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Production Model Based on Lean-TPM to Increase the Efficiency of the Finishing Process in Textile Companies.

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Abstract

Currently, many companies in the textile sector in Peru contribute considerably to the country's economy; year after year these companies have increased the value of exports. This is why, for example, in 2022, before the end of the year, 24% more than the value of total annual exports in 2021 was recorded, for example, as indicated by the Central Reserve Bank of Peru (BCRP). The textile sector in Peru has a very important role in growing and developing the industry and economy of Peru. This is due to the synergy of factors that directly influence its composition, factors such as labor, product design, and services. , among others. Due to this, some companies have chosen to make improvements in different processes in order to improve their efficiency and quality. Some of the tasks to improve within the production processes of some textile companies are the times given during production intervals, having a percentage of efficiency higher than the standard, and improving productivity, among other factors. However, to achieve a considered improvement in the aforementioned, one must begin with having the correct human capital, which works efficiently and has a unification as a company that leads to achieving short, medium, and long-term goals. long term.

Keywords
Textile, TPM, time study, efficiency

1. Introduction
In 2022, according to a study carried out by the world's main textile exporters, Peru will be ranked as the only Latin American country within the Top 10 worldwide. Peru is the main supplier of the textile sector to the United States, the given production is characterized by using the traditional textile method during manufacturing. This factor is widely recognized because the conventional manufacturing method tends to be viewed in a better light than modern manufacturing by different countries internationally. However, the most recognized brands in Peru suffer from a

deficiency regarding the level of competition with other international brands in our country. This means that the international market is more receptive to export models, thus reflecting the need to create brands that significantly represent Peru (Gallardo et al. 2020). During 2023, competition between textile companies increased quite high at an international level, due to the demands on quality standards (Quiroz et al. 2021). Within the framework of the Peruvian economy, a contribution of $14.34 million was made by corporations in the textile industry, increasing the GDP by 9.4%. This amount has increased by 28% compared to the previous year. Since the textile sector contributes to the country's economy, it is worth noting that this sector is responsible for around 20% of global water pollution. Even though the global economy is growing rapidly, there will always be a need to rationalize production processes to avoid downtime or downtime due to failures or irregularities in machines and equipment in manufacturing processes (Schindlerová et al. 2020).

Textile factories generally maintain processes in which different chemicals are used such as dyes, dyes, acids, and other compounds. Although these compounds are used during the production process, they are removed and are not present in the final textile product. However, not all companies treat these products, which can result in significant contamination. Despite this, some responsible companies have implemented proper use of these compounds. Few companies follow the trend of monitoring and optimizing the level of contamination, adjusting the pH of acidic substances, to use them in different processes or minimize the environmental effect that could result from the elimination of said substances. The textile industry is working very hard to find new ways to make clothes without harming the environment. They are also trying to make their factories run better and safer. They use special methods to do this, such as Lean TPM, TQM, and Six Sigma. These methods help them be more efficient, better control their processes, and make sure everything is organized. These factors contribute to the company being able to mitigate pollution and improve in areas that generate significant growth in the sector. The Lean TPM method is the most studied and applied, its goal is the total elimination of defects and the minimization of machine failures in the production chain, to significantly reduce the time that the product remains on the production line (Amiel et al. 2020).

The maintenance of machinery in the processes of textile companies ensures efficient operation, so that not only performance aspects can be optimized in terms of time efficiency, but improvements can also be implemented in pollution issues. It is important to remember that the environmental impact of the textile sector is considerably one of the most influential worldwide. Therefore, as time goes by, several companies have created systems and technologies that can make operations in this industry sustainable and increase efficiency (Guedes et al. 2021).Control and prevention are key elements for optimal and safe maintenance management. It is important to recognize that today quality and efficiency are factors that are directly affected by effective industrial maintenance management. Likewise, for industrial companies, it is essential to minimize variations in processes in order to reduce defects and inconsistencies. Therefore, some companies choose to use methods such as Six Sigma to reduce process variation. In the Six Sigma process, there are two methods called DMADV and DMAIC (Abbes et al. 2022). DMADV is used to create new processes, while DMAIC is used to improve existing processes. The goal of these methods is to understand, measure, analyze, improve and control processes, so that we can see how well they are working and fix any problems that may occur in the future.

