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Improving Availability in a Retail Laundry by TPM, 5S, and Standardized Work: An Empirical Research

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Abstract- The research aimed to develop a maintenance model for a retail laundry using TPM, 5S, and standardized work to improve availability. The literature review discusses autonomous maintenance as a key component of TPM, which aims to eliminate downtime due to machine breakdowns and involves employees in maintenance activities. The research was pre-experimental and found that the leading causes of low availability were the need for a maintenance plan, poor training, and disorganization. A pilot plan was implemented, resulting in a 7% increase in availability from 75% to 82%. The study's results support the effectiveness of the maintenance model developed. The study highlights the importance of good machinery maintenance management and organization in the laundry business.

Keywords-- Availability Rate, Lean Service, TPM, 5S, Standardized Work, Retail Laundry Sector

I. Introduction

Nowadays, there are many companies that, due to problems with the machinery they handle, need help to fulfill the orders from their customers. Because of this, having good machinery maintenance management and great organization is the key to fulfilling all orders on time and reducing costs.

As for Peru, the country represents 17% of Latin America and 2.3% of the world in terms of companies in the laundry business, with a value of 2,096 million USD [1]. In a country that stands out for its agriculture and mining, the value of sales made by the service sector cannot be considered negligible, mainly because of how profitable the business has become for many entrepreneurs who have ventured into this area. This is evidenced by the opinion of many authors, who mention that the laundry business is one of the most profitable businesses in Metropolitan Lima [2].

However, most of the companies in the laundry business are Small and Medium-sized enterprises (SMEs) and, according to [3], SMES are characterized by low levels of productivity and efficiency; they do not prioritize the care of their machines, which causes them to wear out quickly, presenting continuous failures and stopping the entire process of the company. In this context, the SMES from which a large part of the economically active population comes should be included in the search for greater efficiency in the processes [4]. In addition, to ensure the reliable use and maintenance of a washing machine, it is necessary to monitor the condition and detect anomalous operations early so that the company's activities are not stopped [5].

Given this context, we seek to evaluate a company in the retail laundry business, which, throughout its years of service, has faced specific problems, such as the constant breakdown of its machines, the deterioration of garments due to poor supervision of the machines, the poor training of employees that makes them more prone to errors, and the disorder of the work areas. This has implications on the percentage value of availability, which is 75%. This is found thanks to the information provided by the company itself. Once compared to the standard, which represents a value of 90%, this indicates that the current indicator is well below the industry standard.

The overall objective of the current research is to develop a maintenance model based on Total Productive Maintenance (TPM), 5S, and standardized work to increase the availability of a retail laundry in 2023, seeking to solve the problems presented through simulation, thus verifying the model's effectiveness. In addition, it will allow the establishment of a basis for a periodic maintenance and training plan to improve the company's various processes. On the other hand, it will also help it economically since the resources would be used much more efficiently than before.

II. Literature Review

A. Autonomous maintenance

The objective of autonomous maintenance is to eradicate all time-related costs linked to operational system downtime caused by machine malfunctions. Implementing TPM is therefore crucial, given that it enables improved production performance and incorporates the assistance of company personnel. [6].

Autonomous maintenance will check if there are anomalies to avoid breakdowns and defects. It will find the leading causes of these anomalies and create an action plan for each [7].

[8] By implementing this pillar into their work, organizations can achieve favorable outcomes, including increased participation of production staff in maintenance activities through periodic inspections, the development of a training program to educate staff on the operation of their equipment, and the establishment of daily routines to foster employee dedication to machine upkeep.

B. Planned maintenance.

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This pillar helps improve the equipment's availability by reducing existing failures through improvement actions using preventive and periodic routines [9].

With planned maintenance, the equipment will be better maintained, which also means the number of failures will be reduced, thus minimizing downtime. Additionally, lower production costs are generated, and occupational safety is reinforced [10].

In addition, to reduce the likelihood of unscheduled downtime and improve system availability, planned maintenance is crucial. It encompasses a series of operations related to the tools and machinery used in the production process, such as inspection, cleaning, lubrication, adjustment and replacement. In this way, the objective of increasing equipment availability is achieved. [11].

C. 5S

The 5S philosophy focuses on efficient work, a standardized workplace, and processes [12]. 5S creates a visual workplace to classify, tidy, standardize, and sustain [13]. The continuous implementation of the 5S would reveal advantages such as improved quality of products and services, thanks to cleaner and more orderly work environments, which would improve the company's productivity [14].

