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Improvement in a Flexible Packaging Company through Standardization and Preventive Maintenance

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Abstract

In the current industrial context, research efforts are directed towards addressing challenges encountered by manufacturing sectors, particularly concerning cost management, production waste, and downtime issues. This study aims to explore and propose solutions to enhance operational efficiency and overall performance in response to these critical concerns. It emphasizes the significance of standardization and preventive maintenance as key solutions to tackle these challenges. Previous research has demonstrated that implementing these engineering tools not only reduces costs but also enhances overall business processes. The goal is to optimize efficiency and outcomes.

Keywords
Preventive Maintenance, Standardization, Flexographic Printing Process, and Lean Manufacturing

1. Introduction
For many years, flexible packaging has shown significant growth within the packaging industry. The predominant user of flexible packaging has been the food sector, acquiring a significant market share of 70%, which impacted the global flexible packaging market in 2020. According to Balaban et al. (2021), projections for 2021 estimate that the market will reach around 31.5 million tons, representing an average annual growth of 3.3%. Also, Repeta et al. (2023), mentioned that the flexographic printing method for flexible packaging with solvent-based inks for food and industrial products maintains a leading position in this segment compared to other printing methods. Its development is accompanied by constant improvement of materials and technologies.

Valdec et al. (2021) state that flexography is based on the fundamental principle of ink transfer, but delving into a more detailed perspective of the process can unveil various variables that impact this printing process and, naturally, the final quality of production. The ultimate result is influenced by a variety of processes including plate properties, anilox roller conditions, photopolymer printing, and printing substrate characteristics.

In Peru, the company under study has increased its production of flexible packaging in response to higher customer demand, thus consolidating its presence in the plastic printing sector. These efforts have positioned it as one of the industry's major players, recognized for its innovative product offerings. Through an internal investigation, a comprehensive analysis of the production process was conducted, revealing that the total waste accounted for 13.29% of the final product. Specifically, the flexographic printing process emerged as the primary contributor to this waste generation over the past six months. The resulting losses for the company due to this waste amount to an average of 52,779.83 Peruvian soles per month.

This research is essential to address the issue of flexographic print waste resulting from a lack of calibration, maintenance, and standardization in the printing machine, leading to tone loss in light and shadow areas, reduced print contrast, and a cut-tone effect. By analyzing the causes of generated waste, researchers aim to find solutions to eliminate or minimize these errors in the graphic industry through engineering tools such as preventive maintenance and work standardization. The findings from this research can assist flexible packaging manufacturers in enhancing their printing processes and producing higher-quality prints.

Aisyah et al. (2020) noted that standardized work has evolved consistently over many years. It is a topic with a long history that has experienced gradual changes over time. The traditional implementation of lean tools, including standardized work, reflects the perspective that standardized work is a classic tool.

According to Pinto et al. (2020), maintenance has gained increasing importance in the restructuring of the industrial sector. Several companies in the market require the development of a strategic maintenance plan. In their study, the researchers introduced a preventive maintenance plan designed for implementation based on the Total Productive Maintenance (TPM) methodology. In this current research, the use of preventive maintenance will be crucial to enhance the process in this flexible packaging manufacturing company, drawing from past TPM implementations.

1.1 Objectives

This research aims to enhance the flexographic printing process in the company through the utilization of engineering tools, specifically Standardization and Preventive Maintenance. The main objectives are to design and develop effective solution proposals and subsequently validate these solutions through simulation.

2. Literature Review

The literature has been reviewed from two perspectives in this article: the first part covers standardization reviews, and the second focuses on preventive maintenance, both along with related tools that play a role in process improvement, primarily in manufacturing companies or related studies. Additionally, Azemi et al. (2020) state that they conducted research on Lean Manufacturing with the purpose of preparing a company in Kosovo for its transition to the modern concept of Industry 4.0. In this way, it was determined that the most used methodologies and tools in process improvement through engineering tools are Value Stream Mapping and Standardized Work. According to Alves et al. (2020), the VSM System improved productivity by 20% with the same number of resources at a valve manufacturing company in Poland. To enhance setup times on a production line producing cables, several tools such as SMED, 5S, and VSM were utilized. In Figure 1, the chart illustrates the articles utilized in the study, categorized by topic and year of publication. The majority of articles found are related to preventive maintenance. Articles related to standardization, lean manufacturing, and the flexographic process were also found between the years 2018 and 2023.