There are different ways that companies can try to make their products and services really good. One way is called Six Sigma, which is a method of making things perfect by reducing errors. Another way is called total quality management (TQM), which is about making customers happy and making sure everything in the supply chain is good. Sometimes new technologies emerge that companies can use to make things even better, but we don't know for sure if they always work. The various alternatives available to organizations today are important to help them maximize their potential. Therefore, this study will help determine the effectiveness of using lean TPM methods in the Peruvian textile industry.

1.1 Objectives

This study aims to demonstrate that the application of the Lean TPM methodology in the finishing process of a textile factory in Lima would help optimize its efficiency, quality, and productivity. For this, a time study will be carried out to detect stops and reprocessing that occur during finishing. As well as evaluate the technical and operational feasibility of this method.

2. Literature review

Adjusted model - TPM

The main objective of the Lean-TPM model is to reduce waste or losses generated during production processes by implementing different concepts, for example, the Toyota Production System (TPS). One way to be successful with this approach is to use a well-defined maintenance plan. For this reason, this method has been widely used in the industry for decades with excellent results (Pinto et al. 2020).
Some of the benefits of implementing this methodology are that companies become much more competitive and efficient, thus achieving a better positioning in the market. For this reason, it is observed that companies from different sectors that have implemented TPM can observe considerable and beneficial changes for production processes (Canahua 2021).

Lean Manufacturing in the Textile Industry

Lean manufacturing in the textile sector revolves around the production system used by the company. This methodology aims to increase efficiency by eliminating unnecessary activities in production processes. This approach is based on tools such as process standardization, just-in-time ("right parts, the right quantity, the right time"), and Jidoka ("stop solving a problem and make it visible") (Quiroz-Flores et al. 2022). Some of the key concepts of lean manufacturing are the effectiveness, efficiency, and innovation of processes. Likewise, this methodology can be understood as a business culture that seeks to produce what is required based on the exact use of the quantities necessary for production, in this way, it seeks not only to avoid unnecessary activities but also to reduce losses and/or waste that are generated. they can find (Andreu 2023).

Standardized work in the textile sector.

Process standardization focuses on recognizing the time necessary to perform a process activity satisfactorily. After knowing the development of activities in their entirety, both from the inputs and times required to develop the production process, a method can be developed that allows the development of the processes by applying waste reduction. To do this, the method chosen must have the capacity to be flexible in the face of changes that may exist during the production processes (Andrade et al.2019).

5'S Methodology

The 5s are described as an improvement method originating in Japan. This includes classification, order and cleaning of the area, standardization of procedures, and discipline of employees so that they become routine in the work area and achieve a culture of work improvement (Vargas & Camero 2021).
At a global level, for production studies to achieve the best results, it is important to apply the 5s method in practice since it contributes greatly to improving processes, also in terms of quality and productivity, with low costs and effective results (Correa et al. 2022).

Nowadays, most companies use 5s not only as a tool for cleaning, sorting, organizing and operations but also to reduce downtime and non-value-added activities in the manufacturing process (Shahriar et al. 2022).

The innovation needs of different organizations may be affected differently by system complexity. Furthermore, it is important to understand what methods can help us start a continuous improvement process to improve efficiency and safety by involving and informing relevant employees (Jiménez et al. 2015).

3.Methods

The present study has the country's textile industry as a case study, which has implemented different methodologies over time to transcend and implement improvements in the development of the corresponding processes. For this study, the processes to be developed during the stage of production of a fabric company in the textile sector will be analyzed in detail.