The 5S are made up of the following concepts: Seiri (sort), which eliminates unnecessary elements that do not add value; Seiton (set in order), organizes products and materials; Seiso (shine) which tells us how workplaces should be regularly ordered; Seiketsu (standardize) develops visual guidelines to maintain an organized and clean workplace and finally Shitsuke (sustain) which confirms that employees are clear about what the 5S tool is all about [15].

D. Standardized work

Standardized work is an essential instrument for addressing challenges in the manufacturing sector due to its ability to provide nearly instantaneous outcomes in terms of organizational performance, productivity enhancement, and delivery time reduction [16]. As stated in reference [17], the foundational task of standardization is the identification of value-adding activities—that is, those that entail superfluous motions or idle moments.

This tool is a set of specific directions, shown through visual material, that every worker can access and is needed to perform a task efficiently [18].

E. Availability

Availability refers to the percentage of time a machine is operational beyond what is expected to be the case. Enhancing this metric involves reducing unscheduled downtime, which includes periods for machine breakdowns and part replacements.[19].

The availability can be improved during the evaluation and exhaustive monitoring during the whole maintenance phase; because of this, implementing it correctly can avoid possible failures or breakdowns that could have a tremendous negative impact on the activities of the company in question [20].

An investigation was undertaken by [6] with the primary aim of enhancing the value of equipment and machinery availability via the integration of autonomous maintenance.; his work highlights that it has low availability rates compared to the industry standard because their machines suffer frequent breakdowns, so it must stop production.

The value of availability is of utmost importance if we want to evaluate how much time machines are working and, therefore, how much time the company loses if they break down. Also, increasing the system's availability would maximize the company's income [21]. In addition, the value of the availability is obtained from the following equation using Mean Time Between Failures (MTBF) and Mean Time to Repair (MTTR):

$$Availability = \frac{MTBF}{MTTR+MTBF} \quad (1)$$

III. CONTRIBUTION

A. Model basis

This research work is composed of three engineering tools in total. We are discussing using 5S, Standardized Work, and two pillars of TPM. The implementation aims to increase availability, reduce unexpected failures, and reduce human error. Not only that, but this improvement proposal is integral because it is expected to improve the operation of the machines without neglecting human management, working with employees to train them and learn new techniques that can be applied in their work.

B. Proposed Model

As shown in Figure 1, we have three components within the proposed model, where an integral development is made attacking each problem identified in the company that presents them. Everything starts with an analysis of the current state; information is collected, an analysis of the root causes is performed, and initial hypotheses to be tested are proposed. A deficiency in the maintenance of the machines is identified as the main problem.

C. Components of the proposed model

1) Component 1: Organization

The first component of the improvement proposal is the organization, where an audit will be carried out using the first tool, 5S, where some points of improvement for order and cleanliness will be identified, and alternative solutions will be provided. For the development of the 5S, we use the work [22] as a reference. Likewise, responsible persons are assigned to be part of the team in charge of carrying out the following audits to measure the level of progress. The following tool within this component is the Standardized Work, where the current

production capacity is measured to evaluate whether it meets the main objective of this tool.

which indicates the frequency with which the machines located within the plant should receive major maintenance by a specialized supplier.

