and analysis of potential barriers affecting the tool's application. As the second step, the identification of machinery involved in implementing TPM is conducted. Subsequently, the collection and measurement of data are carried out to estimate the Overall Equipment Efficiency (OEE) indicator within the current manufacturing process. On third step, a solution proposal is developed based on the gathered information and a study of the current schedule and company policies related to machinery maintenance. This involves identifying changes and proposing a new scheme after TPM implementation.

As the fifth step, an improvement proposal for the previously analyzed maintenance plan is presented. Strict plans are developed with visual aids and process specifications for preventive maintenance. Additionally, specific processes to follow in the case of unanticipated failures, described as corrective maintenance, are outlined. Entering the sixth step, the implementation phase is initiated. A schedule of training sessions and a plan for disseminating a new preventive culture, in conjunction with the key pillars of TPM, are prepared. The pillars considered include autonomous maintenance, education and training, and quality maintenance. For the seventh step, the focus is on monitoring the implementation with the goal of reducing the lead time of unexpected failures and extending the occurrence of failures as much as possible. This aims to increase the efficiency and productivity of the company, resulting in positive financial implications. To achieve this, the calculation of the following indicators was performed. This can be seen in the following table (Table 5).

Table 5. Percentage of failures in the production process for each machinery in a semester

Activities	**%Semester failures**	**% Failures after the proposal**
Panel Control	3%	1%
Hopper	6%	2%
Dispenser	2%	1%
Extruder (Mold)	4%	2%

(C) **Simulation on Arena 16.1**

The software Arena 16.1 was utilized to model and analyze various systems, providing significant benefits by enabling the simulation of processes in a virtual environment without incurring costs associated with real implementation.

Firstly, in accordance with the explained implementation of the tools, we will use this compilation within the simulation software. Based on the pilot test consisting of 10 repetitions, we calculated the confidence interval based on 10 replicas. This reflects how often a damaged tube or one with standards below permissible levels occurs, with a result of 46.234 +/- 5.83 hours. The pilot test implementation was carried out, leading to another data compilation, which is illustrated in the following table (Table 6).

Table 6. Comparative duration of times in the process activities – Post-Implementation

Activities	**Before**	**After**
Loading and Dosing	TRIA (28,30,32) minutes	TRIA (18,20,22) minutes
Extrusion	TRIA (28,30,32) minutes	TRIA (18,20,22) minutes
Passage through cooling tank 1	TRIA (28,30,32) minutes	TRIA (20,22,24) minutes
Passage through cooling tank 2	TRIA (28,30,32) minutes	TRIA (20,22,24) minutes
Coiled and Welded	Constant: 110 minutes	Constant: 90 minutes
Inspection	Constant: 10 minutes	Constant: 8 minutes
Mold change	TRIA (6.5,7,7.5) hours	TRIA (5.5,6,6.5) hours

Considering the described data, modeling was performed within the software, incorporating previously collected activities and data to conduct respective simulations with data collected before and after the proposed solution implementation. This can be observed in the next figure (Figure 6).

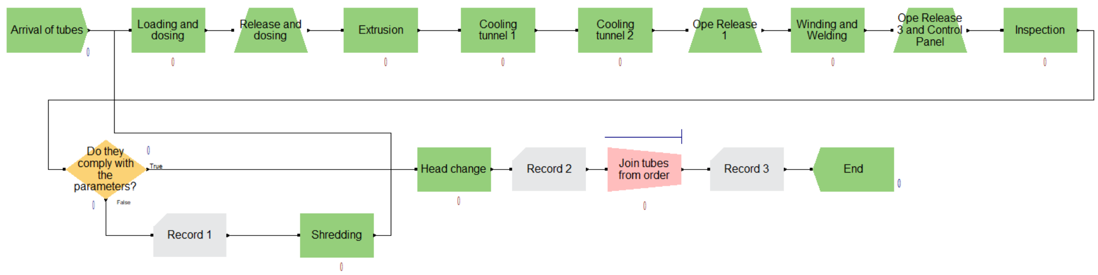

Figure 6. Current Simulation Model of the Company

Ultimately, after the simulation, there was a reduction in times during the tube forming stage from approximately 4 hours to 3 hours and the setup (mold change) from 7 hours to 6 hours with +/- 0.5. Moreover, there is a decrease in faults after inspection from 15% to 6%. The goal is to manufacture an order of 36 pipes in the shortest time possible to achieve a higher level of machinery efficiency.

5.4 Validation

To analyze in detail, the results and the progress of the economic benefits generated by the implemented improvements, the cash flow projection for the next five years is shown below in Figure 7. It is worth mentioning that the currency used to make these calculations present in Figure 7 and Figure 8 are in PEN.