For this study, different factors were considered, such as production time, maintenance time, and finishing time, among other factors that contribute significantly to the methodology to be used by the company for the development of its activities. Likewise, although it is important to know the activities to be carried out based on time and production, it is also important to know the causes that may generate a problem concerning efficiency.
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To determine which are the main causes of process variability, tools such as the Ishikawa diagram can be used, through which we can observe that the most relevant factors for the variability of a process can be governed by factors such as labor. , machinery, and material, among others (Pacana & Siwiec, 2021). In the case of the methods factor, we can determine that one of the factors causing the variability of the production process can be determined by the lack of standardization of times. Likewise, we can also determine that another factor that can influence the variability of the

process is a lack of culture concerning labor, which can determine that the human capital of the company cannot develop its activities efficiently. and in this way negatively impacts the production process.

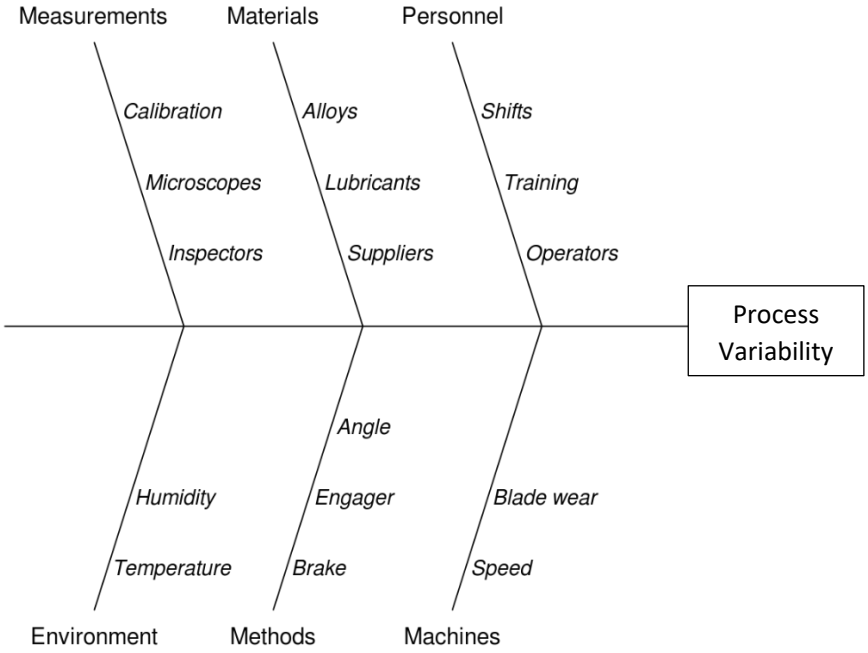

Figure 1. Ishikawa model

After having identified the main causes and problems that can generate a negative impact on the company, we can determine what tools to use to counteract these factors that generate negative variability in the company's production processes. The alternatives that we present and apply for this must generate a positive impact with respect to the production processes and any activity related directly or indirectly during the development of production. Likewise, one should also seek not only to counteract the problems found but also to seek significant improvements to neutralize any new problems that may arise.

Information about the study process.

In textile industries, the finishing process is very important because details are defined, such as the quality of the fabric, resistance, color, texture, among others, which allow the customer to choose whether to make the purchase or not. , according to the parameters of the final product.

Data collection

Obtaining finishing process data involves collecting and measuring information from a variety of sources to achieve a comprehensive evaluation, where a variety of tools such as surveys and interviews are used to obtain information on the activities and engineering carried out in the field of textile production. Pareto is a tool that helps us identify the most severe problems in the area and problem trees to identify the main causes. Once the information was collected, it was determined that tools could be used such as automated maintenance that refers to the pillars of TPM, 5s, standardized work, and in this context, time study.