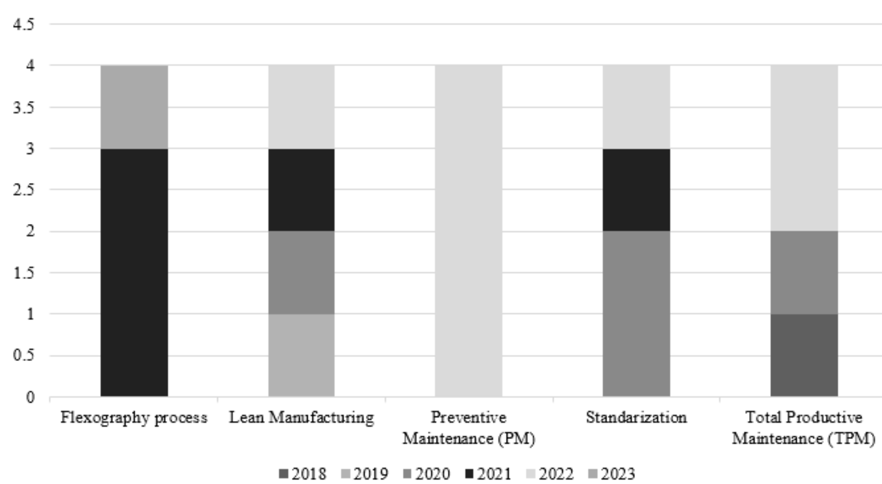


Figure 1. Literature Review Bart Chart

2.1 Standardization

To maintain competitiveness, manufacturing companies efficiently address various production challenges such as bottlenecks, imbalances in production lines, downtimes, late deliveries, overtime, inefficient material handling, movements, and high production costs (Realyvásquez et al., 2019). Standardized work establishes precise procedures for operators based on elements like Takt Time, standard inventory, and job sequence, emerging as a key strategy in the company (Santos et al., 2021). Although many companies recognize the importance of standardizing processes for better production management, they face challenges in its implementation. Process-based restructuring requires a deep understanding of organizational processes, and its implementation depends on talent development, definition, and organization of routine tasks (Espíndola et al., 2019). Standardization, in this sense, contributes to the development of knowledge and talent necessary for employees.

Gavriluta et al. (2021), using the Work Observation method, highlight the need for stability and standardization in the production system to identify and eliminate non-value-added activities. Their findings underscore the importance of standardization in the continuous improvement of processes. In terms of benefits, Gavriluta et al. (2021) observed a significant reduction in standard time, elimination of non-value-added activities, and equipment maintenance costs.

Additionally, associated costs, primarily labor-related, including project design, development, and production, were positively impacted, highlighting the effectiveness of standardization in the industry (Ciccarelli et al., 2022).

2.2 Preventive Maintenance

According to the research conducted by Quiroz and Vega (2022), it is evident that companies in plastic sector are facing challenges in their production processes, leading to inefficient use of resources. Additionally, it is main purpose is to preserve the functionality and reliability of the equipment, avoiding unscheduled stops and minimizing downtime. Based on TPM, preventive maintenance follows a series of steps to maximize its effectiveness. Through this tool, the plant management team is compelled to reconsider the traditional maintenance practices embraced by the plant staff. (Shehzad et al., 2018). However, due to the new regulations affecting this sector, businesses need to devise strategies to enhance their competitiveness in the market by improving the quality, diversity, and efficiency of their production processes.

As per Al Mashkoor, et al. (2022), under TPM, where the sustainability of production is ensured, human resources, materials, and other resources and processes maintain productivity. That study examines the contribution of lean manufacturing techniques in Iraqi manufacturing companies. Similarly, if the tools are efficiently applied, there is a timely flow of money with reduced costs, delivery times, and waste. As mentioned before as Pinto, et al (2020) introduce a preventive maintenance (PM) grounded in the Total Productive Maintenance (TPM) methodology. Based on that, the currently research use preventive maintenance to improve processes.