Year	0	1	2	3	4	5
Investment	- 86,800					
Revenue		42,300	50,760	60,912	73,094	87,713
Expenditure		16,920	20,304	24,365	29,238	35,085
(Depreciation)		12,760	12,760	12,760	12,760	12,760
Earnings before interest and taxes		12,620	17,696	23,787	31,097	39,868
Interest		7,760	6,607	5,282	3,759	2,010
Earnings before taxes		4,860	11,089	18,506	27,337	37,858
(Taxes)		1,434	3,271	5,459	8,065	11,168
Net income		3,426	7,818	13,046	19,273	26,690
Depreciation		12,760	12,760	12,760	12,760	12,760
(Amortisation)	52,080	- 7,740	- 8,893	-10,218	-11,740	- 3,759
Recover. Working Capital						23,000
Book Value						-
Net Financial Cash F	- 34,720	8,447	11,685	15,589	20,293	58,691
Discounted Cash Flo	- 34,720	7,116	8,293	9,321	10,222	24,907
Accumulated Cash F	- 34,720	- 27,604	-19,311	- 9,990	232	25,139

Figure 7. Cash flow Chart

In addition, the calculated financial indicators can be seen in Figure 8.

VAN	25138.98 > 0
TIR	39% > COK (18.70%)
R B/C	1.72 > 1
P. R.	4.33 años

Figure 8. Cash flow Chart

6. Conclusion

The proposed solution for increasing the level of efficiency in the manufacture of pipes has proved to be successful, as it was possible to increase the level of efficiency from 50% to 79.03%. It is worth highlighting that the set of the three tools was the one that directly influenced the increase in efficiency, as each tool with its respective indicator had an individual improvement. This increase in efficiency can have several benefits such as the reduction of production costs, the reduction of idle times and the optimization of resources.

It is necessary to emphasize that the technical gap of the research was overcome. Within the sector, the target efficiency percentage was set at 70%; however, this technical gap was exceeded, reaching 79.03%. This indicates that within the pipe manufacturing industry there is a lot of potential and capacity to develop this type of programme focused on increasing efficiency or productivity.

Likewise, after carrying out the whole research process, it can be concluded that the third objective of the research was successfully fulfilled. A simulation model aligned to real life was developed to be able to apply the improvement without incurring implementation costs. Also, the Arena software is not only used to calculate the main indicators of the improvement, but also to detail calculations within the report that will serve as relevant information of the process itself, for example: how often a non-optimal pipe is formed to have a better view of the picture and refine your proposal.

Finally, it is concluded that, despite the nature of pipe manufacturing, which is linear and has very constant times, there is the possibility of making improvements within the same process without changing the order of activities, but the quality with which they are carried out. To carry out this research, as part of objective one, it was focused on having a good theoretical basis of the subject to be dealt with and, although the types of manufacturing processes were not related, it was possible to apply the same steps and adapt some training to adapt them to the manufacture of pipes, obtaining successful results.

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Biographies

Sofía Valentina Guerrero-Telles Born in Lima, Peru, Sofía graduated with a degree in Industrial Engineering. His academic career began five years ago at the University of Lima. His current research focuses on evaluating efficiency levels through the implementation of Lean Manufacturing and TPM within a company in the manufacturing sector in Peru. Now that Sofía graduated in Industrial Engineering, she actively seeks new challenges to face and overcome, eager to test her skills in new endeavors.

Wilder Daniel Murga-Alvitez Born in Lima, Peru, Daniel graduated in Industrial Engineering. His academic career began 5 years ago with a degree in Industrial Engineering at the University of Lima. His current research consists of measuring the level of efficiency based on the application of Lean Manufacturing and TPM within a leading manufacturing company in Peru. Now that Daniel is a graduate of Industrial Engineering, he is looking for new challenges to tackle and overcome by putting himself to the test.

Martin Fidel Collao-Díaz at ESAN University and Industrial Engineer from Universidad de Lima specialized in supply chain management and operations. A leader with more than 25 years of local and international experience in national and multinational companies in industrial, hydrocarbon, and mass consumption sectors. Broad experience in supply chain management (purchasing, inventory, suppliers and supply sources management, logistics: transport, distribution, and warehouse management), operations (planning and control of production and maintenance), and integrated system management (ISO 9001, ISO 14001, and OHSAS 18001). Business alignment based on sales and operations planning (S&OP). Besides, continuous search for improvements in profitability based on process optimization and saving projects using tools such as Six Sigma methodology, among others, focused on being a High-performance Organization (HPO). Development of a high-performance team. Member of IEEE and CIP (College of Engineers of Peru).

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