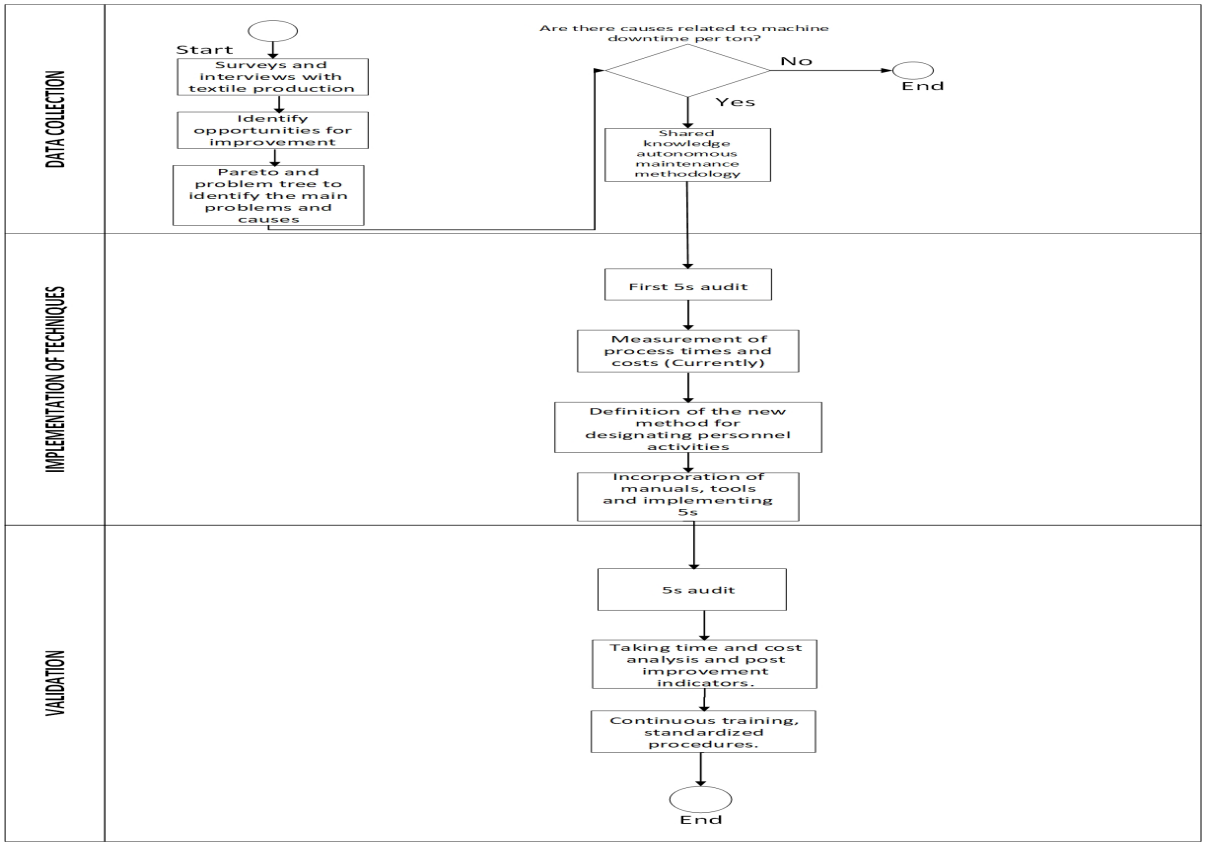

Figure 2. Diagram of the results.

Implementation of 5S, Autonomous Maintenance, and Work Standardization

5S is a set of steps that allow you to optimally develop a project. The steps of this methodology are classification, order, cleaning, standardization, and discipline.

a. Classification: For this process, it is important to be able to carry out a study based on which products are really necessary for the production processes and which ones, in this way, we will seek to eliminate the development of activities that do not contribute to the company.

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b. Ordering: Order is an important factor because the materials necessary for production must be available to the operators.

c. Cleaning: Carrying out the steps in correct order during production must go hand in hand with cleaning the machinery to be used during productivity activities, which is why cleaning before and after using the machine is necessary to guarantee that the machine does not presents problems that prevent the correct development of activities.

d. Standardization : In this phase it is necessary that the procedures are developed in correct order and cleanliness so that production times are average and no variables are made with respect to the development of productive activities.