In the research by Lastra et al. (2022), it is emphasized that in preventive maintenance, as an improvement on corrective maintenance, technicians must detect the problem as early as possible in order to prevent the problem. Then they could analyze if the spare part could be printed and know the print time (PT) and the replacement time (RT) and incorporate them in the manufacturing chain before production stops. This results in an improvement in both the process and the products. Drewniak and Drewniak (2022) discuss preventive maintenance, which entails the daily maintenance of machines through activities such as cleaning, inspection, lubrication, and verification. These activities are aimed at preventing machine wear, keeping them in good condition, and thereby avoiding failures.

3. Methods

According to Bouchard et al. (2022), following a thorough search, various scientific articles, reports, and conference presentations related to the research topic have been identified, including standardization and the business model, concepts that contribute to agility. In this context, the key aspects focus on Standardization and Preventive Maintenance, which can be located in databases such as Scopus, Scielo, and others. Additionally, in the development process of these tools, techniques like Value Stream Mapping, Pareto diagram, and problem tree are employed to identify potential issues in business processes.

In order to analyze processes throughout the supply chain, a Value Stream Mapping (VSM) has been implemented, as visualized in Figure 2. This approach allows the identification of waste and deficiencies in material and information flows from suppliers to customer satisfaction. The process begins with planning and production, where orders and resources are coordinated. Then, in the extrusion process, polyethylene is melted to form a film that is printed with flexographic inks on a printing machine. Afterwards, a metallic layer is applied for shine and protection, followed by the cutting process, and finally, the products are stored until they are shipped.

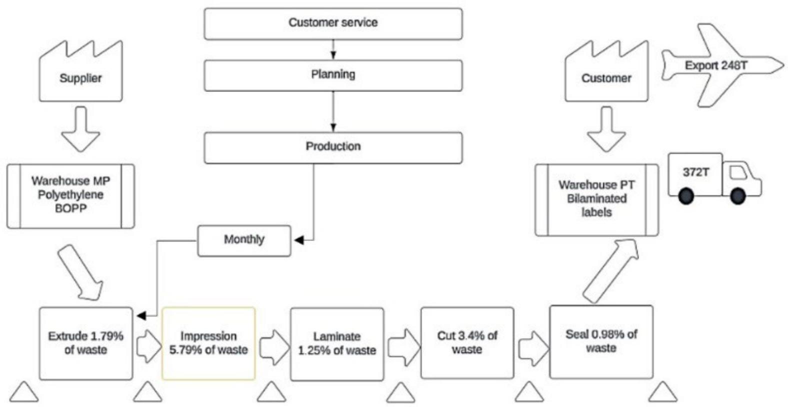


Figure 2. Value Stream Mapping

Next, to identify the causes, in Figure 3 a Pareto analysis was carried out to identify the main problems in the printing process. Problems were identified on the machines, such as cliche wear and anilox rollers as shown below.

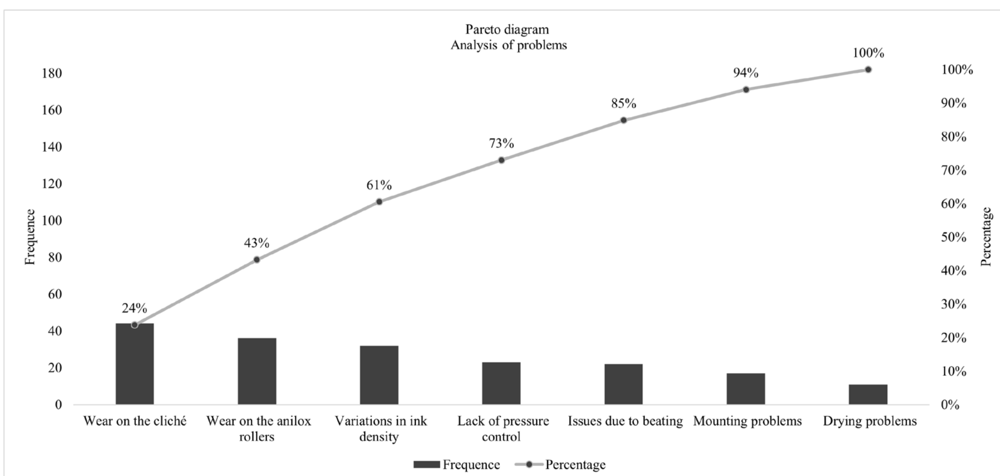


Figure 3. Pareto Diagram

The indicators to consider were derived from articles proposing improvements in company processes through various tools. According to Santos et al. (2021), Takt Time is defined as the time it takes a company to manufacture a specific product. In Santos' research, Takt Time calculation considered the quantity of products manufactured per day on the assembly line and the available time per shift. Ultimately, by reducing workload according to Takt Time, it is possible to decrease downtime and waste. According to Domínguez et al. (2020), concerning the selected product, the manufacturing process in the forming area and the necessary machinery are identified. Machine setup time allows for evaluating changes. The goal is to assess time reduction and avoid waste. The author successfully standardized times and reduced them by 66.29%.