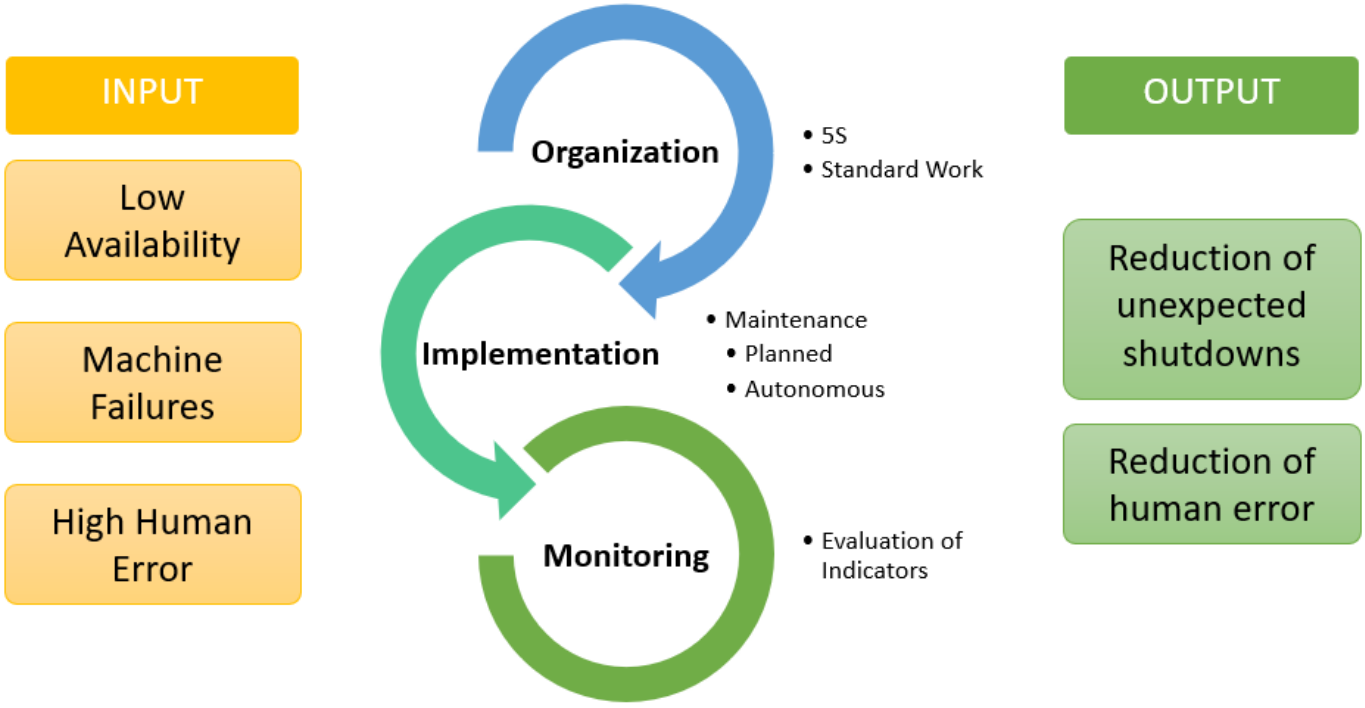

Fig. 1 Proposed Model

For this tool, the work done by [23] was used as a reference in this work. The main objective of standardized work is to reduce variability in operations and eliminate waste. Not all workers perform their tasks with the same skill since they all have different capabilities but having them standardized is ideal.

2) Component 2: Implementation

The following component deals with TPM; for its development, the work of [20] was taken as a reference, where they point out the importance of TPM in reducing downtime caused by failures. In this work, two pillars of this philosophy are specifically mentioned: autonomous and planned maintenance. The first one is about empowering workers to act by their own means if their scope allows it. Explaining how this pillar works teaches the operator not to be afraid to make some minor mistakes on his machines to prevent serious failures that can bring a negative financial impact to the company. Operators should be more informed about how they can perform routine preventive checks to ensure their machine is in good condition. However, it is mentioned that there will also be other failures that they cannot repair on their own. However, at least the tool fulfills its purpose if the operator notifies his superiors of the severe failure that has already occurred and that he cannot repair it because it requires more expertise than some minimal failures. The second pillar to be implemented is planned maintenance, with a structured plan of no less than one year,

3) Component 3: Monitoring

Finally, there is the third component, where the improvement of the proposal is validated with quantitative indicators that are reflected in a dashboard for continuous monitoring. In addition, the validation is done in simulation software. This software helps to show quantitative improvements in the model and gives a much more accurate view of how the proposed model works.

D. Indicators

- Availability: Availability is an indicator measuring the time a piece of equipment or system is operational and ready to perform its function.

Objective: Increase equipment availability to the industry standard, i.e., 15%.

$$Availability = \frac{Operating\ time}{Total\ time\ available}\ x\ 100 \quad (2)$$

- Transfer time: This indicator measures and evaluates the efficiency of operator movement between each workstation.

Objective: Reduce transfer time by about 10 seconds.

$$Transfer\ time = arrival\ t. - departure\ t \quad (3)$$

- Takt time: It represents the time required to process clothes, while keeping rate with customer demand.