According to the study carried out on the company, in the finishing machine process the tasks were developed in a specific order. However, it is worth remembering that the company does not carry out a specific maintenance system that benefits the looms that are stopped during the development of activities.

Table 1. shows the cleaning and preventive maintenance program in a branch with the standard time for each activity before the improvement. The people involved are mechanical technicians, cleaning staff, and machine operators.

No.	Operation	Start time	Standard T. before updating	End of time	Activities Manager
1	Machine without load	5:00	0:40	5:40	Branch operator
2	Review of inputs	5:40	0:35	6:15	
3	Machine cleaning	6:15	1:30	7:45	Branch operator
4	Use of Calandra machine	7:45	3:00	10:45	Branch operator
5	Calandra machine review	10:45	0:50	11:35	Maintenance technician
6	Removal and cleaning of filters.	11:35	1:00	12 :3 5	cleaning operator
7	Interior and exterior cleaning	12:35	0:25	13:00	cleaning operator
8	Final technical review	13:00	0:45	1 3: 45	Maintenance technician

Likewise, it is important that, for the development of tasks, companies have not only effective planning of activities, but also have a preventive system of cleanliness and order so that the activities to be carried out do not present problems during the production process. .

Cost analysis

For the amount of production to be used, it is also necessary to take into account the costs that were incurred during the development of the production of the product.

Likewise, it is very important to know the cleaning and maintenance time that will be required:

1. The average downtime for cleaning will be 25 minutes, however, for maintenance and technical inspection the average time will be 1 hour and 38 minutes.

Given these conditions, the indicators for a day of cleaning and preventive maintenance are calculated.
Effective time = 21 h/day x 60 min/hour = 1,260 min/day
Branch availability = Effective time - Cleaning and preventive maintenance time = 1235 min/day - 98 min/day = 855 min/day.
Finishing area efficiency = 67.85%.

Table 2 below shows the costs in soles involved in downtime for cleaning and preventive maintenance before the upgrade.

Table 2. Production per kg of special finishes

03. ACABADOS ESPECIALES				
0301. CALANDRA	10.50	1,156.25	606.50	1,773.25
0302. PERCHA			280.00	280.00
0304. CENTRIFUGA	132.1		39.8	171.90
	142.60	**1,156.25**	**926.30**	**2,225.15**

In the present study, it can be seen that the calendar is the most required special finish due to the texture of the fabric.

Results and Discussion

The company implemented improvements concerning the maintenance and use of machinery, which is why it was proposed to provide constant training to the personnel who manage these machinery (biweekly training). On the other hand, maintenance must be carried out with deep cleaning, because in finishing machines there are obstructions in the gears due to the accumulation of dust or shrinkage, which prevents the machinery from being used continuously. To do this, a pilot test was carried out applying the training and alternatives provided to the company. In this way, it was observed that the average inactive time was reduced to 3:45 minutes, which contributed to optimal development.

Table 3. Standard time for cleaning and preventive maintenance activities after the upgrade.

No.	Operation	start time	Standard T. before updating	end of time	Activities Manager
1	Machine without load	5:00	0:20	5:20	Branch operator
2	Review of inputs	5:20	0:15	5:35	
3	Machine cleaning	5:35	0:45	6:20	Branch operator
4	Use of Calandra machine	6:20	3:00	9:20	Branch operator
5	Calandra machine review	9:20	0:30	9:50	Maintenance technician
6	Removal and cleaning of filters.	9:50	0:45	10:35	cleaning operator
7	Interior and exterior cleaning	10:35	0:25	11:00	cleaning operator
8	Final technical review	11:00	0:45	11:45	Maintenance technician

Due to the reduction in downtime, we can see that efficiency and production capacity increase considerably in favor of the company. To do this, you must remember the following:

1. Due to the training provided, it was observed that the average inactive time was 3 hours and 45 minutes after having applied the recommendations. Likewise, this procedure should be performed at least 2 times a week.