According to Quiroz and Vega (2022), TDPP (Tons of defective product in process) is used to evaluate the percentage of waste by calculating the division of the total tons of defective products by the total tons injected. This provides a percentage that facilitates the analysis of defective products generated during the production process. Additionally, it is important to note that OEE monitors time losses due to stops, speed, and equipment quality, translating into actual productive time. Below, Table 1 shows the indicators under study by component, each indicator is displayed with its formula and description. In this way, the loss of product in tons and the time used in the flexographic printing process are identified.

Table 1. Description of key indicators by component

Component	Key indicators	Description	Formula
Standardization	Takt time	Time required to satisfy demand	Available production time/demand
	Machine setup time	Time required to set up the printing machine before starting production.	Setup time in minutes
Preventive Maintenance	Tons of defective product in the process (TDPP)	Percentage of waste obtained during the process	# Tons of defective product / # Tons of process
	Overall Equipment Efficiency (OEE)	Performance of the machines in use throughout the production process.	Availability × Performance × Quality

4. Data collection

The information was gathered from the database provided by the company, combined with on-site visits, utilizing observation methods, interviews, and a review of the company's records from the last 6 months. This approach focuses on data collection to demonstrate waste reduction, quality improvement, and cost reduction in the operational process.

In this analysis, interviews were conducted with multiple individuals to understand the execution of the flexographic printing process and identify areas with higher time losses. It was observed that there were spaces hindering smooth workflow, leading to regular accidents according to recent records. As a proposed tool, standardization enables the use of norms for workspaces and guidelines in processes. This tool allows us to assess times and select activities that do not add value to the production process. The five processes for the production of flexographic labels were evaluated, using cycle time, which is the elapsed time from the start of an operation until it is completed. The time for each process was obtained by reviewing records, as shown in Table 2.

Table 2. Cycle time per production process

Process	Impression	Cut	Extrude	Laminate	Seal
Cycle Time (sec/kg)	4.5	3	1.74	1.65	0.97

For data collection aligned with preventive maintenance, access to the plant, collected data, and a detailed description of processes were provided, encompassing production times, downtime, and reasons for downtime, as well as indicators of availability, quality, and performance. In fact, for time measurement, databases managed by the integrated system of the plant were utilized, and executed from a computer for each machine. This system continuously measures machine setup time for starting a new job, effective working hours, downtime, and maintenance, thus providing machine production hours, as seen in Table 3.

Table 3. Times collected from bilaminated labels

# Orders	Hrs. Setup	Hrs. Effective	Hrs. Stops	Hrs. Mant.	Hrs. Production

1	3:59	3:16	4:30	0:00	11:46
2	1:25	3:01	2:18	0:00	6:45
3	4:54	12:59	10:15	0:00	28:08:00
4	5:20	10:36	17:40	0:22	34:00:00
5	5:27	8:06	6:22	0:00	19:57
6	2:07	8:24	5:52	0:00	16:24
7	4:26	23:26	17:27	0:00	45:20:00
8	4:27	1:48	1:21	0:00	7:36
9	4:03	40:38:00	30:35:00	0:00	75:16:00
10	4:34	13:04	11:41	0:06	29:25:00
Total	40:45:00	125:22:00	108:04:00	0:28	274:40:00

Subsequently, the three most significant causes of loss of productive time and stoppages in the printing process were isolated. These causes are identified in the company's integrated production system and are activated by a code entered by the main operator of each machine when one of these causes occurs. Each time a code is entered, a timer is initiated, recording the time from entry to the completion of the cause.