Objective: Reduce Takt time value to at least 30 minutes per order.

$$Takt\ time = \frac{time\ available\ to\ produce}{Costumer\ demand} \quad (4)$$

- MTBF: This indicator measures the reliability of a system or equipment and represents the average time elapsed between two consecutive failures.

Objective: Increase MTBF by ten days due to failures.

$$MTBF = \frac{Total\ operating\ time}{Number\ of\ failures} \quad (5)$$

- MTTR: This indicator measures the average time repairing equipment after a failure.

Objective: Reduce its value by at least 3 minutes per repair.

$$MTTR = \frac{Downtime\ due\ to\ failures}{Number\ of\ failures} \quad (6)$$

IV. Validation

To make a correct validation of the improvement proposal, a pilot plan of all the tools to be implemented was carried out. Training, delivery of materials, and supervision of progress were given for about two weeks so that through Arena Software, it was possible to simulate both scenarios to demonstrate a quantitative improvement. This model has been implemented in a laundry plant, where small laundries supply the plant with clothes daily. The main problem is machine availability, which is a critical problem since the plant's reputation is at stake when handling third-party products. Availability is 75% for 2022, which is decreasing, given that 2021 availability was 78%. Both numbers are still considered low, so action must be taken on this indicator.

A. Initial diagnosis

As already mentioned, the main problem of availability is currently latent; it has a value of 75%, which indicates a high technical gap compared to the standard of 90%, and there is an opportunity for improvement to be covered. The low availability has an impact of 33% on the company's operating cost. It should be noted that the main reason for this problem is the repetitive and unexpected failures of the machinery.

B. Model design for comparison

To design the initial situation within Arena Software, a time measurement had to be made for each activity within the laundry process, from the customer's reception to the final delivery of the finished product. In this time measurement, we made a sample of 15 garments that completed the whole process. With this, we made a table of values that was finally introduced to the Input Analyzer, a program that helps calculate the distributions of the times and know what kind of times they were. After that, the model was assembled in Arena, and the time distributions were entered in their respective activity.

The process was repeated after having carried out the pilot plan, where the values were slightly lower. However, we simulated again within Arena and analyzed the differences between both time frames to have evidence.

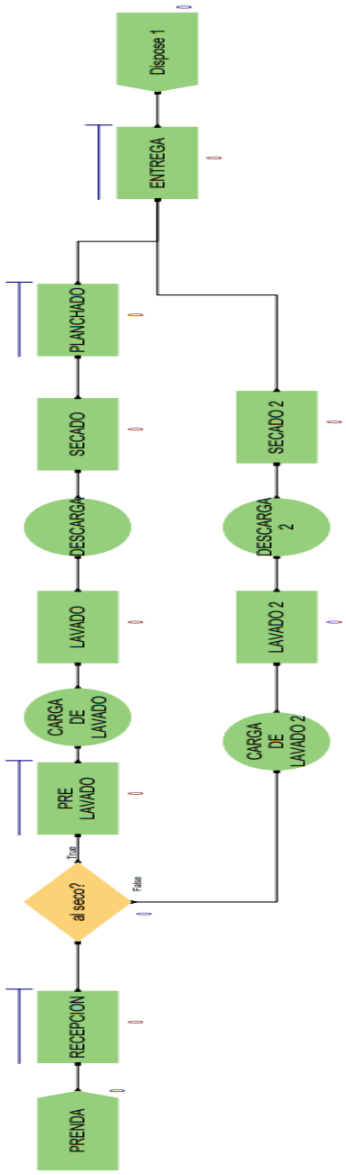

Fig. 2 Representation of the improvement system

Table I below shows the indicators that are expected to be obtained.

TABLE I. INDICATORS CURRENT SITUATION vs. EXPECTATIONS

Tools	Selected Indicator	As Is	To Be
-	Availability	75%	90%
5S	Transfer time	30	20
Standardized Work	Takt Time	46	30
Autonomous Maintenance	MTBF	18.93	28
Planned Maintenance	MTTR	6.24	3

C. Pilot plan

1) 5S's implementation

The pilot plan is carried out to show the validation of the 5S tool within the laundry premises studied. This is because the disorder and lack of cleanliness in the premises negatively affect the time the operators carry out the process.

Seiri (Sort): The first phase of the 5S implementation consisted of classifying the resources. Red cards were used to identify the elements that should not be near the work area.