There are 3 daily shifts of 21 effective hours.

Due to this, a calculation can be made regarding the indicators based on improvements in cleaning and preventive maintenance.
Effective time = 21 h/day x 60 min/hour = 1260 min/day
Branch availability = Effective time - Cleaning and preventive maintenance time = 1235 min/day - 360 min/day = 1035 min/day.
Production of a branch = 18 m/min x 900 min/day = 16,200 m/day
Finishing area efficiency = 85.85%

Due to the data, it can be seen that downtime decreased, the percentage of machinery use efficiency increased, which can contribute to increasing production per day by having greater availability of machinery to carry out the desired finishes.

According to the data obtained in the last month of November, a total production of 5828 kg was obtained, however, with the proposed improvements it is expected that this month the company can produce a total of 7054.94 kg, this is a considerable improvement with respect to production. monthly, which will contribute to the company's culture being reflected in the data to be obtained subsequently.

Cost analysis

Analyzing the data obtained from the time study, the cost-benefit is 678.50 soles for cleaning and preventive maintenance per month. This is significant because the investment proposal for the necessary process changes is small compared to the additional profits the organization will realize each year. The required investment is 8,142 soles, this amount refers to the purchase of tools and personnel that will facilitate our work at each stage of the implementation of 5s and automated maintenance. The tools would be: heavy work gloves, industrial scissors, cutters, marking labels, pencils, adhesive tape, and metal shelves to organize the accessories and materials of the machine and filing cabinet. Finally, take advantage of office hours by introducing tools and signs in work, training, and inspection areas.

Validation

The proposed model was validated through a month-long pilot test, analyzing a total of eight cleaning and preventive maintenance procedures from October to November 2023. Based on new data obtained after its implementation, the proposed metrics yielded the following percentages:
Table 4 presents existing and improved indicators that show that the results achieved at the end of the implementation in terms of machine availability, industrial production, and efficiency exceeded the goals set by the organization.

Table 4. Compare metrics between scenarios

Indicators	Initial situation	Aim	Improved situation
Machine availability	855 min/day		1260 min/day
Production of a branch.	69.23%	75%	83.80%
efficiency	67.85%	80%	85.85%

Efficiency: Could be improved from 67.85% to 85.85% due to an increase in the number of meters of fabric processed compared to the number of meters of fabric processed as planned in the fourth quarter of 2023. The proposed goals have been achieved and there are still opportunities to continue working on the improvement of various technical resources

Downtime for cleaning and preventive maintenance: Reduced by 44.44% from 5 hours 45 minutes to 3 hours 45 minutes using training and methodologies that allow the company to improve and use the machine optimally.

Conclusions

The evaluation that was carried out in a textile company in Peru is in line with the general objective that we had at the beginning of the study, which was to reduce non-productive times in the textile processing process and thus increase the efficiency of the production area. fabric finishing treatment. Dedication to innovative work methodologies, transparency and unification of all team members, from management to operations, is crucial. This is because it will generate great advantages and increase competitiveness in the textile sector. It is essential to collect historical data from the equipment in order to reexamine the indicators. From this analysis, it is possible to propose the integration of technical instruments, adapt the equipment to a model that can be replicated and assist in maintenance management. This will optimize team efficiency and improve overall productivity.

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Martín Collao-Díaz from ESAN University and Industrial Engineer from the University of Lima with specialization in supply chain management and operations. A leader with more than 25 years of local and international experience in national and multinational companies in the industrial, hydrocarbon, and mass consumption sectors. Extensive experience in supply chain management (purchasing, inventory management, suppliers and sources of supply, logistics: transportation, distribution, and warehouse management), operations (planning and control of production and maintenance), and integrated systems management (ISO 9001, ISO 14001 and OHSAS 18001). Business alignment based on sales and operations planning (S&OP). In addition, the continuous search for improvements in profitability based on process optimization and project savings using tools such as the 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).