- ***Anilox Breakage:*** If an anilox roller suffers a blow or scratch, as it is a ceramic cylinder with microscopic perforations, it will be necessary to stop the machine, which may take a short time, typically around 15 minutes, for replacement. In Figure 5, the operator is next to a functional anilox roller.
- ***Plate Breakage:*** If a printing plate is scratched or damaged, it is reflected in the print, necessitating replacement.
- ***Ink Loss in Anilox:*** If ink loss towards the trays is observed, it will be necessary to stop the printer, remove the blades to avoid hindering the printing process. All these issues are mainly caused by a lack of scheduling in the maintenance of the following parts, as shown in Table 4.

Table 4. Elements per machine considered in preventive maintenance

Machine	Printing machine (Comexi Printer)	Nordmecanica rolling mill	Ultraflex Rewinder
Component maintenance	Anilox roller	Rubberized Rollers, Transport Roller and Laminating Press	Unwinder

The visits allowed important data to be collected for the investigation, together with the records, the points of improvement were identified and, according to these, engineering tools were selected to solve them.

5. Results and discussion

5.1 Numerical results

After implementing the tools based on the proposed indicators, the results by indicator are shown in Table 5. The displayed results were obtained from a simulation, where the initial and final situation of the indicators under study is evaluated by our own development, with a confidence level of 90% in the Arena Software Simulator.

Table 5. Indicator results

Indicator	Initial Situation	Final Situation	Improvement
Takt Time (Cycle Time)	4.05 sec/kg	2.79 sec/kg	31,11%
Preparation Time	2446 min	513.66 min	79.00%
OEE	33.72%	76.21%	43.69%
TDPP	13.29%	8.42%	4.87%

For standardization, the takt time was calculated by dividing the available time (77,760.00 seconds/daily) by the demand (25,826.07 kg/daily), resulting in 3.01 seconds/kg. The Takt time was utilized, and standardization measures were applied to reduce the process with the highest cycle time, achieving a 31.11% improvement in seconds/kg in the printing cycle time, as it should not exceed the Takt Time. Then, procedures were implemented to reduce non-value-added activities, and processes were identified through Value Stream Mapping (VSM) and feedback from operators.

Another indicator is machine setup time, which was reduced by 79%. Domínguez et al. (2020) achieved a 66.29% reduction in the average machinery setup time, marking significant progress in research. Standardization and activity diagrams were employed to eliminate non-value-added activities. In addition, to reduce equipment setup time, Miranda et al. (2022) reduced the setup and die and plate installation time.

Furthermore, using the SMED technique. However, our results show differences in tool usage and types of machines, even though they are printing machines, the models vary. Also, practice-based standardization was chosen due to the positive results obtained with this tool. This improvement is the result of modifications to printing process activities and the training provided to operators, reducing downtime and improving machinery productivity.

In contrast, in terms of preventive maintenance, according to Quiroz (2022), any company with an overall equipment efficiency (OEE) below 65% is considered unacceptable, leading to economic losses. On the other hand, an OEE above 75% is deemed acceptable if the company is in the process of improvement. The current situation of the company indicated quality and performance above 85%, but availability was below 50%, resulting in an OEE of 33.72% due to maintenance failures, operational inactivity, and spills of inks and/or adhesives. Therefore, after implementing a supervision procedure at the critical points of the printing process prone to adhesive or ink contamination, and conducting monthly preventive cleanings, it is expected that within a 6-month period, there will be a 43.69% improvement, projecting an OEE of 76.2%. Finally, the amount of defective product in the process has seen a reduction of 13.29%, bringing it down to 8.42%. This represents a monthly reduction in waste of 4.87%. This was achieved through the implementation of a training plan for operational staff, scheduled inspections to anticipate failures, regular equipment checks, and constant analysis of potential product losses.

5.2 Graphic results

If the cycle time exceeds the Takt Time, it indicates that the time is not optimal, and may have losses, as mentioned by Santos, et al (2021). In Figure 4, It is observed how the printing time exceeds the Takt Time in each process, at the beginning and at the end, referred to as Cycle 1 and Cycle 2 respectively.