Fig. 3 Red Card Designed

This card is used to identify those tools that are out of place. Figure 4 shows paint brushes and a flashlight, materials used for other work and left on the shelf for pre-washing.

Fig. 4 Elements before sorting

Fig. 5 Elements after sorting

Thus, Figure 5 shows the result of applying the first S; only the materials necessary for the activity to be performed should remain in the work area.

Seiton (Set in Order): This second phase has the purpose of ordering the elements that are out of place, such as sheets, galleys, buckets, and bags full of clothes for which a space has been designated in which they should be stored.

Fig. 6 Spaces before Set in Order

Fig. 7 Spaces after Set in Order

Seiso (Shine): In this third phase, the resources and the premises were cleaned. First, this is to discard defective resources or those that no longer have a use, such as an almost empty bottle of detergent, and to keep the aisles clean and tidy so that operators can move between areas more easily.

Also, to ensure continuity and get people used to keeping their space clean, a chart was created to keep track and let other operators know if the cleaning team has previously cleaned their workstations.

CONTROL DE LIMPIEZA

Nombre: _____ Mes: _____ Semana: _____

	TURNO DÍA	COMENTARIO
LUNES		
MARTES		
MIÉRCOLES		
JUEVES		
VIERNES		
SÁBADO		

	TURNO NOCHE	COMENTARIO
LUNES		
MARTES		
MIÉRCOLES		
JUEVES		
VIERNES		
SÁBADO		

Fig. 8 Shine control format.

In this material, the person in charge of cleaning should mark if she has done her job and leave a comment in case, she requires any extra material, or any incident occurs while performing the activity.

Seiketsu (Standardize): The fourth phase consisted of using signage that would serve as visual support for the rest of the operators who are not familiar so that in this way, no mistakes are made, or at least an attempt is made to reduce them.

Fig. 9 Standardization Signage

Shitsuke (Sustain): Once these 4S's are implemented, operators should be reminded of their importance on a daily basis, so a checklist was proposed to corroborate their implementation.

Checklist	Marcar
¿Está haciendo la limpieza e inspección diaria de sus equipos y centro de trabajo?	
¿Los informes diarios se realizan correctamente y en su debido tiempo?	
¿Estás usando ropa limpia y adecuada?	
¿Utiliza equipos de seguridad?	
¿El personal cumple con los horarios de las reuniones?	
¿Ha sido capacitado para cumplir con los procedimientos y estándares?	
¿Las herramientas y partes se almacenan correctamente?	
¿Existe un control en las operaciones y en el personal?	
¿Los procedimientos son actualizados y revisados periódicamente?	
¿Los informes de las juntas y reuniones son actualizados y revisados periódicamente?	

Fig. 10 Progress checklist

In the same way, an order and cleanliness policy will be posted in a visible place for all workers so that they are aware of the changes implemented and follow them to the letter.

CLEANER LAVANDERÍAS S.A.C.

POLÍTICA DE ORDEN Y LIMPIEZA

Elaborado por:	Revisado por:	Aprobado por:	Fecha:	Versión: 1
Rodrigo L.	Fabián O.	Miguel L.	18/11/2023	

1. Los trabajadores de Lavanderías Cleaner están en la obligación de conocer y seguir la metodología de las 5S.
2. El gerente es el encargado de supervisar y hacer el seguimiento respectivo para asegurarse que la metodología esté siendo utilizada.
3. Todos los trabajadores deben revisar sus materiales de trabajo y solicitar reposición de ser el caso, con anticipación de un par de días.
4. El formato de limpieza entregado a cada área deberá ser presentado al finalizar la semana al gerente.
5. Cada nuevo trabajador deberá recibir capacitaciones en la herramienta de 5S para su normal desarrollo y continuidad
6. Todas las tareas tienen un espacio designado, está prohibido realizar una actividad o tarea en otro lugar que no sea el destinado para su fin.
7. El área de Prelavado debe ser usado exclusivamente para ello, mas no para almacenar ropa.
8. Los trabajadores deben comunicar al gerente en caso alguna de sus herramientas esté defectuosa o malograda por el uso normal.

Fig. 11 Order and Shine Policy

The following figure compares the initial audit versus the final audit.