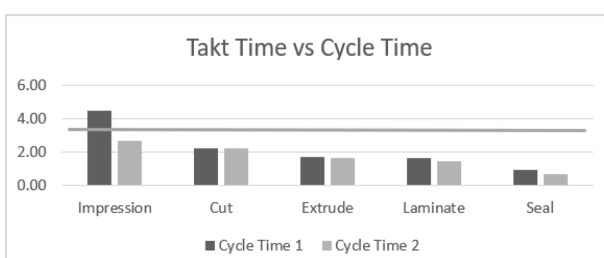


Figure 4. Takt Time vs Cycle Time

Through the OEE, an improvement is observed in the equipment, mainly focusing on the improvement in availability to have an acceptable OEE. Figure 5 shows the three elements of the OEE (Quality, Performance and Availability) before and after the simulated improvements.

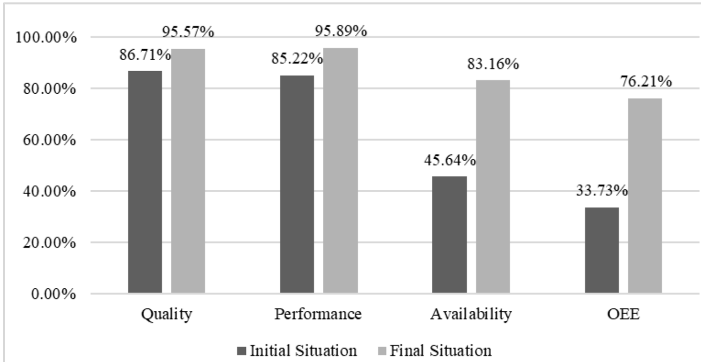


Figure 5. Overall equipment effectiveness elements

5.3 Proposed improvements

The proposed model shown in Figure 6 is integrated by the Standardization and Preventive Maintenance tools, identified according to the needs of the study. As the first phase, the plant processes, improvement points such as production time and waste in each process were identified. The indicators are then applied and evaluated through a simulation to verify the results of the implementation plan.

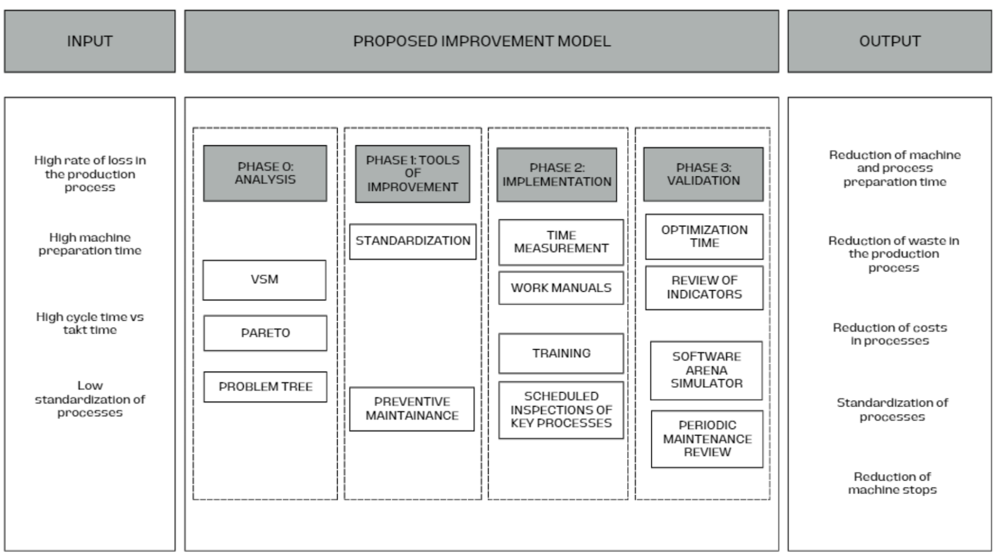
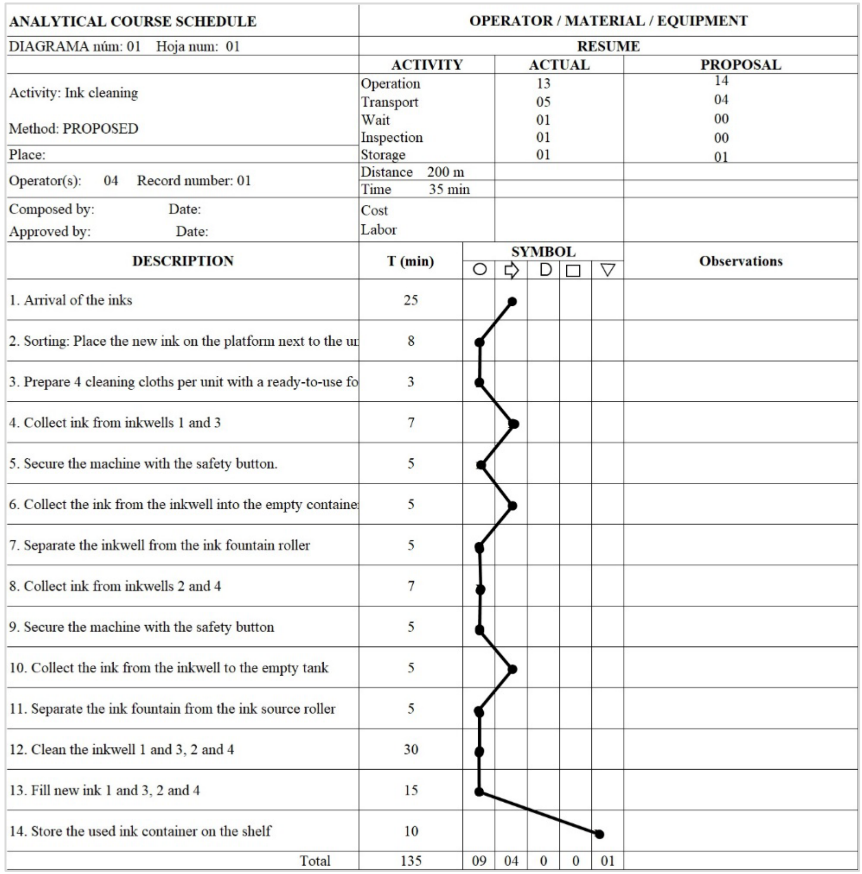