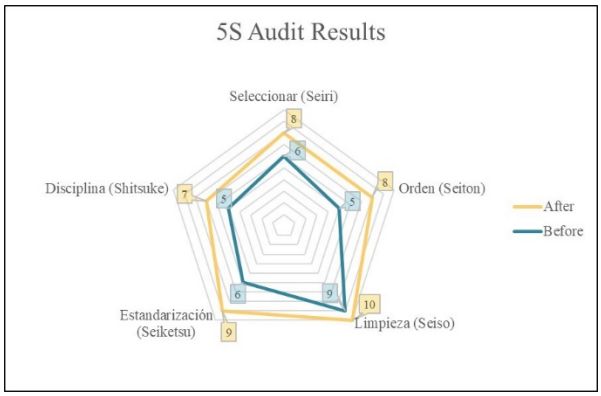

Fig. 12 Audit radial diagram

This diagram compares the two audits performed; the initial value corresponds to a total score of 31 points, while the result was 42. With this, there has been an increase of 35% thanks to the pilot plan implemented.

D. Improvement - Simulation

By modeling the current state and the proposed improvement with the Arena simulation software, conclusive indicators demonstrating the usefulness of the proposed model were generated.

To perform an adequate calculation of the optimal replicas of the simulation system, a preliminary sample of 30 was used, and a desired value of 1 for the half-width was maintained.

$$N = No\ x\ (\frac{ho}{h})^2 = 30\ x\ (\frac{1.1}{1})^2 = 36.6 = 37 \quad (7)$$

Once the formula was applied, an optimum value of 37 replications and a desired Half Width with an interval of [91.41,108.59] were obtained. Figure 2 shows the simulation of the process.

The findings are displayed in Table II, which contains a comparison of the simulation values with the actual values.

TABLE II. INDICATORS CURRENT SITUATION vs. SIMULATION

Tools	Selected Indicator	As Is	Simulation
-	Availability	75%	82%
5S	Transfer Time	30	25
Standardized Work	Takt Time	46	34
Autonomous Maintenance	MTBF	18.93	30
Planned Maintenance	MTTR	6.24	5

V. Discussion

Here, we will evaluate and analyze how the proposal influenced the company. In the present work, a total of five indicators were considered, the main one being availability, while the other four would belong to the analysis of each tool, as follows: MTTR for the planned maintenance tool, MTBF for autonomous maintenance, Takt time for standardized work and transfer rate for 5S.

At the beginning of the investigation, there was a percentage of 75% efficiency; this was because the time programmed to operate the machines was more significant than the time they worked, being 2880 hours per year, of which only 2158 worked; this due to various reasons such as breakdowns or errors of workers.

Due to this, a root cause analysis was performed using a problem tree; thanks to this, the necessary tools to combat each cause were determined. First, we have the 5S tool, which was used to reduce the transfer time. First, an audit was conducted in which specific values were obtained; to improve these values mentioned above, it was proposed to classify the resources to use to distinguish them more clearly and then order them according to their use in each workstation. Additionally, cleaning was carried out, and different signs were hung to show how specific tasks related to the 5S should be performed; the importance of all this should be clear to the workers. Therefore, different announcements were made to encourage the tool's implementation, and after the implementation, a checklist was made to confirm that it was done correctly. All these actions helped to reduce the transfer time from 30 seconds to 25, improving the efficiency of the workers. It may seem that the result obtained did not have as much quantitative impact and that the results were not as expected, however, order and cleanliness within the plant results in operators becoming more effective by having workstations free of obstacles and distractions.

On the other hand, implementing the standardized work tool is an important strategic step that seeks to reduce Takt time and improve efficiency and consistency in operations. By developing a standard work diagram, clearly defined processes and procedures allow workers to perform their tasks more uniformly and efficiently. This diagram is especially valuable not only for experienced workers but also for new employees joining the team. By having a standardized guide, new workers can be trained more quickly and have less room for error in the early stages of their work. Thanks to the application of this tool, it was possible to improve the Takt time indicator value, reducing it from 46 minutes per order to a total of 34 minutes per order, which is a significant improvement since this value is very close to the expected 30 minutes per order.

In the same way, the autonomous maintenance pillar of the TPM tool was used to increase the MTBF; this indicator is the time between each occurrence of a specific stop due to the failure of a process. Initially, we had a value of 18.93 days per failure, data due to the high number of stops made every month due to failures. Therefore, training was planned to create procedures for the operators to check their machines. Thanks to this, the operators can perform simple maintenance tasks on their machines to avoid breakdowns; for example, in the ironing process, the operator learned to check the proper water pressure parameters to avoid damaging the steam iron. In this way, the value can increase and thus reduce downtime due to failures to 30 days per failure, far exceeding the expected value of 28 days per failure.