Figure 6. Proposed improvement model

The proposed model seeks to reduce waste and improve processes, resulting in a reduction in costs and times. In line with applying measures that reduce stops and failures in operations outside the printing process, it was necessary to develop an activity diagram as shown in Figure 7 and identify activities that do not add value to the printing process.



ANALYTICAL COURSE SCHEDULE	OPERATOR / MATERIAL / EQUIPMENT		
DIAGRAMA núm: 01 Hoja num: 01	RESUME		
	ACTIVITY	ACTUAL	PROPOSAL
Activity: Ink cleaning	Operation	13	14
	Transport	05	04
Method: PROPOSED	Wait	01	00
	Inspection	01	00
Place:	Storage	01	01
Operator(s): 04 Record number: 01	Distance 200 m		
	Time 35 min		
Composed by: Date:	Cost		
Approved by: Date:	Labor		

DESCRIPTION	T (min)	○	⇨	D	□	▽	Observations
1. Arrival of the inks	25		●				
2. Sorting: Place the new ink on the platform next to the ur	8	●					
3. Prepare 4 cleaning cloths per unit with a ready-to-use fo	3	●					
4. Collect ink from inkwells 1 and 3	7		●				
5. Secure the machine with the safety button.	5	●					
6. Collect the ink from the inkwell into the empty containe	5		●				
7. Separate the inkwell from the ink fountain roller	5	●					
8. Collect ink from inkwells 2 and 4	7	●					
9. Secure the machine with the safety button	5	●					
10. Collect the ink from the inkwell to the empty tank	5		●				
11. Separate the ink fountain from the ink source roller	5	●					
12. Clean the inkwell 1 and 3, 2 and 4	30	●					
13. Fill new ink 1 and 3, 2 and 4	15	●					
14. Store the used ink container on the shelf	10					●	
Total	135	09	04	0	0	01	

Figure 7. DAP of the printing process

Furthermore, the proposed training is divided into training sessions for operators and supervisors; these training sessions at different levels allow them to complement the knowledge they currently have, as shown in Table 6.

Table 6. Training

Operators	Supervisors
Training in the use of manuals and periodic reviews according to the preventive maintenance plan.	Training aimed at supervising compliance with the standardization and preventive maintenance plan.

Monitoring procedures have been implemented at critical points in the flexographic printing process, especially focusing on areas prone to fouling by adhesives or inks, and monthly preventative cleanings are carried out.

Additionally, through the training plan for operational staff, which includes scheduled inspections, they represent a solid starting point to improve efficiency and prevent problems in the printing process. For future improvements, it is planned to optimize the approach by incorporating new production and quality systems, consolidating the preventive models created for more effective decision making.