Finally, the planned maintenance pillar of the TPM tool was used to reduce the MTTR, i.e., the mean time until the failure was repaired. Initially, there was a value of 6.24 days per failure, given by both the maintenance time of the machines and the number of repairs performed. Because of this, a maintenance chart was designed to know when to perform maintenance on each machine in the company so as not to interrupt the company's washing process, and in this way, the value of the indicator was reduced to 5 days per repair, which, although it does not vary much from its initial value, is close to its expected value of 3 days per repair.

Future works: This work can be expanded to more SMEs in this service subsector in order to increase their competitiveness and the overall sectoral customer satisfaction indicator.

VI. Conclusions

As seen in the results, the proposed maintenance model solves the company's main problem, which is the low availability of machines and equipment. Increasing the leading indicator was achieved thanks to the implementation of several engineering tools that allowed us to attack different problems suffered by the company, which, although they were not directly related to the availability, influenced its value. For this purpose, a pilot plan was implemented, as well as a simulation where it was possible to appreciate the improvement of the different indicators. The model resulted in a 7% increase in availability value, from 75% to 82%.

In conclusion, conducting an audit at the beginning and end of an investigation is an essential practice in the 5S implementation process, as it plays a vital role in evaluating, monitoring, and continuously improving these management principles. The audit provides an objective and systematic view of how the 5S is applied in the workplace and whether the desired objectives are achieved. It also provides an ongoing, data-driven assessment that facilitates informed decision-making and ensures that 5S standards are maintained over time, promoting a more organized, cleaner, and efficient work environment. Thanks to its implementation through visual aids and a reorganization of its work areas, it was possible to observe how the transfer time indicator was reduced by 5 seconds, resulting in a final transfer time of 25 seconds, a value close to the approximate target of 20 seconds.

References

[1] Euromonitor International. Laundry Care in the Perú. https://www-portal-euromonitor-com.ezproxy.ulima.edu.pe/statisticsevolution/indexDas

[2] Rodriguez, R. (2017). ANÁLISIS DE NEGOCIO DE UNA LAVANDERIA COMERCIAL. Universidad de Piura.

[3] Quispe, H., Takahashi, M., Carvallo, E., Macassi, I. & Cardenas, L. (2020). Combined model of SLP and TPM for the improvement of production efficiency in a MYPE of the Peruvian textile sector. Proceedings of the LACCEI international Multi-conference for Engineering, Education and Technology. Doi: 10.18687/LACCEI2020.1.1.322Asd

[4] Bernardo-Saavedra, Ernesto & Carpio-Najera, Miguel & Quiroz-Flores, Juan Carlos. (2023). Production Management Model Based on SLP, 5S, and Standardized Work Tools to Increase OTIF Rate in a Shoe Repair Shop. 181-188. 10.1145/3625469.3625511.

[5] Shul, Y., Yi, W., Choi, J., Kang, D. & Choi, J. (2023). Noise-based self-supervised anomaly detection in washing machines using a deep neural network with operational information. Mechanical Systems and Signal Processing. Doi: 10.1016/j.ymssp.2023.110102Asd

[6] Guariente, P., Antiniolli, I., Pinto, L., Pereira, T. & Silva, F. (2017). Implementing autonomous maintenance in an automotive components manufacturer. Manufacturing Engineering Society International Conference. Doi: 10.1016/j.promfg.2017.09.174

[7] Amir, A. (2015). Evaluation Improvement of Production Productivity Performance using Statistical Process Control, Overall Equipment Efficiency, and Autonomous Maintenance. 2nd International Materials, Industrial, and Manufacturing Engineering Conference. Doi: 10.1016/j.promfg.2015.07.032

[8] Quispe, H., Takahashi, M., Carvallo, E., Macassi, I. & Cardenas, L. (2020). Combined model of SLP and TPM for the improvement of production efficiency in a MYPE of the Peruvian textile sector. Proceedings of the LACCEI international Multi-conference for Engineering, Education and Technology. Doi: 10.18687/LACCEI2020.1.1.322