5.4 Validation

Figure 8 represents the simulation of the printing process through three subprocesses: pre-press, assembly, and tinting. The simulation aimed to ensure that the identified improvement points were enhanced through the proposed enhancements, leading to a significant improvement within the company.

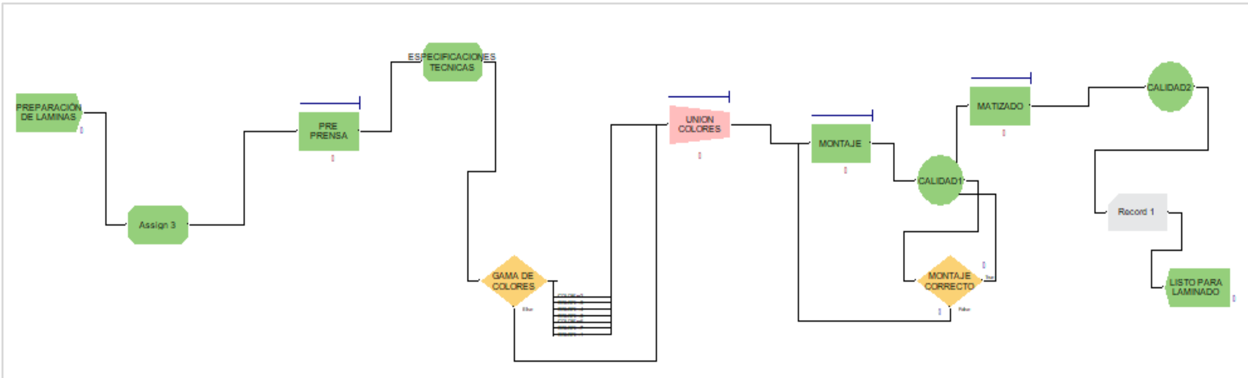


Figure 8. Simulation in Software Arena

The software simulated machine times, starting with the "Create" module to indicate where the plates go at the beginning of the printing process. Then, the quantity of plates to be printed is defined. Next, there is a waiting period before entering the pre-press area to validate that materials are in the workstation. If any material runs out after printing, a signal is sent to the operator to ensure replenishment. Technical specifications are then assigned as attributes, considering the different types of laminates with which it works, up to 8 printing colors. Subsequently, the "Batch" block is used to simulate printing batches of sheets simultaneously. Following assembly, a vital part of achieving the requested color and tone on the plates, which is inspected. Finally, in the tinting subprocess, variable-sized dots are used instead of fixed dots to create a print with different ink densities and, consequently, different color tones. The "Dispose" block represents the removal of printed sheets from the system once the printing process is completed, continuing with the laminating machine.

According to the software report, regarding time, a confidence interval of [151, 210] minutes was obtained, with a pre-printing wait time of [114, 134] minutes. This leads to the expected reduction in time. Implementation of manuals and improvement of activities is carried out, where operators are observed working more efficiently. OEE increases in the short term, and from the third month onwards, a slight reduction in waste is seen, projecting towards achieving the expected goal.

6. Conclusion

The proposed model led to significant improvements in customer responsiveness through greater production efficiency thanks to the focus on improving equipment availability through monthly maintenance scheduling and procedures that reduced equipment failures and waste. these.

Regarding the problem, it is observed that there are not many articles that address the reduction of waste in companies; however, there is extensive research on engineering tools such as TPM, 5S and SMED to improve the processes of manufacturing companies. According to Domínguez et al. (2020) SMED is a proven method that consistently delivers positive results in scenarios where the machine is directly involved in the process. For companies that have implemented this methodology, it is observed that machine preparation time has been reduced. However, these results can be achieved through the tools chosen in this study, as standardization helps companies reduce waste and costs.

Furthermore, by implementing preventive maintenance, the operation of the machines and their capacities is facilitated, reducing downtime. Likewise, a more in-depth analysis could be done in the other processes and work with the entire plant team to obtain favorable results for the company. Finally, it is expected that this research will promote the use of these tools in the flexographic printing sector or in manufacturing companies. In addition, it seeks to raise awareness about the reduction of waste generated by companies and thereby assume environmental responsibility towards customers and employees.

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