[9] Hardt, F.; Kotyrba, M; Volna, E & Jarusek, R. (2021). Innovative Approach to Preventive Maintenance of Production Equipment Based on a Modified TPM Methodology for Industry 4.0. Applied Sciences Basel. DOI10.3390/app11156953

[10] Diaz-Reza, JR; Garcia-Alcaraz, JL; Avelar-Sosa, L; Mendoza-Fong, JR; Diez-Muro, JCS & Blanco-Fernandez, J. (2018). The Role of Managerial Commitment and TPM Implementation Strategies in Productivity Benefits. Applied Sciences Basel. DOI10.3390/app8071153

[11] Cupe-Escalante, Fiorella & Neyra-Bravo, Cesar & Quiroz-Flores, Juan Carlos. (2023). Operations Management Model Based on Mixed Methodologies to Increase Production Efficiency in a Retail Laundry. 231-237. 10.1145/3625469.3625512.

[12] Daly, A., Teeling, S., Ward, M., McNamara, M. & Robinson, C. (2021). The Use of Lean Six Sigma for Improving Availability of and Access to Emergency Department Data to Facilitate Patient Flow. International Journal of Environmental Research and Public Health. Doi: 10.3390/ijerph182111030

[13] Santos, E., Lima, T. & Gaspar, P. (2023). Optimization of the Production Management of an Upholstery Manufacturing Process Using Lean Tools: A Case Study. Applied Science-Basel. Doi: 10.3390/app13179974

[14] Daly, A., Teeling, S., Ward, M., McNamara, M. & Robinson, C. (2021). The Use of Lean Six Sigma for Improving Availability of and Access to Emergency Department Data to Facilitate Patient Flow. International Journal of Environmental Research and Public Health. Doi: 10.3390/ijerph182111030

[15]Realyvasquez, A., Arredondo, K., Blanco, J., Sandoval, D., Jimenez, E. & Garcia, J. (2020). Work Standardization and Anthropometric Workstation Design as an Integrated Approach to Sustainable Workplaces in the Manufacturing Industry. Sustainability. Doi: 10.3390/su12093728
[16]Carmen Alondra-Torres Millones, Juan Carlos Quiroz-Flores, S. Nallusamy, "Enhancement of Productivity and Efficiency through a Service Model with Lean Service Tools - Case Study," SSRG International Journal of Mechanical Engineering, vol. 10, no. 9, pp. 18-30, 2023. Crossref, https://doi.org/10.14445/23488360/IJME-V10I9P102.
[17]Realy, A., Flor-Montalvo, F., Blanco, J., Sandoval, J., Jimenez, E. & Garcia, J. (2019). Implementation of Production Process Standardization Case Study of a Publishing Company from the SMEs Sector. Processes. Doi: 10.3390/pr7100646
[18]Ben, J., Mohamed, A. & Muduli, K. (2021). Effect of Preventive Maintenance on Machine Reliability in a Beverage Packaging Plant. International Journal of System Dynamics Applications. Doi: 10.4018/IJSDA.2021070104
[19]Manchadi, O., Ben, F. & Jioudi, B. (2023). Predictive Maintenance in Healthcare System: A Survey. IEEE. Doi: 10.1109/ACCESS.2023.3287490
[20]Raghav, Y., Mradula, Varshney, R., Modibbo, U., Ahmadini, A. & Ali, I. (2022). Estimation and Optimization for System Availability Under Preventive Maintenance. IEEE Access. Doi: 10.1109/ACCESS.2022.3204394
[21]Santos, E., Lima, T. & Gaspar, P. (2023). Optimization of the Production Management of an Upholstery Manufacturing Process Using Lean Tools: A Case Study. Applied Science-Basel. Doi: 10.3390/app13179974
[22]Realyvasquez, A., Arredondo, K., Blanco, J., Sandoval, D., Jimenez, E. & Garcia, J. (2020). Work Standardization and Anthropometric Workstation Design as an Integrated Approach to Sustainable Workplaces in the Manufacturing Industry. Sustainability. Doi: 10.3390/su12093728
[23]Amiel, G., Vargas, E. & Viacava, G. (2022). Increase the efficiency of the machine production process in textile companies through a model based on TPM and SMED. Proceedings of the LACCEI international Multi-conference for Engineering, Education and Technology. Doi: 10.18687/LACCEI2022.1.1.752